Cross, Roy
A handbook of petroleum, asphalt and natural gas

A HANDBOOK
of
PETROLEUM ASPHALT
and
NATURAL GAS

Methods of Analysis, Specifications, Properties, Refining Processes, Statistics, Tables and Bibliography

by

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Member of American Chemical Society, American Society for Testing Materials, American Association for Advancement of Science, American Society for Municipal Improvements, Kansas City Engineers Club

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Preface to Bulletin No. 16.

This handbook includes the following new matter, as well as addition to and revision of:

Universal gauging tables for horizontal cylindrical tanks.

Gauging tables for the bumped ends of horizontal cylindrical tanks.

Methods for the determination of the capacity of oil pipe lines.

Detail cost on the refining and cracking of oil.

The laws and taxes governing the sale and transportation of refined petroleum.

The detailed description of the decomposition of petroleum hydrocarbons in the presence of aluminum chloride.

The most recent specifications for the quality of petroleum products as used by the trade.

Standard method of drilling oil wells.

Detailed and explicit methods of analysis of all types of petroleum products giving preference to accepted or standardized methods.

New developments in the decomposition of heavy hydrocarbons for the production of gasoline.

Formulae for the calculation of the total gasoline obtainable by any means from crude oil of different gravities and bases.

The properties of crude oils from all of the important fields.

New matter on the uses, properties and value of fuel oil.

Specific gravity and Baume' gravity correction tables for very light petroleum oils and for very heavy petroleum oils.

Baume' gravity and Specific gravity equivalents for oils heavier than water, but on the lighter than water scale.

The combustion of gasoline and the products of combustion of internal combustion engines.

The properties of gasoline made by present methods of decomposition.

The properties of average gasoline as now sold on the market.

The vapor volumes of petroleum distillates and different temperatures and of different gravities.

Processes and U. S. patents issued to 1922.

The statistics of the production, transportation and refining of petroleum up to 1922.

Preface to Bulletin No. 15.

The purpose of this publication is to set forth in concise form for the petroleum producer, seller, refiner, and technologist, scientific information and statistics on the production, properties, handling, refining and methods of valuation of petroleum and related products.

All matter formerly published in Bulletin No. 14 has been revised and included in this publication. In addition there has been added fifty-five new illustrations, complete temperature—Baume′ correction tables, extensive tank gauging tables, refinery engineering formulae, complete specifications for petroleum products, much additional data on oil cracking, geology, lubricants and asphalt, a complete set of methods of analysis of petroleum, asphalt and natural gas and a fairly complete bibliography.

The sources of original information have been from the research, commercial and engineering departments of the Kansas City Testing Laboratory and from the bibliography published at the end of the book.

November 1, 1919,
Kansas City, Missouri.

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(General outline only. See index for detailed subject matter.)

PETROLEUM—GENERAL DESCRIPTION OF USES.

The word petroleum has its derivation from the Latin "petra," rock, and "oleum," oil. Synonymous terms are mineral oil, rock oil, crude oil and crude naphtha. In the widest sense, the word embraces the whole of the hydrocarbons, gases, liquids and solids occurring in nature. In a commercial or practical sense, the word applies to natural liquid hydrocarbons, and the term asphalt applies to the solid forms, such as asphaltum, albertite, elaterite, gilsonite, ozokerite, glance pitch and hatchettite.

The occurrence of petroleum has been recorded from the earliest times and has been spoken of as oil springs, burning water and the like. The first probable exploitation of petroleum in the way of distillation was by Jas. Young, an Englishman. in 1850. Petroleum was obtained by well drilling first in 1858 by E. L. Drake. The depth of this well was 70 feet and the yield of oil was 25 barrels per day.

The original use of petroleum was in the preparation of illuminating oil to replace coal oil. After the production of illuminating oil from petroleum, it was soon shown that the heavy petroleum oil had far superior lubricating properties to vegetable and animal fats and oils so that at the present time, practically all lubricating oils are obtained from petroleum.

The development of the gasoline engine is due principally to the need of a commercial outlet for gasoline. Gasoline was originally used for lighting purposes and domestic stoves. It is now the most valuable and important product of petroleum, being approached in value only by that of lubricating oil. There are 10,000,000 gasoline automobiles in the United States at this time.

The following outlines some of the main uses of petroleum products:

Gasoline and Naphtha—Gas lighting, laboratory solvents, cleansing, gasoline stoves, automobiles, extraction of seed oils, metal polishes, gasoline engines, paint vehicles, asphalt paint and road binder solvent, refrigerant.

Kerosene and Illuminating Oils—Lamps, distillate engines, signal lights, gas washing and absorbents, portable stoves.

Gas Oil—Pintsch gas, Blaugas, town gas, straw oil, heating, cracking, anti-corrosives.

Heavy Distillates—Lubricants, spindle oil, auto oil, machine oil, engine oil, cylinder oil, greases, vaseline, wax, medicinal oil, waterproofing for fabrics, candles, soap filler, paints, polishes.

Liquid Residua—Steam fuel, heating, concrete waterproofing. road and macadam oils, dust prevention, cracking, cylinder oil.

Semi-solid Residua—Asphalt pavement, waterproofing, brick filler, roofing, rubber filler or substitute.

Crude Oils—Diesel engines, dust prevention, waterproofing, steam fuel.

The following statistics show the extent of the petroleum industry at this time:

PETROLEUM IN 1919, 1920 AND 1921.

CRUDE OIL BALANCE SHEET. (U. S.)

	1919	1920	1921
Stocks on hand January 1st	117,204,000	123,344,000	133,690,000
Crude oil produced during year	377,719,000	443,402,000	472,439,000
Crude oil imported	52,822,000	106,175,000	125,307,000
	547,745,000	672,921,000	731,436,000
Stocks on hand December 31st	123,344,000	133,690,000	197,089,000
Crude oil consumed during year	418,477,000	531,186,000	525,407,000
Crude oil exported	5,924,000	8,045,000	8,940,000
	547,745,000	672,921,000	731,436,000

PRODUCTION BY STATES IN UNITED STATES.

	1919	1920	1921
Oklahoma	87,000,000	105,725,700	115,680,000
California	101,564,000	105,668,000	114,900,000
Texas	85,900,000	96,000,000	105,200,000
Kansas	30,000,000	38,501,000	35,750,000
Louisiana	14,853,000	35,649,000	25,835,000
Wyoming	13,000,000	17,071,000	19,550,000
Kentucky	9,346,700	8,680,000	8,975,000
Illinois	10,165,000	10,772,000	10,000,000
Pennsylvania	7,500,000	7,454,000	7,425,000
West Virginia	7,900,000	8,173,000	7,990,000
Ohio	7,300,000	7,412,000	7,275,000
Indiana	9000,00	932,000	1,155,000
New York	890,000	906,000	970,000
Colorado	120,000	110,000	109,000
Arkansas	0,000	0,000	9,850,000
Montana	297,300	348,700	1,775,000
Total	377,719,000	443,400,700	472,439,000

PRODUCTION BY DISTRICTS IN UNITED STATES.

Mid Continent	115,897,000	144,226,000	258,885,000
California	101,764,000	105,668,000	114,709,000
Central and North Texas	67,419,000	70,952,000	Incl. Midco.
Gulf Coast	20,568,000	26,801,000	34,160,000
Appalachian	29,232,000	30,511,000	30,574,000
North Louisiana	13,575,000	33,896,000	Incl. Midco.
Illinois	12,436,000	10,772,000	10,935,000
Lima-Indiana	3,444,000	3,059,000	2,411,000
Rocky Mountain	13,584,000	17,517,000	20,765,000
Total	377,919,000	443,402,700	472,439,000

WORLD'S PRODUCTION OF PETROLEUM.

	1919	1920	1921
United States	377,919,000	443,402,700	472,439,000
Mexico	87,359,000	163,039,000	191,418,000
Russia	34,284,000	34,284,000*	34,284,000*
Dutch East Indies	15,780,000	15,780,000*	16,000,000*
India	8,453,000	8,453,000*	8,500,000*
Roumania	6,353,000	7,200,000	7,500,000*
Galicia	6,255,000	6,255,000*	6,000,000*
Trinidad	2,780,000	2,780,000*	3,000,000*
Peru	2,561,000	2,561,000*	3,600,000
Japan	2,120,000	2,120,000*	2,000,000*
Germany	1,000,000	1,000,000*	500,000*
Argentina, Egypt, Persia, Canada, Italy, etc.	14,028,000	14,028,000*	17,000,000
Total	558,892,000	700,902,700	762,241,000

*Estimated

PRODUCTS OF PETROLEUM. (U. S.)

	1919	1920	1921
Total crude oil consumed (all purposes)	418,477,000 bbl.	531,186,000	525,407,000
Crude oil refined	361,520,000 bbl.	433,915,000	443,363,000
Gasoline produced	94,210,000 bbl.	116,250,000	120,939,000
Kerosene produced	55,740,000 bbl.	55,240,000	46,300,000
Lubricating oils	20,160,000 bbl.	24,900,000	20,900,000
Gas oil, fuel oils, distillates, road oils, flux oils	181,540,000 bbl.	246,500,000	230,100,000
Crude oil used for fuel	56,957,000 bbl.	97,271,000	82,044,000
Wax	467,235,000 lb.	541,404,000	433,887,000
Coke	603,460 ton	576,613	604,465
Asphalt	901,885 ton	1,290,614	1,214,536
Losses (cracking, etc.)	15,000,000 bbl.	18,742,939	11,280,000

FIELD OPERATIONS.

Wells drilled during the year	28,512	33,385	21,152
Dry wells or gas	7,833	9,647	5,013
Per cent producing at end of year	72.54%	71.10%	76.30%
Producing wells in U. S. December 31st	239,650	263,388	279,520
Average production per well per day	4.41 bbl.	4.60 bbl.	4.63

Geographical Distribution of Petroleum.

(U. S. Geological Survey.)

United States—The oil pools of the United States are grouped in certain major areas or fields which originally were delimited according to their geographical position alone. As the fields have been extended areally, the geographic boundaries of some of them have become in places less distinct and the grouping has been determined more and more by commercial usage which in turn is in part determined by the quality of the oils.

The Appalachian field embraces all the oil pools that lie east of Central Ohio and north of Alabama, including those of New York, Pennsylvania, West Virginia, Eastern Ohio, Kentucky and Tennessee. Most of the strata that yield oil in this field are sandstones and conglomerates of Devonian and Carboniferous age. The typical oils are of paraffin base, are free from asphalt and objectionable sulphur, and yield by ordinary methods of refining, large percentages of gasoline and illuminating oil. They range in color from black to light amber, but most of them are of some shade of green. In gravity they range from 25° to 53° Baume' and average about 43° Be'.

The Lima-Indiana field embraces all the pools in Northwestern Ohio and most of those in Indiana. The oil-bearing beds in this field belong to the Ordovician, Silurian and Carboniferous systems, but the most productive are lenses of porous dolomitic rock in the "Trenton" limestone, a member of the Ordovician system and the oldest known oil-bearing rock in the United States. The oil obtained from the Carboniferous rocks in Southwestern Indiana properly belongs to the Illinois field, next to be considered, for the formations lie in the same structural basin and the two fields are continuous. The oil in the pre-Carboniferous rocks of the Lima-Indiana field is of lower grade than that from the pre-Carboniferous rocks of some parts of the Appalachian field and contains sulphur compounds that must be removed by special treatment. In color the oils obtained in this field range from green to brown and their average gravity is probably about 39° Baume', although some of them are much heavier.

The principal productive area in the Illinois field is in the southeastern part of the state, along the LaSalle anticlinal axis, but there are also small scattered pools in Central and Western Illinois. Most of the oil is obtained from beds of sandstone in the Pennsylvania and Mississippian series of the Carboniferous system. The oils in the northern part of the field are heavy, have an asphaltic base and carry sulphur. The oils in the southern part of the field are of better grade. In gravity the oils range from 27° to 37° Baume'.

The Mid-Continent field includes the oil-producing area in Kansas, Oklahoma, Northern and Central Texas and Northern Louisiana. Most of the oil produced in Kansas, Oklahoma and Northern Texas is obtained from beds of sandstone in formations of the Pennsylvania series (upper Carboniferous). The oil produced in Southern Oklahoma is obtained mainly from several pools in beds of sandstone of the Pennsylvania series, though some oil is found in the "Red Beds" of the Permian series (latest Carboniferous).

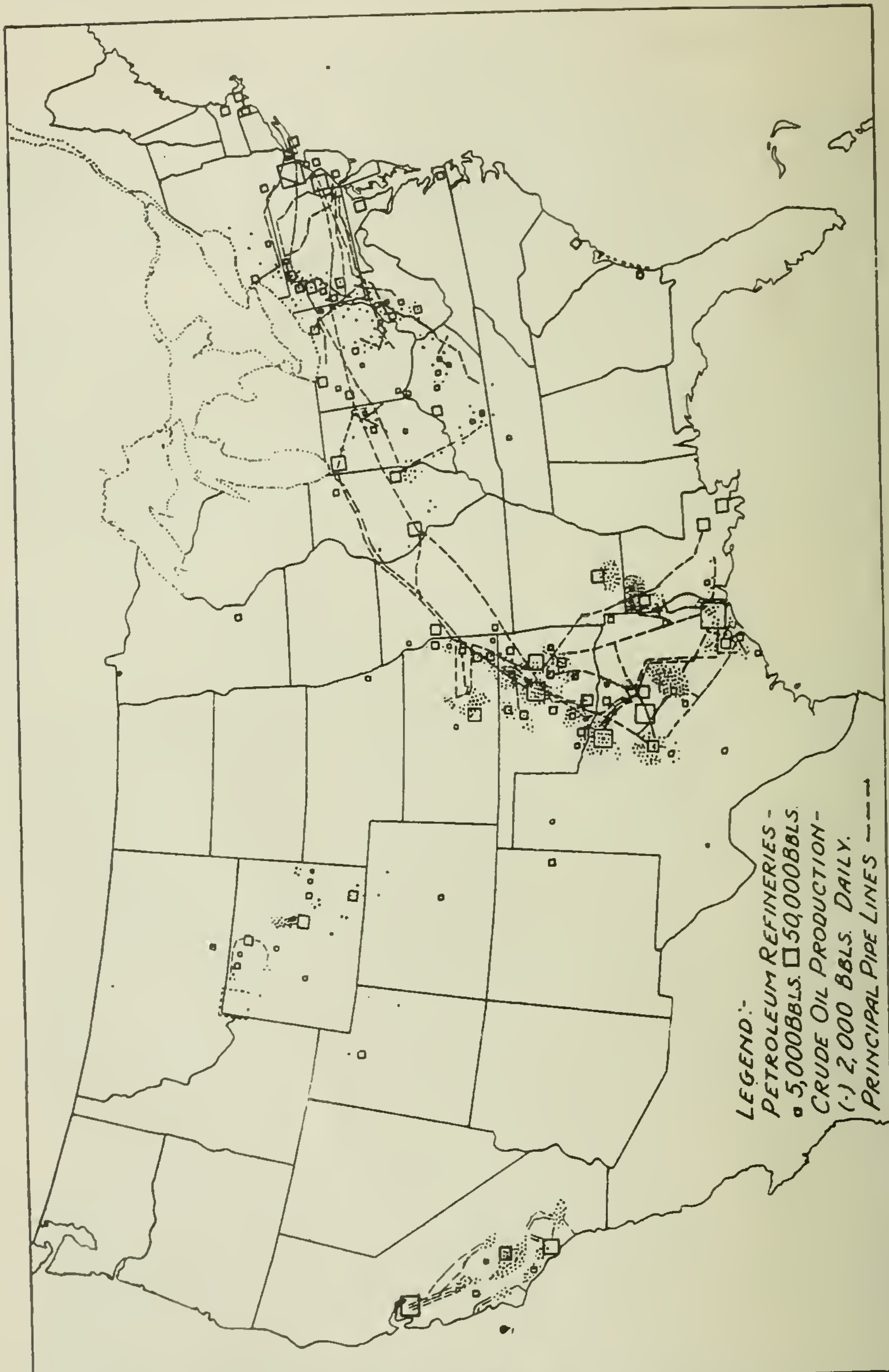


Fig. 1—Map of the United States Showing Refineries, Production Fields and Main Trunk Pipe Lines of Petroleum.

The oil found in Northern Louisiana and Central Texas is obtained from sandstones or other porous rocks of the Cretaceous and Tertiary systems. In the Mid-Continent field the oil has accumulated in anticlines, domes and terraces throughout an extensive region where the strata have a general westerly dip. The oil grades in appearance and gravity from the thick, black oil of some of the Louisiana fields, which have a gravity of 21° Baume', to the almost colorless product of the so-called "gasoline well" near Cushing, Okla., which has a gravity that is reported to be above 55° Baume'. However, the average oil from the Mid-Continent field is light green and has a gravity of about 35° Baume'.

The Gulf Coast field includes that part of the Gulf Coastal Plain of Texas and Louisiana in which petroleum is associated with masses of rock salt and gypsum in domes. The age of the oil bearing strata ranges from Cretaceous to Quarternary, and the reservoir rock is generally either sandstone or porous dolomitic limestone. The field includes a great number of small, scattered pools, few of them more than three miles in diameter, which produce oil having an asphaltic base. The productivity of some of the wells is enormous but the production of most of the pools soon reaches a maximum and then steadily declines. The value of some of the oil is impaired by its high content of sulphur, which may be as much as 2.3 per cent. The gravity ranges from 15° to 30° Baume', and averages about 22° Be'. Most of the oil is dark brown to black but some of it is green. There is no apparent relation between color, gravity and content of sulphur.

The Rocky Mountain field embraces all areas that produce petroleum in Colorado, Wyoming and Montana as well as some areas of prospective production in Utah and New Mexico. The petroleum now obtained in this field is derived from strata of Pennsylvanian, Permian, Triassic and Cretaceous age. Most of the oils from Paleozoic and Mesozoic strata are dark and heavy with gravities averaging about 23° Baume', although some of them have a gravity as low as 11° Baume'. The Cretaceous oils are remarkably light in color and their gravity ranges from 25° to 50° Baume'. The average gravity for the Rocky Mountain field is about 32° Baume'.

The California oil fields may be roughly divided into two geographic groups, one occupying two sides of San Joaquin Valley and commonly known as the Valley fields, and the other occupying a large area along the coast and commonly known as the Coastal fields. All the Valley fields, except one, lie on the west side of San Joaquin Valley and the oil in most of them is obtained from porous Tertiary sandstones that have been folded into anticlines and synclines. The conditions in the Coastal fields are in many respects similar to those in the Valley fields, but the structure is much more varied. A very small part of the oil produced in California is obtained from Cretaceous formations. The oils range in color from black to honey-yellow and in gravity from 9.9° to 54° Baume'. Heavy dark oils that contain little sulphur predominate. A fair average gravity is about 21° Be'.

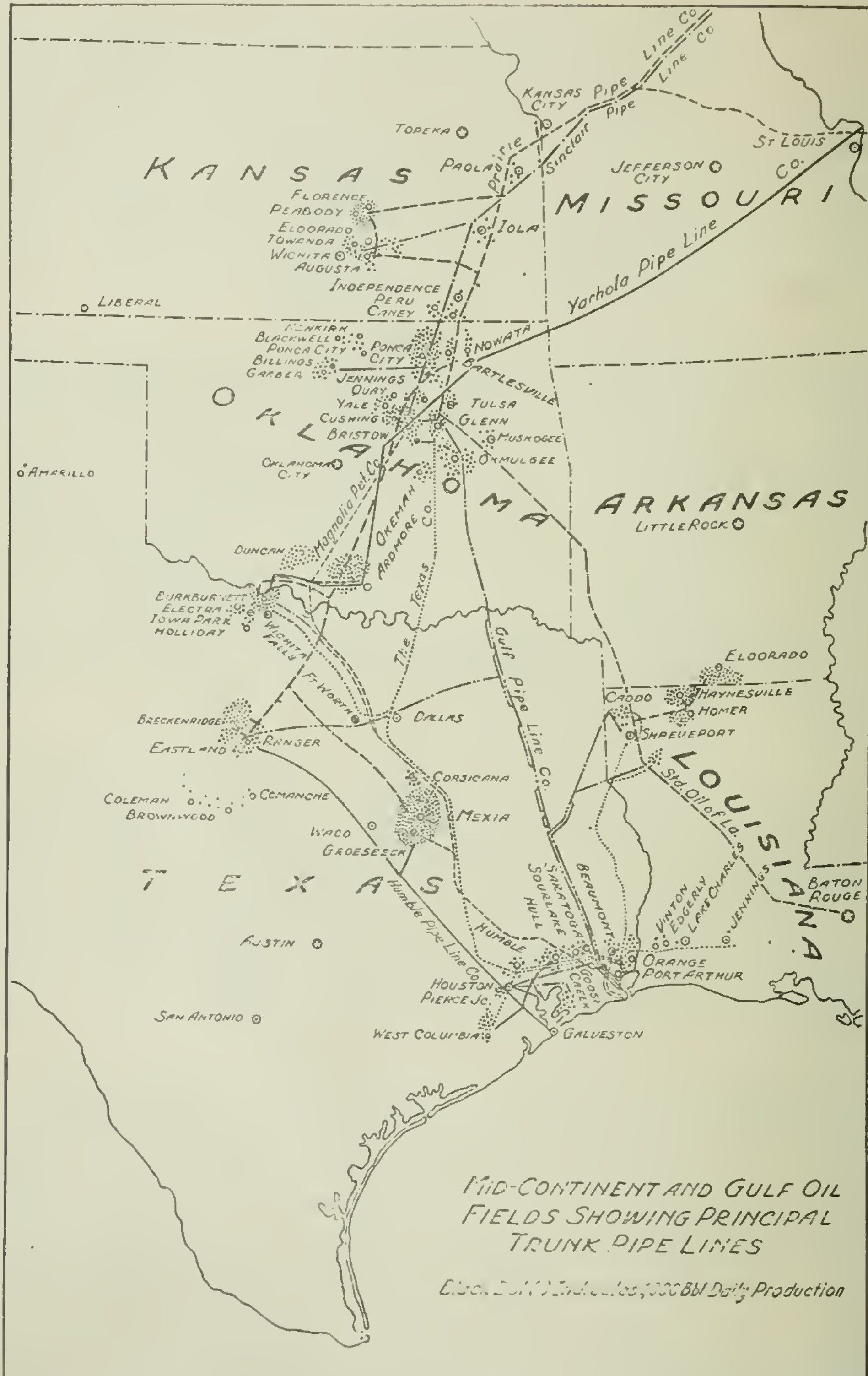


Fig. 2 Map Showing Producing Areas and Pipe Lines for Petroleum in the Mid Continent and Gulf Fields.

Nearly all the petroleum produced in the United States is carried to refineries through buried pipes. Some pipe lines extend from the fields in the interior of the country to the Gulf of Mexico and to the Atlantic seaboard for the distances of many hundreds of miles. The trunk pipe lines, that is, the main lines only, not the subsidiary branches, now cover more than 34,000 miles.

Canada—Indications of petroleum have been observed in many parts of Canada but no fields have been much exploited, except those in Ontario, where the oil occurs in sandstones and limestones of Silurian and Devonian age. Most of the Ontario oil has a paraffin base but contains large quantities of sulphur. The Calgary field in Alberta has produced only a small quantity of oil, but a field in Northern Alberta, where the famous Tar sands of early Cretaceous age occur, gives promise of commercial production

Mexico—The petroleum fields of Mexico that now seem to promise the greatest production are in the eastern part of the country in the Gulf Coastal Plain. There are two fields which are distinct geographically and geologically and which produce different kinds of petroleum.

The Tampico—Tuxpan field lies in the northern part of the State of Vera Cruz and the southern part of the State of Tamaulipas. In this field indications of oil are found in a region about 250 miles long and 40 miles wide. The Tehuantepec field forms a similar long, narrow area which extends along the Gulf coast from southern Vera Cruz about 200 miles eastward to the eastern limit of Tabasco.

Most of the oil in both fields is found in porous limestone of Cretaceous or Eocene age but some oil in the Tehuantepec field is found in later Tertiary rocks. In the Tampico-Tuxpan field, the oil accumulates either in anticlines or at underground dams formed by intrusive necks and dikes of igneous rocks by which the oil pushed up or along by salt water has been impounded. In the Tehuantepec field, the oil is associated with rock salt and gypsum in domes similar to the domes in the Coastal Plain of Texas and Louisiana. The oil generally becomes lighter from north to south through the two fields but nearly all of it should be classed as heavy. Its gravity ranges from about 10° to 43° Baume'.

Pronounced indications of oil are reported in western Mexico but no development has yet been undertaken there.

Mexico, which has furnished the largest gushers known, is now the second largest producer of petroleum in the world.

Central America—Oil seepages are reported to occur in Honduras, Costa Rica, Guatemala and Panama but no oil has been developed commercially in any of these countries.

South America—Much interest centers in the known and prospective oil fields in South America along the Caribbean Sea. Exudations and seepages of oil and deposits of asphalt are scattered through northern Columbia and Venezuela from the Gulf of Darien to the delta of the Orinoco. The oil is found in porous sandstones that afford good reservoirs at horizons extending through several thousand feet of Cretaceous and Tertiary beds which are both folded and faulted. Most of the oil has a heavy asphaltic base but some is lighter. The production has been small but development has been carried far enough to prove that both Colombia and Venezuela contain large reserves of petroleum.

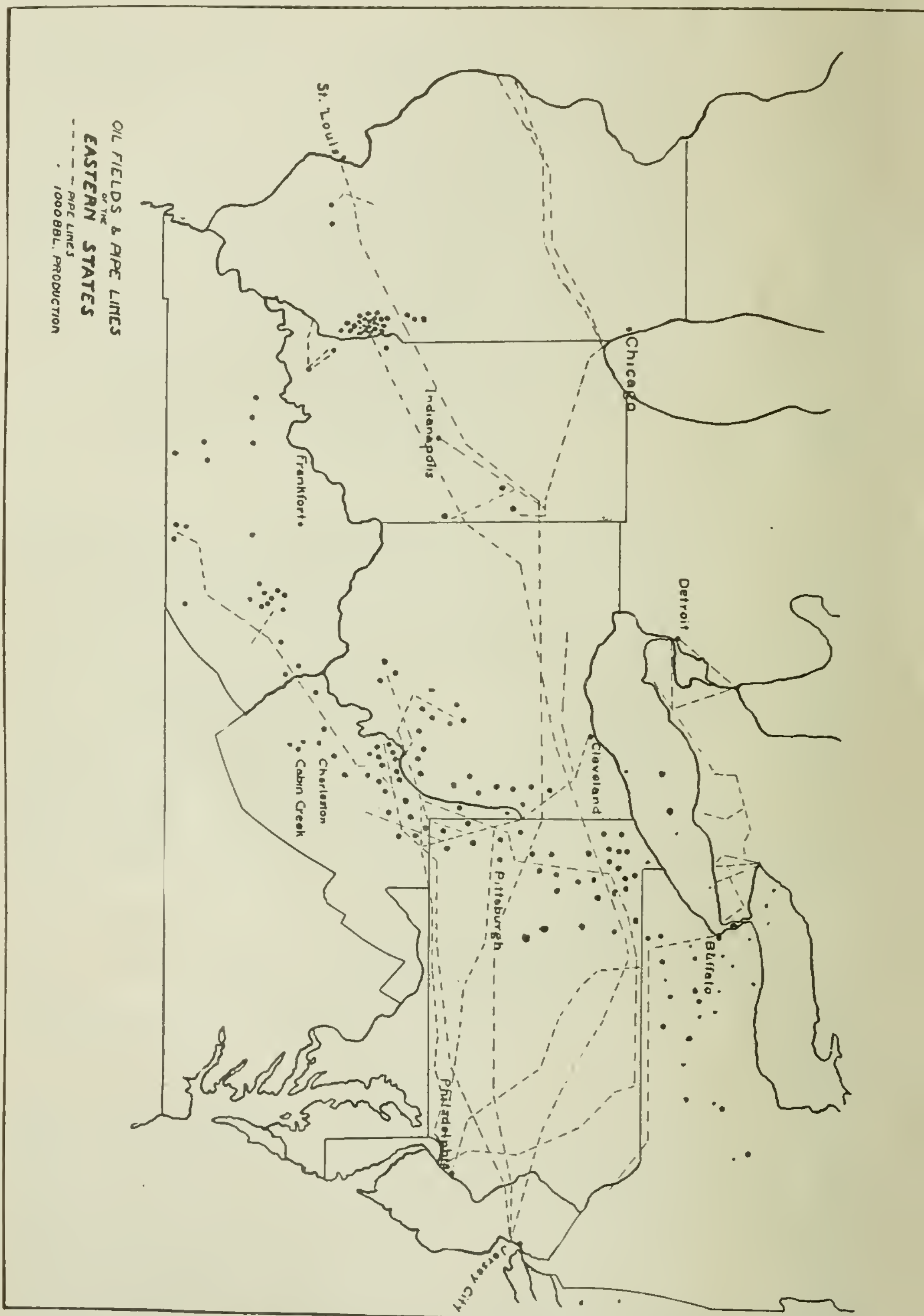


Fig. 3—Map Showing Producing Areas and Pipe Lines for Petroleum in Eastern United States.

Peru is the only country on the Pacific coast of South America that has contributed much petroleum to the world's supply. Most of the indications of oil are found in the broad promontory at the north end of Peru in a belt that extends along the coast from the frontier of Ecuador southward for about 200 miles to a point south of Payta. The oil occurs at several horizons throughout 2,000 feet or more of folded and faulted beds of rather soft sandstone and shale of early Tertiary age. It escapes at numerous seeps and asphaltic outcrops and is an excellent refining oil.

Bolivia, Ecuador, Argentina and Chile appear to contain considerable reserves of petroleum which however are apparently not comparable in extent to those of Colombia and Venezuela. Argentina has produced oil since 1908 from the Comodoro Rivadavia field on the coast of Patagonia where oil occurs in nearly horizontal supposedly Cretaceous beds which are covered by Tertiary beds. The oil is heavy, black and of asphaltic base. Indications of oil have been found at intervals in a belt that extends along the eastern flanks of the Andes from Tierra del Fuego northward to Colombia. The whole belt has produced only a few thousand tons of oil but probably contains extensive reserves.

So far as known, Brazil contains no marked surface indications of petroleum but it does contain extensive deposits of oil shale.

West Indies—Traces of petroleum are scattered through Cuba, Porto Rico, Santo Domingo, Trinidad and Barbados but Trinidad is the only one of these islands that has produced it in any considerable quantity. The oil fields of Trinidad are mainly in its southern part and the oil is obtained from lenses of sandstone of Tertiary age which are closely folded into a series of parallel synclines and anticlines. Trinidad gives promise of large future production.

Africa—In Africa, oil has so far been produced only in Egypt but Algeria contains encouraging prospects. The Egyptian oil fields lie along the Gulf of Suez. The oil occurs in sandstone and in cavernous dolomitic limestone associated with thick beds of gypsum in Miocene (Tertiary) age, accompanied in some places by thick beds of salt. The underlying Nubian (Cretaceous) sandstone also contains some oil. This field occupies a strategic position on a great trade route and shows promise of considerable production.

Little work has been done in Algeria but some oil has been obtained in the Cheliff River area, in the Oran province, northwestern Algeria. The oil bearing formation is probably upper Miocene, and its structure is complex.

Promising indications of petroleum have been reported in the Tertiary coastal plain formations in Angola and Ashanti (Gold Coast) and oil seepages are reported to extend over a large area in Western Madagascar.

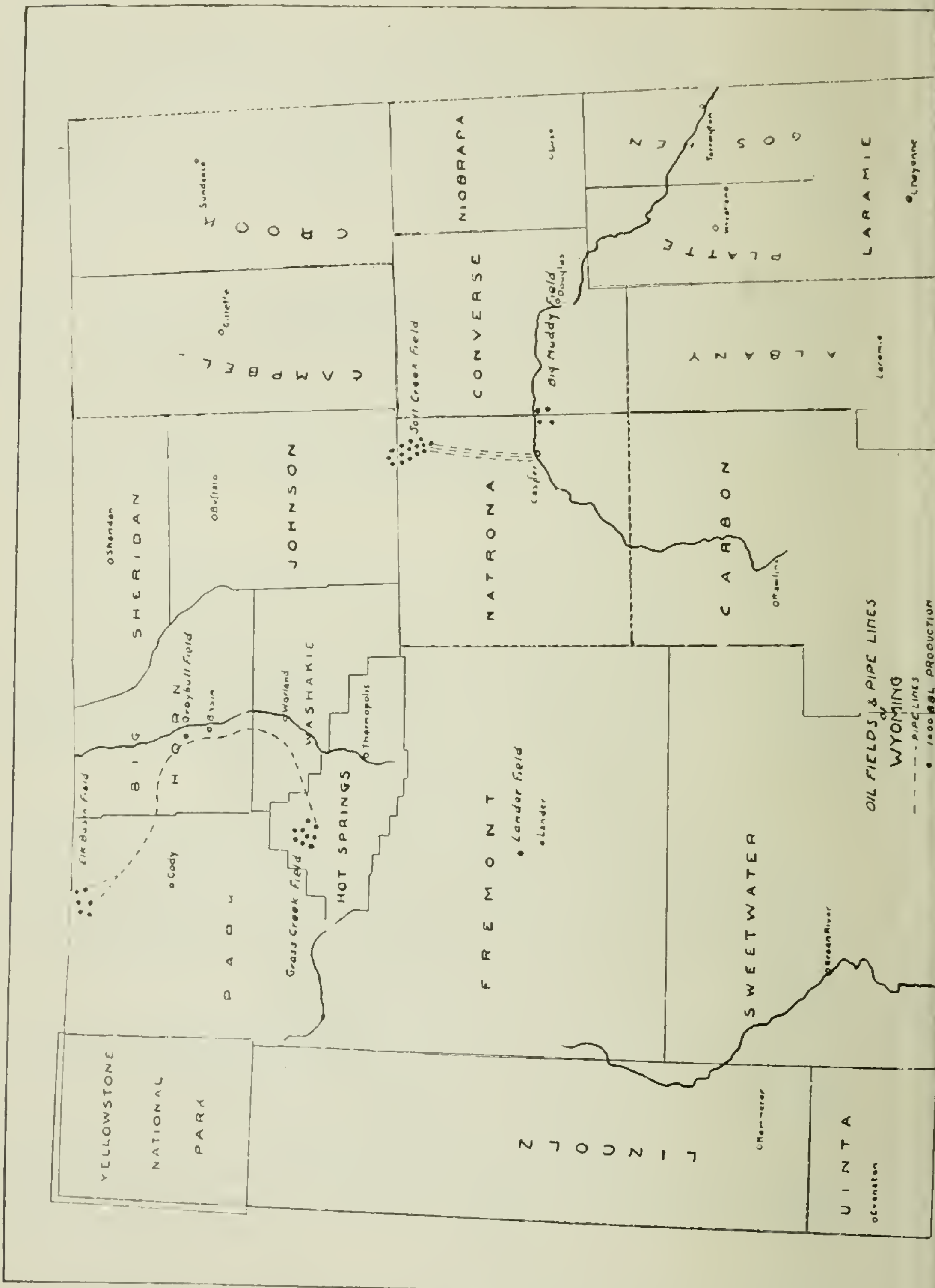


Fig. 4—Map Showing Producing Areas and Pipe Lines for Petroleum in Wyoming.

Europe—Most of the known deposits of oil in Europe are in its southeastern part. More than half of the oil thus far produced in Europe has been taken from an area of not more than 50 square miles in the Apsheron Peninsula, in southeastern Russia, on the Caspian Sea, and a large part of the remainder from Rumania and Galicia. A second reserve in the Caspian region, discovered only recently but undoubtedly very large, lies in the Ural-Caspian area along the north shore of the Caspian Sea east of the Volga. Most of this area appears to lie east of the political boundary between Asia and Europe but there is no insurmountable barrier to transportation to Europe and the oil there will doubtless become of great commercial value throughout southeastern Europe.

Probably more than 90 percent of the oil found in Europe occurs in highly disturbed formations of comparatively recent age (Tertiary) similar to those of California. Beds of this type offer great difficulties to the driller and the average wells make a high initial yield and decline rapidly in production.

The oil fields of Russia are scattered among ten provinces but the field in the province of Baku has been by far the most productive. This relatively small area has produced more than a quarter of the world's total output of oil and though it reached a peak in its production in 1901 when Russia furnished more than half the world's output, its decline has been a decline in world rank rather than in actual quantity of oil produced. Other highly productive oil fields of Russia are the Grosny, Maikop, Ural-Caspian and Tcheleken fields. A number of smaller fields also have excellent prospects. The Grosny field lies on a sharp anticline of Miocene beds about 500 miles northwest of Baku, north of the Caucasus range. The Maikop field is in the province of Kuban, on the north flank of the Caucasus, northeast of the Black Sea. The other fields of Russia have not produced large quantities of oil but extensive showings of oil are found in the Ural-Caspian and Tcheleken fields of Asiatic Russia, the former covering a large area in the Emba-Uralsk region and around the north end of the Caspian Sea and the latter lying on the east shore of the Caspian Sea in the Trans-Caspian province.

The oil fields of both Galicia and Rumania lie in a narrow belt that follows the northern, eastern and southern foothills of the Carpathian Mountains. Throughout this belt, oil is obtained from highly disturbed Tertiary strata. In Rumania most of the oil is obtained from Miocene and Pliocene beds but part of it is obtained from Eocene and Oligocene and possibly from Cretaceous beds. In Galicia, the largest output is obtained from Eocene beds The geology of this zone is very complex, the rocks being sharply folded and in some places faulted by overthrust In 1913 the chief producing area in Rumania was the Prahova, although Buzeu and Bacau also produced some oil. Promising indications of oil are also found in Bukowina, Hungary which also lies in this productive belt.

The oil produced in Germany is obtained largely from fields in Hanover where it occurs in domes associated with rock salt similar to those of the Gulf Coastal Plain of the United States. The rocks that contain it are chiefly limestones and sandstones of Upper Jurassic age. In Batavia some oil has been obtained from sandstone of Eocene age.

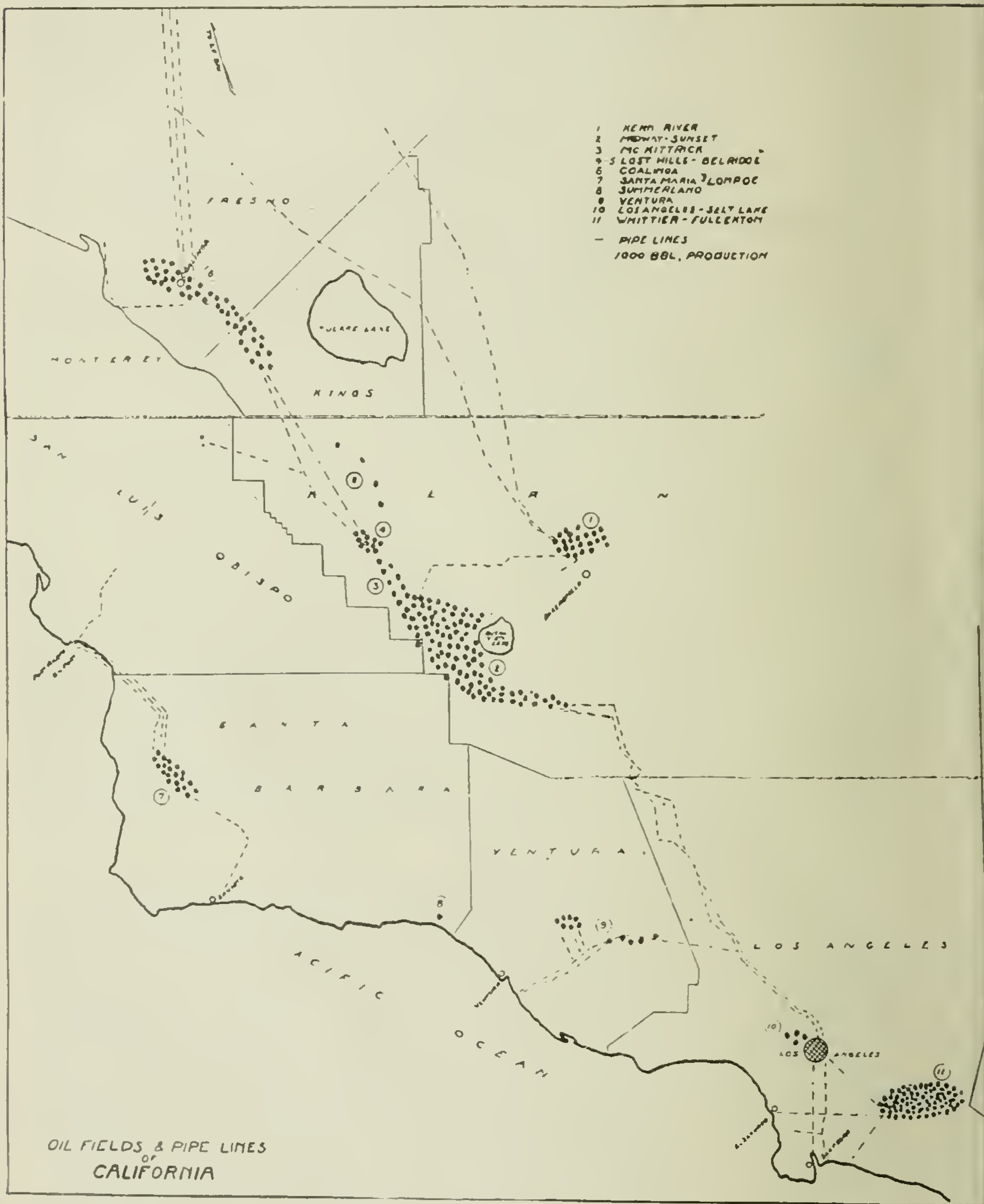


Fig. 5—Map Showing Producing Areas and Pipe Lines for Petroleum in California.

In Alsace some oil has been produced from sandstone of Eocene and Oligocene age but the general structure is not such as would ordinarily be considered favorable.

In Italy oil occurs in the Emilia district, on the northeast slope of the Appenines in disturbed lenticular sandstones of Eocene and Miocene age. A small output of petroleum has been obtained in two other districts in Italy—in the Pescari Valley, central Italy and in the Liri Valley, midway between Naples and Rome.

Indications of petroleum are found at many places in Europe other than those described including England. In fact, practically every country in Europe contains some indications of petroleum. Intelligent and efficient search is likely to lead to further discoveries of oil in many areas, including some where the presence of oil is not now suspected.

Asia—The principal producing oil fields of Asia are in India, Persia and Japan. Almost the entire output of India is produced in Burma. The main oil field is in rocks of Miocene age along the Irrawaddy in Upper Burma about midway between Rangoon and Mandalay. In Assam and in Punjab, coal bearing rocks of Eocene age have yielded oil in small quantities.

The chief oil fields in Japan are on the island of Nippon, about 200 miles northwest of Tokyo but indications of petroleum have been found and a small output has been obtained at many other places in Japan as well as in Taiwan (Formosa). Most of the oil is obtained from loosely cemented sandstones that lie on the flanks of well developed closely folded anticlines.

In Persia and Mesopotamia, along the northeast side of the Persian Gulf and the Tigris-Euphrates basin, lies what is probably destined to be one of the large oil fields of the world. The indications of oil extend over an immense area and oil has been produced in small quantities here for many years. The only notable development however is in Persia, 150 miles north of the head of the Persian Gulf, where about 1,000,000 metric tons of crude oil was produced in 1918.

Other promising oil fields lie in the Ural-Caspian and Trans-Caspian regions of Russia, in Ferghana (eastern Turkestan) in Chinca and on Sakhalin Island. In the Ferghana basin, oil occurs in Lower Tertiary beds in rather closely folded anticlines on the borders of the mountains around the basin. In China, small quantities of oil have been obtained for centuries in the Shensi province, from which large future production may be expected. The oil occurs in Carboniferous strata and the general geologic conditions are similar to those in the Appalachian and Mid-Continent fields of the United States. Indications of oil have been noted in other provinces. In Sakhalin (Saghalien) Island the oil is similar to that in Japan in quality and mode of occurrence. Oil springs and asphalt deposits are scattered through a belt that extends along the greater part of the eastern coast of the Russian part of the island. Pronounced indications of oil are also reported from Palestine and from the vicinity of Lake Baikal in Siberia.

Oceanica and the Malay Archipelago—The islands of Borneo, Sumatra and Java in the Dutch East Indies contain oil fields that may be of immense value and other neighboring islands show promising signs of productive fields. The oil is found in anticlinal folds that have sharply dipping flanks. Most of the oil bearing rocks are as-

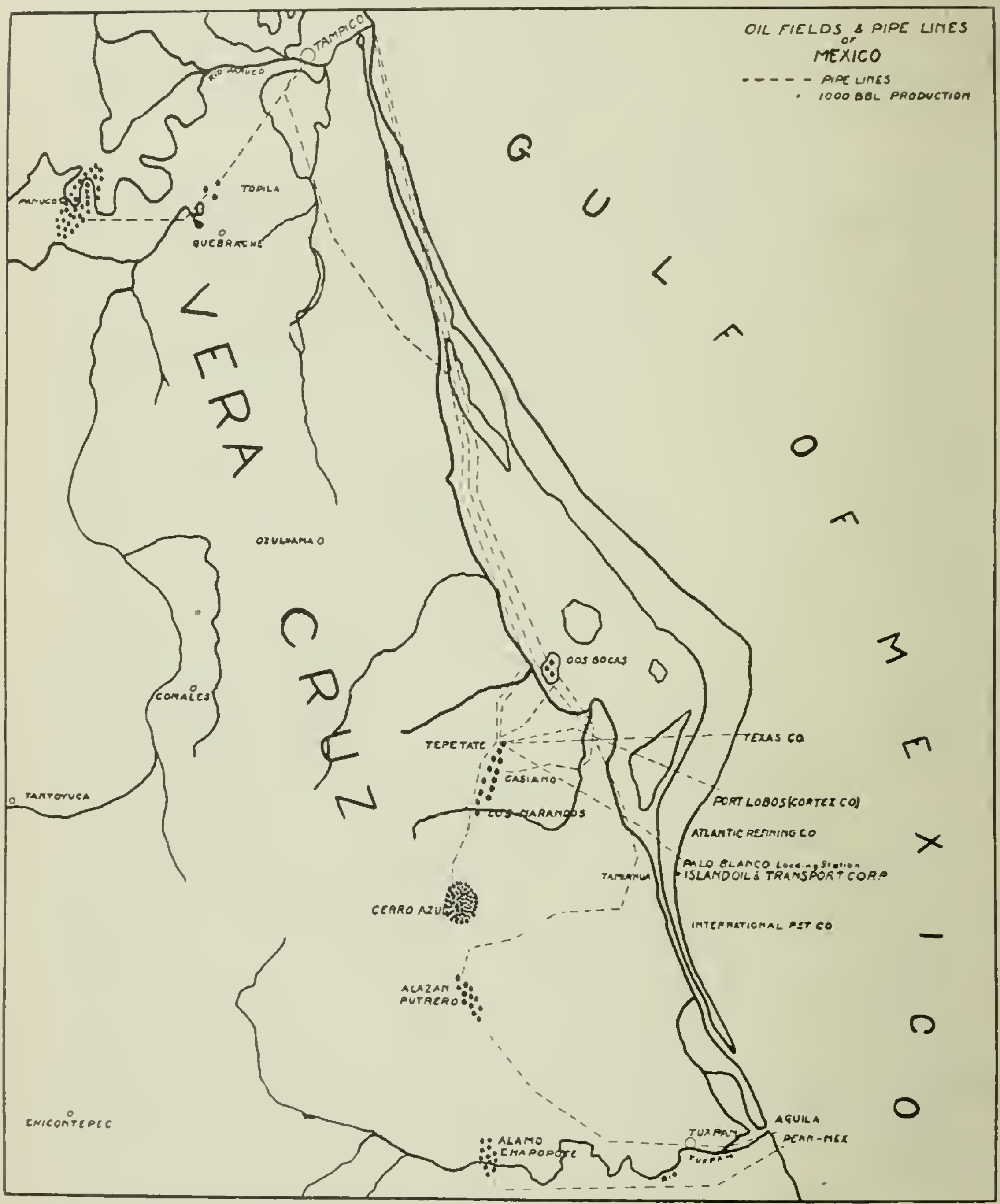


Fig. 6—Map Showing Producing Areas and Pipe Lines for Petroleum in Mexico.

sociated with beds of coal and lignite of Miocene age. In Borneo, oils of both asphaltic and paraffin base are found at different depths in the same fields. Sumatra produces some oils that are very rich in the lighter products and make a much larger output than the other two islands of the group.

Indications of oil are found at many places in the Philippine Islands and small quantities have been obtained there for nearly 50 years.

PRODUCTION AND PROSPECTS.

The most notable contributions to the world's supply of petroleum in the next decade will undoubtedly be made by the South American countries that border the Caribbean Sea, by Mexico and by Mesopotamia and Persia.

The annual production of petroleum in Mexico increased from 21,000,000 barrels in 1913 to nearly 64,000,000 barrels in 1918 and the future production in that country will certainly be very great. Exploratory work done in Venezuela and Colombia shows that both those countries may become large contributors to the world's supply of petroleum within the next decade. In Trinidad, the production of petroleum which for several years has exceeded 1,500,000 barrels a year, has been doubled within the last four years and with the improved facilities for ocean transportation of oil that are now available will no doubt be further increased. Argentine and Bolivia give promise of considerable production. Cuba is not likely to become a large producer of petroleum and our present knowledge of the petroleum resources of the Central American countries is not sufficient to warrant the assertion that oil fields of great output will be developed in them.

The production of petroleum in the United States has probably nearly reached its maximum and is likely to decline slowly but rather steadily, though this country may remain the leading oil producer of the world for many years.

The oil fields of Persia produced about 7,000,000 barrels of oil in 1918 and the wells already drilled are reported to be capable of producing five times that quantity. The capabilities of the field are practically undetermined. Difficulties of transportation have greatly retarded development but an enormous increase in production in the near future is predicted.

The petroleum resources of Russia are believed to be sufficient to make that country the leading producer of petroleum in the Eastern Hemisphere for a long time. The oil fields of both Rumania and Galicia are believed to have passed their maximum yield and valuable new fields will probably not be found in those countries.

The next decade will doubtless witness a steady increase in the production of oil in India and Persia and the development of one or more highly productive oil fields in Mesopotamia and possibly in Asia Minor, Ferghana and China. The same period will doubtless witness a material increase in the production of petroleum in Taiwan (Formosa) and Sakhalin and in the Dutch East Indies and possibly also the opening of new fields in Papua (New Guinea). The oil resources of the Philippine Islands are untested. Africa, including Madagascar, will doubtless receive attention from oil operators during the next ten years, but the output there during that period will probably not be large enough to affect the world's petroleum market seriously.

Geologic Occurrence of Petroleum and Natural Gas.

Petroleum and natural gas are formed by the decomposition of organic matter of any kind under the proper conditions. Usually it originates from plant and animal remains that have been deposited with sediment in the sea. They are never found in commercial quantities in igneous rocks, in the metamorphosed rocks or in fresh water sediments not associated with marine formations. They generally originate in shales, marls or limestones. Petroleum cannot ordinarily accumulate in shales in large quantities because of their close texture. Sands or sandstone are distributed more or less through all shales and these sands as well as porous limestones offer adequate reservoirs for the accumulation of petroleum and gas.

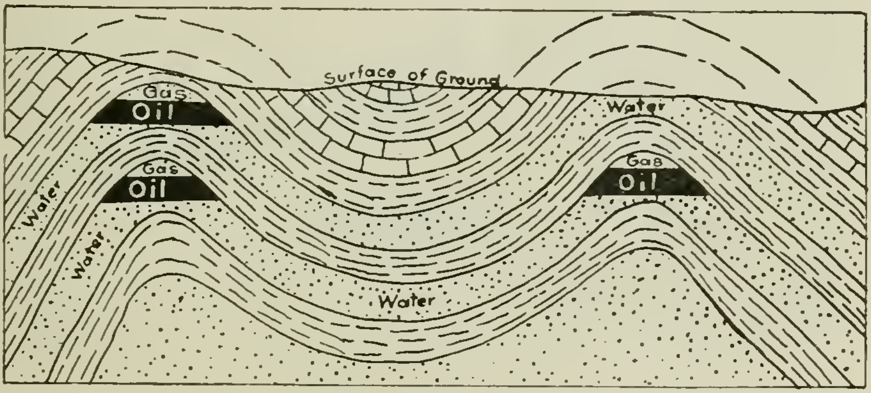


Fig. 7—Diagram Showing Accumulation of Oil and Gas in Anticlines

The following summarizes the geological conditions under which petroleum and natural gas occur:

1. They occur in sedimentary rocks of all geologic ages from Silurian upward. The most productive areas are the Paleozoic in North America and the Miocene in Russia.

2. There is no relation of the occurrence of petroleum to volcanic or igneous action. There seems to be some relation particularly in the Carboniferous and the Mississippian to the deposits of coal.

3. The most productive areas for oil in great quantity are where the strata are comparatively undisturbed. Oil frequently occurs where the strata are highly contorted and disturbed but in less abundance and gas is usually absent.

4. In comparatively undisturbed as well as in disturbed areas a folded or domed structure often favors the accumulation of oil and gas in the domes or anticlines.

5. Important requisites for a productive oil or gas field are an impervious cap rock or cover and a porous reservoir.

6. Salt water almost universally accompanies oil and gas in the same sand.

In the United States, oil is found most abundantly in the Tertiary rocks in California and the Gulf Coast, in upper Cretaceous in Wyoming, in Carboniferous locally known as the Cherokee Shales in the Mid-Continent field, in the sub-Carboniferous or Mississippian and the Upper Devonian in the Appalachian field and in Illinois, and in the Ordovician in Ohio and Indiana. The oils from the Tertiary are heavy and of low grade, those from the Cretaceous, Carboniferous and sub-Carboniferous are light, high grade oils. The Mississippian in the Mid-Continent field is not believed to carry any oil and very little is known of it or deeper strata in this territory. It is assumed that the deeper strata have vanished west of the Ozark uplift.

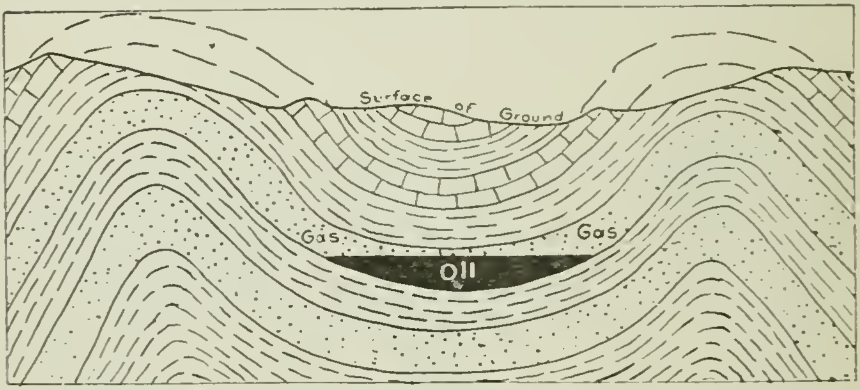


Fig. 8—Diagram Showing Accumulation of Oil in Synclines.

The accumulation of petroleum occurs in a pervious reservoir which usually consists of a loose sand though it may be a coarse gravel or a disrupted shale or limestone. It is merely necessary that the rock should contain a considerable amount of voids. The ordinary sand will have from 15 to 35 percent of voids and the amount of oil contained and the ease with which it is discharged into a well vary greatly. As a general rule, one gallon of oil may be obtained from one cubic foot of oil sand. It is probable that never over 75 percent of the oil surrounding a well is discharged into it even with the lighter oils, and the percent abstracted is much lower with the heavier and more viscous oils. Porous sand and gravel and heavy gas pressure are conducive to rapid expulsion of oil. Fine sand and low pressure give steadily producing wells of great longevity. The ultimate production of a well would be determined by the depth and extent of the sand, the physical character of the sand, the physical character of the oil and the pressure. Water is a very important element in the actual production of a well. It frequently causes very extensive subterranean oil movements destroying one productive structure and making new productive structures.

In nearly every oil sand there occur together, gas, oil and salt water. Salt water is believed to be sea water that filled the pores of the sand when it was deposited in the sea. Water from oil bearing strata differs from sea water in concentration and composition but changes might readily have taken place in the original sea water while stored in the rocks. In rare instances, oil bearing strata are associated with fresh water and in some cases there is no water at all. When these three substances are associated, the gas of course occupies the uppermost portion of the sand, the salt water the bottom, and the oil, the intermediate portion. The sand commonly lies at the same angle or dip as the stratum in which it is contained. This fact offers the basis to a great extent, of the engineer's work in locating the favorable formations. The strata that contain petro-

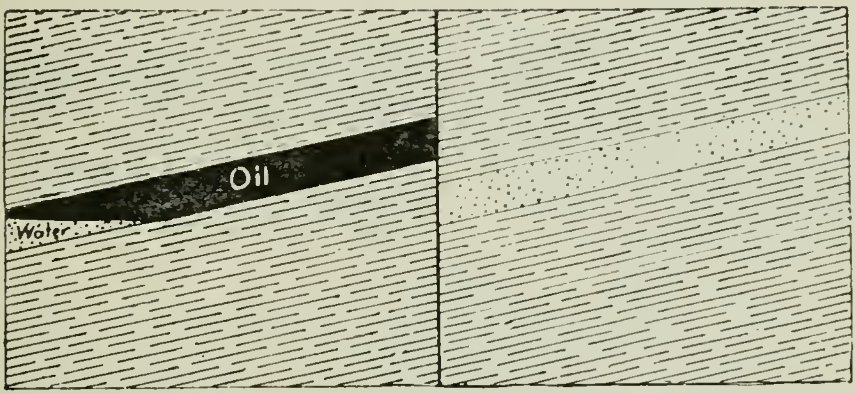


Fig. 9—Diagram Showing Accumulation of Oil in Faults.

leum are folded. In some places, the folding is very slight, in others the strata are thrown into sharp folds, the beds dipping as much as 30°. In consolidated rocks such as shales, limestones and sandstone which have been intensely deformed by faulting and sharp folding, oil is generally not found in large amounts. In loose or uncompressed rocks such as clays, marls, sands and conglomerates, large accumulations are known in areas of highly complicated structures. The tops of the folds or the anticlines offer the cover for the principal accumulation of petroleum, particularly when water and gas are associated. The bottom of the folds or the synclines may carry oil when water is absent in the porous stratum. Many oil fields are on monoclines on which are developed secondary folds such as anticlines, domes and terraces. In rocks that are highly saturated with oil and in beds that dip very gently, the oil gathers in domes if these exist, but accumulation takes place also in gentle folds and in some structures such as terraces which are not completely closed. Surface topography as a general rule, bears no relation to the probable location of oil or the strike of the formation beneath the surface.

Asphalt exposures or oil springs are not usually good indications of oil in immediate vicinities. If oil is found in the immediate vicinity, it is likely to be of heavy asphaltic character.

Asphalt exposures, however, are of value in that they indicate that oil of good quality may be found where this same geologic structure is capped by an impervious cover. The depth at which oil is found of course varies greatly. Oil of good quality is usually found at sufficient depth that the lighter fractions have not evaporated, though some good wells are found at depths as shallow as 250 feet. The best wells of the Mid-Continent field vary from 1,000 to 3,500 feet in depth. The deepest well in the United States is the Lake Well in Harrison County, West Virginia, and is 7,579 feet deep. Wells at Ranger, Texas, are about 3,400 feet deep. A well in Banner County, Nebraska, is 5,600 feet deep. Named in order of depth the

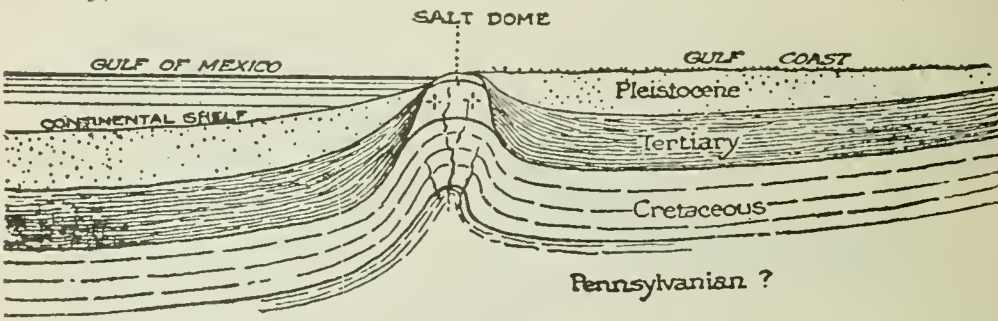


Fig. 10—Diagram Showing Theoretical Salt Domes of Texas Coast District. (Oil and Gas Journal.)

three deepest wells in the world are the Lake; the Goff, West Virginia, 7,386 feet and a well at Czuchow, Germany, 7,348 feet. In comparison with these great depths, other depths reached by wells or mines sunk in the crust of the earth are rather insignificant. The deepest mine in the world is Shaft No. 3 of the Tamarack mine in Houghton County, Michigan, which has reached a depth of 5,200 feet.

The temperature at which oil issues from the ground depends more upon the depth than upon the latitude of the country in which the well is located. The temperature of the oil issuing from wells near the Arctic circle is very much the same as that from the Temperate zone. Gradients as to increase of temperature from the surface of the earth inward have very little bearing upon the average yearly air temperature. As a general rule, the temperature increases at the rate of about 1° F. for each fifty feet in depth. On this basis, the temperature of the earth at a depth of ten miles would be 1000° F. This is a far greater temperature than necessary for the decomposition of organic matter or heavy petroleums into light hydrocarbons. The record of a well in West Virginia as to increase in temperature is as follows:

100 feet	55 6°
1,000 feet	63.5°
2,000 feet	74 9°
3,000 feet	87.6°
5,000 feet	114.2°
6,000 feet	132.1°
7,000 feet	153.2°
7,310 feet	158.3°

Correlation of Oil Sands in Oklahoma
Fritz Aurin
Oklahoma Geologic Survey

Legend
o Oil Producing
✡ Gas Producing
★ Oil & Gas Producing
◆ Showing of Oil

	Name of Formation	Name of Sand or Horizon	Correlation with Other Named Sands	Healdton	Duncan	Blackwell	Cushing	Cleveland	Pawhuska	Caney	Hogshooter	Henryetta-Schulter	Glen Pool	Bixby	Beggs	Morris	Muskogee
		Range		3W.	6W.	1E	7E	8E.	9E	12E.	13E.	13E.	12E.	13E.	12E.	14E.	18E.
		Township		3&4S.	1N.	29N.	17&18N.	21N.	25N.	29N.	24-25-26N.	12N.	17&18N.	17N.	14&15N.	13N.	14N.
Cretaceous	Trinity	Sand															
Permian	Redbeds	Sand		725 ✡	250 •												
		Sand		781 ✡	•												
		Sand		820 •													
		Sand		925 • 80													
		Sand		1040 • 50													
		Sand		1070 • 30													
	?	Sand		2000 ★													
	Undescribed Series Above Herington Ls.	Sand				350 ✡ 25											
		Sand				435 ✡ 10											
	Garrison Form'n.	Blackwell				715 ✡ 25											
	Eskridge Shale	Sand				920 ✡ 20											
Pennsylvanian		Sand															
	Elgin Sandstone	Newkirk	Elgin			1440 35											
	Buxton Formation	Sand				1750 ✡ 25											
		Sand				1800 25											
		Ponca				1960 ◆ 20											
	Ramona Formation	Musselman					700 ✡ 25	500 100									
		Sand				2280 ◆ 15											
		Sand					1240 ✡ 25	1000 •									
	Curl Form'n	Layton				2655 ◆ 95	1480 • 20	1300 • 40	1275								
	Nowata Shale	Wayside	Jones McEwen			2765 25	1730 ✡ 25	1450									
	Oologah Form'n	Big Lime				2980	1800 5		1485 50	615	450		750 75				
	Labette Shales	Cleveland				3050 ◆ 20	1920 ✡ 40	1600 • 75									
		Peru				3300 30					500 • 40						
	Ft Scott Ls.	Oswego Lime	Wheeler Swenson			3360 ★	2250 ★ 70	2075 110	1672 75	815	685	700 •	950 20				
	? Cherokee Formation	Squirrel					2375 ✡ 90		1700				1000 20				
		Skinner					2620 ✡ 20	2200 • 25			885 • 30		1050 •				
		Red Fork											1400 • 20				
		Nemire							1880								
		Sand	Glenn Gas of Morris														
		Bartlesville					2700 • 80	2400 • 70	1940 •	1185 ★ 50	1085 ★ 20	1100 • 80	1500 ★ 60		1530 160	700 150	
		Sand											1650 ✡ 35				
	Atoka Hartshorne McAlester Savanna and Bogy Formations	Tucker	Meadows Booch				2830 •	2700 • 30		1460 ★	1160 ★ 15	1250 •	1750 • 25	1225 ✡ 60		1100 • 20	
		Sand	Second Booch											1300 ★ 20		1220 • 15	
		Dutcher	Colbert										1850 •		1800 40		
		Sand															
		Mounds											2270 50	1600 ✡	2120 ✡		
		Sapulpa	Morris										2350 25	1690 o 15		1620 • 25	
		Glenn of Morris											2500	1750 ✡		1720 • 35	
		Leidecker													2310		
		Sand															
		Muskogee	Boynton													1960 ✡ 25	1050 • 15
		Miscellaneous Sands	Sand not Correlated														
	Morrow Formation	Sand															
		Sand															
		Sand															
Miss.	Pitkin Ls.				Top Figure Depth of Sand Bottom Figure Thickness of Sand in Feet												

Fig. 11—Correlation Chart of Oil Sands of Oklahoma.

The rate of temperature increase varies continuously from 1° F. in 97.5 feet at the surface to 1° F. in 46.5 feet over the interval 6,000 to 7,000 feet. In the Texas and Oklahoma fields, temperatures at a given depth differ widely from those found in Pennsylvania and West Virginia. The temperature of the oil in two wells near Mannington, West Va., is 83.2° F. at a depth of about 2,900 feet. In the Ranger field, Texas, the temperature of the oil at 3,400 feet is estimated from measurements at higher levels, to be about 135° F. The average rate of temperature increase at the surface for thirteen wells in Texas and Oklahoma is about 1° F. in 51 feet as compared with 1° in 91.5 feet for twelve wells in Pennsylvania and West Virginia. Mexican oil issues at an average temperature of 165° F.

Salient Features of Certain Oil Fields (Emmons).

FIELD	RESERVOIR ROCKS		Cover	Principal Structural Features	Surface Indications of Oil or Its Associates
	Age	Kind			
Appalachian	Pennsylvanian or Devonian	Sandstone and Limestone	Shale	Anticlines, terraces, and dry synclines	Oil and gas seeps Grahamite.
Ohio-Indiana	Ordovician	Porous dolomite	Shale	Half domes and terraces on Cincinnati anticline, domes	Gas seeps at Findlay, Ohio.
Illinois	Pennsylvanian and Mississippian, Ordovician	Sandstone and porous oolitic limestone Limestone	Shale	LaSalle anticline and minor flexures	Oil seeps rare or lacking.
Northeast Oklahoma and Kansas	Pennsylvanian	Sandstone Limestone	Shale	Anticlines, domes, half-domes and terraces	Asphalt to East where oil bearing strata crop out.
North Central	Pennsylvanian and Mississippian	Sandstone	Shale	Arched monocline	Rare.
Gulf Coast (salines)	Miocene and Eocene; some in Cretaceous	Porous dolomitic limestone and sandstone	Clay or shale	Domes	Mounds, acid waters salt water, sulhur gas, "paraffin dirt."
Sabine, La., and Texas	Cretaceous (Upper)	Sandstone Limestone	Clay	Domes	Gas seeps, etc.
Rocky Mountains Wyoming-Colorado	Cretaceous and Carboniferous	Sandstone	Shale	Domes are typical; fracture zone at Florence, Colo., fault traps	Some tar springs and gas seeps.
California	Late Tertiary, mainly Miocene to Cretaceous	Sandstone	Shale and Clay	Anticlines, domes plunging anticlines, fault zones fault traps, overturns, monoclines	Asphalt, brea, tar springs, etc.
Tampico, Mexico	Basal Tertiary and Cretaceous	Limestone and sand	Shale	Anticlines, domes and disturbances near igneous rocks	Oil seeps, asphaltum.

Salient Features of Certain Oil Fields (Emmons)—Continued.

FIELD	RESERVOIR ROCKS		Cover	Principal Structural Features	Surface Indications of Oil or Its Associates
	Age	Kind			
Trinidad	Tertiary and Cretaceous	Sandstone	Clay	Anticlines	Asphalt, seeps.
Venezuela	Tertiary and Cretaceous	Sandstone	Clay shale	Anticlines	Asphalt,
Colombia	Tertiary and Createous	Sandstone	Clay Shale	Anticlines	Asphalt, mud volcanoes,
Rivadavia, Argentina	Upper Cretaceous	Sandstone, coarse pebbly	Shale	Flat, minor anticlines	None.
Lower Alsace	Oligocene	Sandstone	Marl	Faulted monoclines	Pitch springs, asphalt.
Boryslaw, Galicia	Miocene and Oligocene	Sandstone	Clay and Shale	Anticlines, synclines	Oil seeps, ozokerite.
Schodnica, Galicia	Eocene, Cretaceous	Sandstone Conglomerate	Clay and shale	Anticlines, synclines	Oil seeps.
Rumania	Pliocene, Miocene and Oligocene	Sandstone conglomerates	Clays Shales	Anticlines, fault traps	Mud volcanoes, oil seeps, gas seeps.
Baku, Russia	Miocene and Oligocene	Sandstone	Clays Marls	Anticlines, Monoclines	Oil seeps, mud volcanoes, gas seeps.
Grozny, Russia	Miocene	Sandstone	Clays Shales	Anticlines	Oil seeps, gas seeps.
Maikop, Russia	Oligocene	Sandstone	Shale	Unconformity	Oil seeps, asphalt.
Egypt	Miocene and Cretaceous	Sandstone		Anticlines in part	Oil seeps, asphalt.
Burma	Miocene	Sandstone	Clay	Anticlines	Oil seeps, gas seeps.
Sumatra	Miocene	Sandstone	Clays Shales	Anticlines	Oil seeps, mud volcanoes.
Java	Miocene	Sandstone	Clays Marls	Anticlines	Oil seeps, etc.
Japan	Tertiary	Sandstone and tuff	Shale	Anticlines	Oil seeps, etc.

General Description of Oil Well Drilling.

The usual method of drilling for oil and gas is the cable system which depends upon the weight of a heavy string of tools hung on a stretched rope or cable. Rope is more satisfactory than cable for shallow depths. Wire cable is satisfactory below 1,000 feet. The general equipment required excepting the power plant is shown in figure 12. A timber or metal derrick 60 to 100 feet high with a 16 to 20 foot base is mounted on heavy frame. On one side of the derrick, the rig is erected. The main drive is transmitted from the engine to a large wooden wheel known as the band wheel which is from 8 to 12 feet in diameter. The shaft of the band wheel at one end is attached to a crank that transmits through a connecting rod an oscillating movement to an overhead beam known as the walking beam. Holes are bored in the crank enabling the pin to be placed at varying distances from the center thus allowing an adjustment of the stroke of the walking beam to suit requirements. From the end of the walking beam just overlying the mouth of the well is hung a temper screw and rope clamp to which the cable is attached when the string of tools is lowered into the well. The string of tools is suspended from a cable which is coiled on the bull wheel shaft on the side of the derrick opposite the rig. The bull wheel is driven by a chain or crossed drive-ropes leading from a tug wheel on the side of the band wheel to a corresponding bull wheel about 8 feet in diameter on the end of the bull wheel shaft. Immediately behind the band wheel is the sand reel at the inner side of which is fitted a small pulley that can be drawn against the face of the revolving band wheel by levers thus causing its rapid rotation. The sand line is coiled on the sand reel and carries the bailer. The bailer is allowed to descend by gravity, its speed being regulated by forcing the lever backwards and bringing the friction pulley in contact with a stationary wood block brake. Many combinations of the bailer operation are used to facilitate and speed the operation of drilling.

The calf wheel is used for manipulating the line from the casing block. It is mounted on a shaft on the rig side of the framing and is operated by ropes from a groove or sprocket pulley on the end of the band wheel shaft.

Three pulleys are placed at the summit of the derrick over which pass respectively, the drilling cable, the sand line and the casing line. For cable drilling, a reversing engine is necessary, enabling the operator by means of a rope or rod to have full control from the derrick.

The string of tools is shown in fig. 14 and is about 40 feet long. It consists of a bit or drill, auger stem, jars, sinker and rope socket. When attached to the rope, they are suspended in the derrick and lowered into the well, a band brake on one end of the bull wheel shaft being used to retard the speed of descent. When the tools are at or near the bottom of the well, the temper screw is attached to the cable, the weight then being thrown onto the walking beam and the bull wheel shaft is released. Some slack cable is uncoiled from the

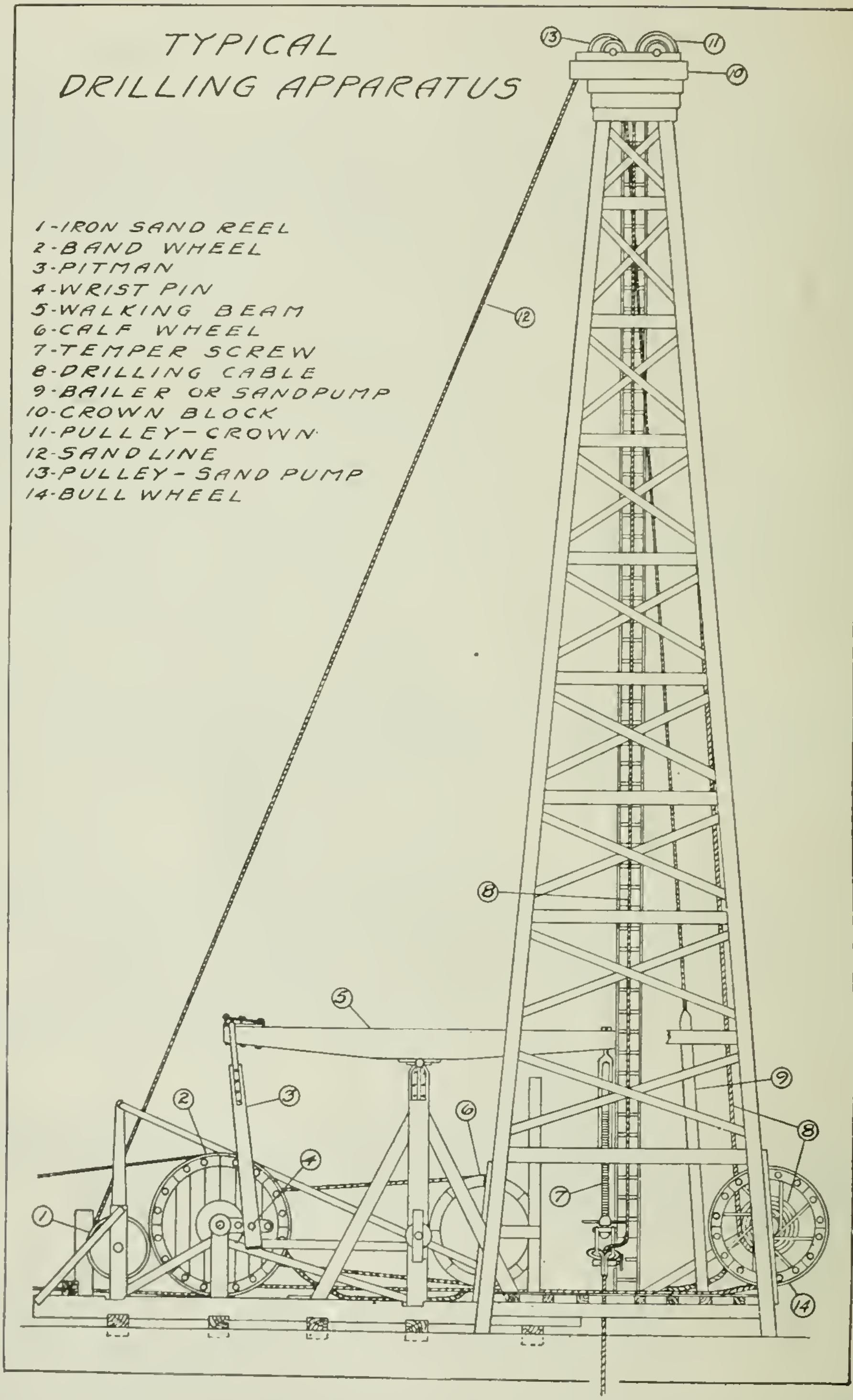


Fig. 12—Standard Derrick and Equipment for Drilling Deep Oil Wells.

bull wheel shaft. The engine is started and the speed is adjusted to correspond with the vibration of the drill rope. The temper screw is fed out a little at a time, lowering the bit until a blow is delivered on the bottom of the well. The tools are then fed out with the temper screw so that the bit strikes an effective blow. When the bit shows signs of not falling freely, the slack rope is taken up and the temper screw is relieved of weight, the connecting rod or pitman is disconnected from the crank pin, the beam is allowed to take an inclined position and the tools are raised to the surface. The bailer is now lowered and the well is cleaned out, sufficient water having previously been run into the well to make a thin mud such as can be taken up by the bailer.

In starting a well, it is not possible to operate with the cumbersome string of tools so that the first 100 to 150 feet are drilled by the method known as spudding. The method of spudding is shown in fig. 15. A special spudding shoe is connected by a rope to the roller, gripping the drilling cable near the bull wheel shaft. The figure clearly shows how the vertical motion is imparted to the tools.

The proper operation of a drill is a matter of expert manipulation as considerable judgment is needed to secure the full capacity of a cable drilling outfit. The speed of drilling must be carefully regulated to accord with the depth of the well, the nature of the formation and the amount of fluid in the well. Ordinarily, it is not necessary to rotate the rope to get equal distribution of the attrition of the bit as the changeable strains in the cable and beam take care of this.

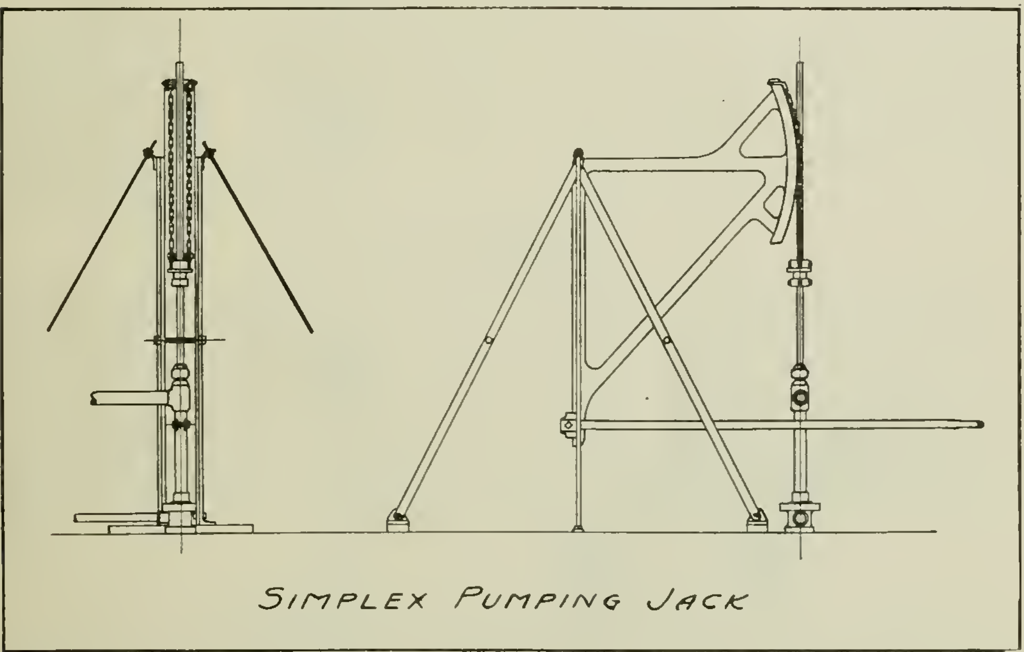


Fig. 13—Individual Simplex Pumping Jack for Connection with Central Powers.

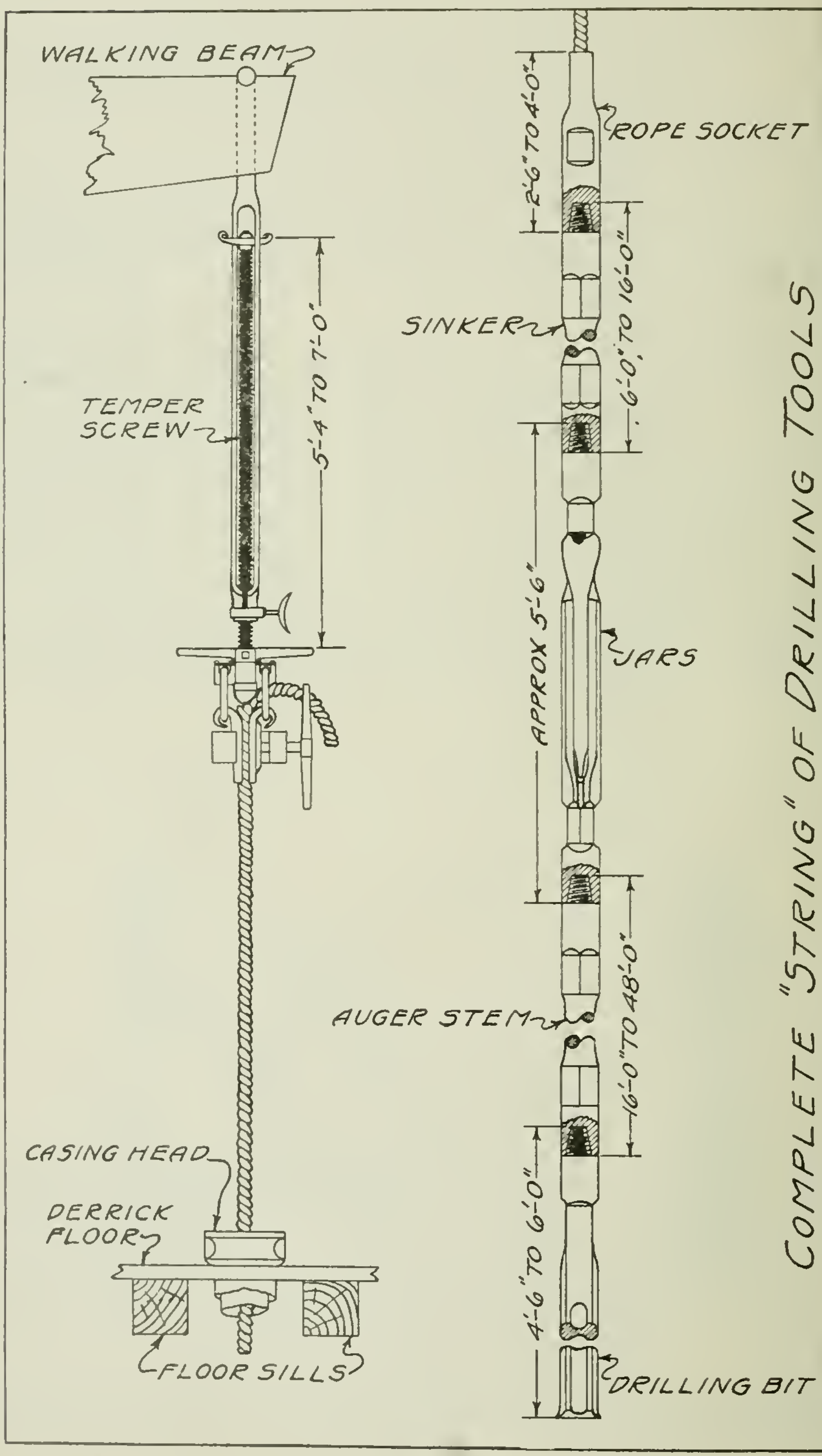


Fig. 14—Standard String of Cable Drilling Tools.

Rotary or Flush Drilling.

Rotary flush drills are successfully used on a large scale particularly in Texas and Louisiana. They have the advantage that very rapid speed may be made, as much as 3,100 feet of hole being drilled in a month. Rotary drilling is not advisable nor is it used in wild cat or prospect work when it is necessary to know the character of all formations that are passed through. It is very easy for a rotary drill to pass through a rich formation without any evidence of its presence. This type of drilling then is used where the producing horizon is very definitely known and the well is drilled to within a hundred feet or so of this producing horizon and is finished with the ordinary cable tools.

The main feature of all rotary flush drills is a rotating table driven by a gear erected on one side of the derrick. The rotary motion is transferred by means of pipe to a special bit. A typical bit is a double cone shaped affair with numerous wedge shaped knives which turn with the bit. The circulating fluid for removing the cuttings is set over the bit under a pressure of about 150 to 200 pounds per square inch by pumps with a capacity of about 200 gallons per minute. For rotary drilling, derricks of 120 feet in height are desirable for convenience in withdrawing the drill pipe.

Percussion Drilling.

A system of drilling by percussion is used to a very limited extent. Very rapid blows at ths rate of 100 to 150 per minute are struck by using an eccentric instead of a walking beam.

Fishing Operations.

The most difficult features in drilling wells are those occasioned by the losing of tools, collapsing of casing or locking of tools by caving. These accidents occasion weeks and even months of delay and sometimes cause abandonment of the wells. To recover these tools or to proceed with the drilling it is necessary to clear the hole by means of special fishing tools. Almost every conceivable type of tool has been produced for this service.

Under-Reaming.

On the end of the casing is applied a special steel ring known as the casing shoe to protect the end of the casing from bending or distortion. The casing shoe is larger than the drill and when it is necessary to lower the casing, the hole below the casing shoe must be enlarged. This is done by under-reaming. Under-reamers are instruments provided with side cutters which are opened automatically when the under-reamers are lowered below the casing. Some under-reamers provide for both drilling and under-reaming at the same time. Under-reamers are used whenever it is desirable to enlarge the hole at any point.

Portable Rigs.

When wells of slight depth are to be drilled, light portable rigs are used to avoid the expense of dismantling and re-erecting a derrick and rig at each well site. For depths less than 1,000 feet, portable rigs are satisfactory but are not ordinarily used for depths greater than 1,000 feet.

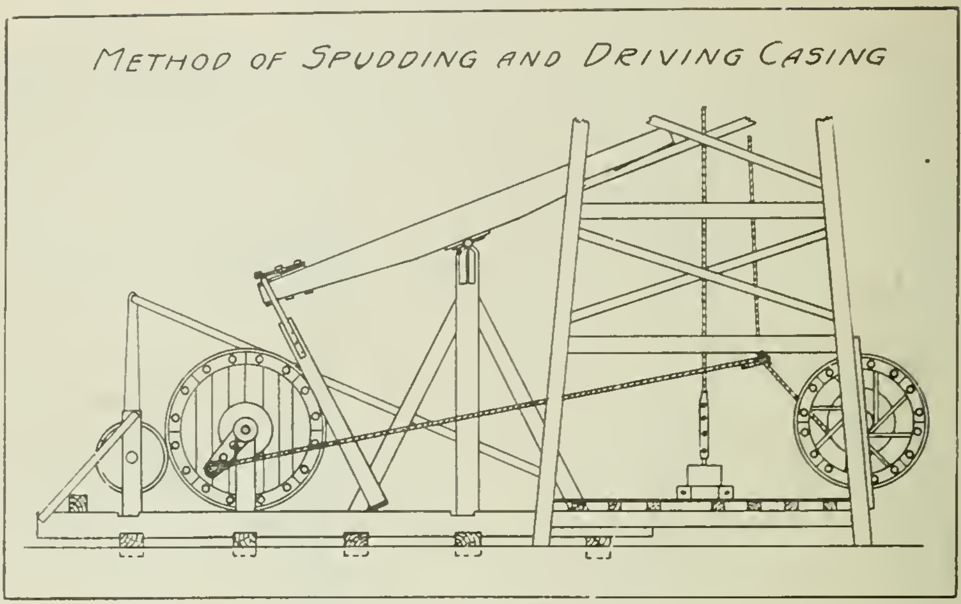


Fig. 15—Adaptation of Drilling Rig for Spudding In.

Shooting of Wells.

When an oil well is drilled in, in some sections, the formation is so hard that it is necessary to break it up so that the oil will flow. In Oklahoma and Kansas, wells are nearly always shot soon after they are drilled in. The shooting consists in setting off a large charge of explosive placed in the well at the level of the oil sand. The explosive used is usually nitro-glycerin. The explosive is set in the bore of the well corresponding as nearly as possible to the producing sand. The amount of the charge depends upon the thickness of the producing sand. A sand 40 feet thick is usually given a charge of about 150 quarts of nitro-glycerin. The nitro-glycerin is introduced into the well by means of a shell containing 20 quarts. Whenever it is thought that the shooting may have a bad effect and cause a well to be flooded out with salt water or whenever any other damage may possibly result, shooting is eliminated. Hard compact sands are universally benefited by shooting. Some sands will not produce at all until they are shot. The action is to form cracks and crevices in the oil bearing formation for a considerable distance from the hole.

Sand Screens or Strainers.

In pumping the oil from the well, the fine sand cuts away the valves and plungers so rapidly that the plungers must be frequently removed and replaced. The sand also clogs up the well so that the flow of oil is considerably diminished. To overcome these difficulties, sand screens are set in the bottom of the well to keep out the sand. These screens consist of perforated brass cylinders wound with heavy copper or brass wire. The screens are commonly used in the Gulf Coast territory but not in the Mid-Continent field. The screens themselves frequently clog up so that the production can often be much increased by removing them.

Bailers.

Bailers are long cylindrical vessels fitted on the bottom with a lift valve and of sufficient flexibility that they can be lowered to the bottom of a well. When the lift valve strikes the bottom of the well, fluid is admitted until the bailer is full. It is then withdrawn and emptied at the top of the well. Bailers are used particularly for cleaning out the well and sometimes for obtaining the actual oil production.

Swabbing.

The swab consists of a steel bar with an internal ball valve made to closely fit the casing by means of rubber rings. The swabbing consists in very rapidly pulling the swab upwards in the casing so that it suddenly creates diminished pressure with much agitation of the fluid contents of the well. It momentarily removes the pressure head due to the height of the fluid in the well as well as producing a partial vacuum beneath the swab. This causes the oil or gas in the formation to flow out readily and cleans off the wax, mud or other adherent matter on the exposed face of the sand. When there is a high pressure against the oil sand or a tendency for the well to wax up, swabbing is extensively used for obtaining the actual oil production of the well.

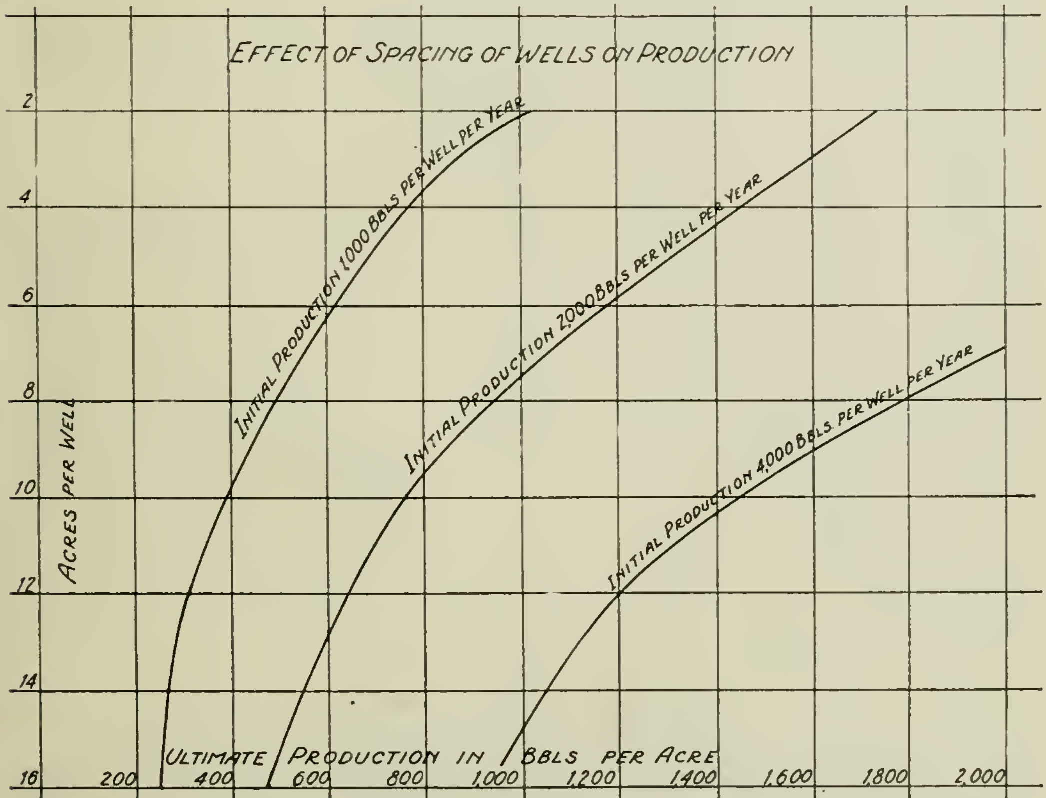


Fig. 16—Effect of Spacing Oil Wells on Their Ultimate Production.

Pumping of Oil.

The production of oil when there is no natural flow or the natural flow has subsided is obtained by the use of ordinary lifting pumps. The kind of pumps used are practically the same as those used for deep pumping of water. Some pumps are double acting in which each stroke lifts oil and balances against a counter stroke. In this case, a sucker rod operates on a piston which is inside of a pipe which operates the other piston. Oil is produced to a limited extent by the use of compressed air in the same manner that it is used for water. A very common method of lifting oil is by means of free air. In this case a double pipe is introduced into the oil in the bottom of the well, the inner pipe being perforated at the bottom with holes, the air being introduced in the annular space between the two pipes. The air in entering the inside pipe greatly diminishes the length of the column of oil so that it is raised in the well. This causes it to overflow at the top of the well. This operates on the same principle as the original gas found in the crude oil which is a frequent cause of the gushing of the oil.

Pump Equipment.

The pumping equipment above ground on a lease consists of a power plant which operates a horizontal spindle eccentrically attached to several wheels. On the periphery of each wheel are attached several pins on which are connected the wire jerker lines. These jerker lines radiate to the various wells where they are attached to the pumping jack which operates the pump.

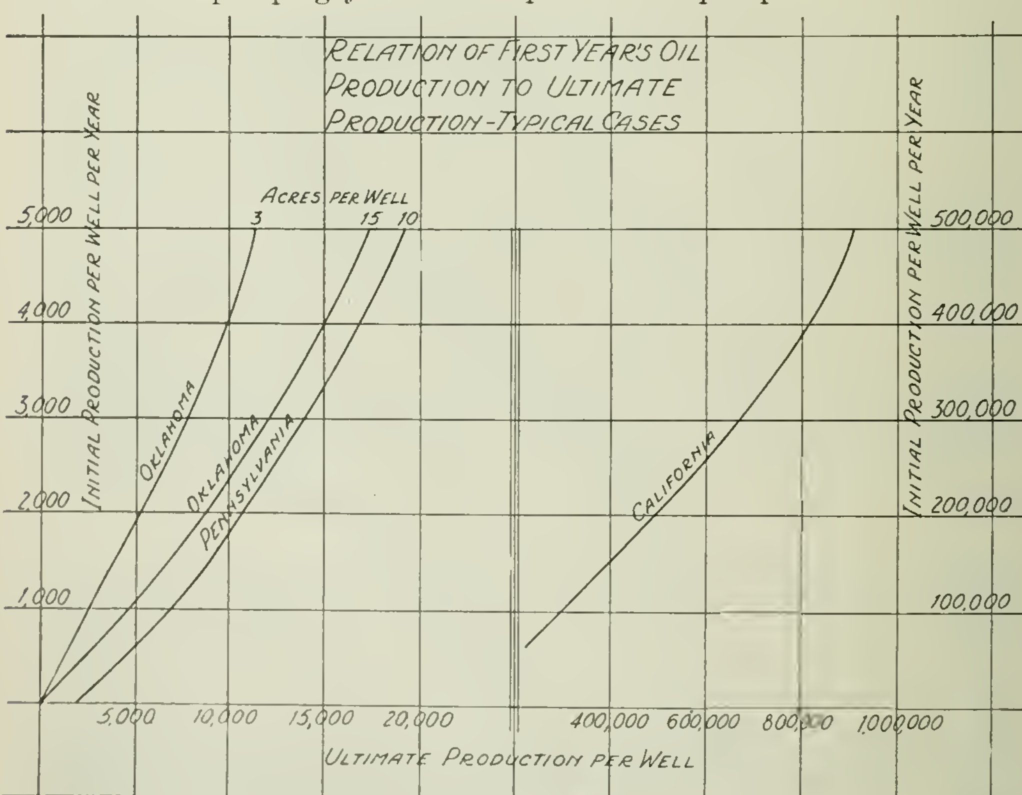


Fig. 17—Relation of First Year's Production of Oil to the Ultimate Production Per Well.

Casinghead.

When a well is first brought in, the walking beam of the drilling rig is generally used for operating the pump. The casinghead is attached to the top of the casing and from it are side outlets, one at the top for conducting the gas and the other at the bottom for conducting the oil. The gas is usually conducted to the gas engine for the source of power and the oil is carried in pipes to the flow tank where the water is separated by a swing pipe on the outside. Oil flows from the top of the flow tank to another tank in which the gauging is done when the pipe line takes the oil. The flow of the oil into the flow tank usually does not correspond exactly with the stroke of the plunger. It is discharged at times more or less violently, usually with a slow expulsion of foam followed by rapid ejection of oil or oil and gas. This lack of uniformity of flow is caused chiefly by the expansion of the gas that is dissolved in the oil when the pressure is lowered as the oil reaches the surface.

Well Drilling by Motor.

A test by Empire Gas & Fuel Co. at 2,500 feet in Kansas showed the following costs:

	Boiler and Engine	Motor	Loss	Saving
Initial cost	$1,862.00	$1,625.00	....	$237.00
Cost of installation (including belts, etc.)	432.50	*768.03	$335.53	....
Estimated depreciation per well	290.00	32.50	....	257.50
Cost of water	480.00	60.00	....	420.00
Estimated cost of fuel oil at $36 per day	2,160.00	....	....	....
Cost of electric power	....	574.93	....	....
Saving in cost of power	....	....	....	1,585.07
Saving in installing pumping motor in same house on same foundation	....	....	....	186.16
Saving in oil production during change to pump	....	....	....	1,305.00
Total	....	....	$335.00	$3,990.73

Net estimated saving of electric drilling over steam.............$3,955.20

* The installation charge of the motor drilling equipment was high due to the fact that the equipment was new and changes had to be made which involved labor charges that will not be necessary in future outfits. It also includes the cost of building the motor house.

Table Showing Price Per Foot for Drilling Oil and Gas Wells in Various Fields.

(Oklahoma Geological Survey)

	Feb. 22, 1916	June 23, 1917	July 27, 1917
To shallow sand in Bartlesville, Nowata and Tulsa districts	$0.80 to $1.00	$1.00 to $1.25	$1.25
To Layton sand in Cushing field	$1.35	$1.50	$2.50
To Bartlesville sand in Cushing field, northwest	1.50	2.00	3.50
To Bartlesville sand in Cushing field, southesat	2.00	2.25	$3.50-$4.00
To shallow sand in Newkirk, Ponca City and Garber fields	1.50	1.50	1.50
To deeper sands in Newkirk and Ponca City fields (over 2,500 feet)	2.50	3.50	3.50- 4.00
Healdton field	1.40- 1.50	1.75	1.75
Electra and Burkburnett to 1200 feet depth	2.00		
Electra and Burkburnett to 2100 feet depth	8.50		
Electra and Burkburnett to more than 2,500 ft. depth	5.00		

NOTE.—Price for rotary drilling to 2,000 feet is $3.00.

The regular charge for work by the day Feb. 22, 1917, was $50.00 for a double shift. This held good thorughout the above fields. All wildcat propositions some distance (50 miles or more) from any of the above mentioned fields demanded $3.00 per foot. Contracts were let in 1918–1919, in Pine Island, La., at $11,000 to $15,000 per well.

The following table showing the cost of drilling Oklahoma oil wells and operating the same is clipped from a recent issue of the Oil and Gas Journal, and shows advances in drilling and operating costs for oil wells and gas wells.

OKLAHOMA DRILLING AND OPERATING COSTS.

	1913	1914	1915	1916	1917	1918	1919
Lumber for rig	460.00	506.00	552.00	667.00	839.00	1,069.50	1,200.00
Contract price for building rig	175.00	175.00	175.00	200.00	200.00	250.00	300.00
Complete rig irons	405.35	383.00	304.60	481.10	636.10	683.00	700.00
Contract drilling 2,500 feet	2,025.00	3,375.00	3,650.00	4,375.00	5,000.00	5,625.00	7,625.00
Contract day labor	800.00	850.00	900.00	1,000.00	1,200.00	1,375.00	1,800.00
Gas engine house	140.00	150.00	145.00	145.00	165.00	200.00	300.00
Gas engine and setting	615.00	615.00	615.00	685.00	935.00	1,200.00	1,500.00
Tanks and tank houses	830.00	875.00	850100	900.00	1,200.00	1,500.00	1,750.00
Miscellaneous material	650.00	725.00	800.00	900.00	1,080.00	1,200.00	q,500.00
Other well labor	276.00	314.00	296.00	296.00	395.00	500.00	750.00
Setting gas engine	100.00	105.00	100.00	100.00	115.00	125.00	175.00
Miscellaneous labor	139.00	158.00	149.00	149.00	148.00	225.00	275.00
Hauling	185.00	210.00	199.00	199.00	237.00	300.00	500.00
Casing, rods and tubing, including working barrels	5,025.66	5,025.66	4,867.54	6,544.45	9,256.77	10,323.70	12,000.00
Total for complete well	11,826.01	13,308.54	13,558.02	16,642.05	21,447.37	24,576.20	31,500.00

The Exploitation of Petroleum by Means of Pits and Galleries.

M. Couran, ex-engineer of the Corps des Mines and a former member of the French General Committee on Petroleum, calls attention to the exploitation of petroleum by means of pits and galleries in Technique des Petroles, according to L'Echo des Mines et de la Metallurgie. "The complete exploitation of a deposit," says M. Couran, "should logically pass through three distinct phases, whose abilities of extraction should correspond approximately to the following proportions of the total volume of oil originally contained by the sandstone: Drilling, 10% to 20%; drainage by means of subterranean galleries, 30% to 40%, and mining of the sandstones and washing with boiling water, 30% to 40%."

These figures given by Paul de Chambrier, director general of the Pechelbronn mines are not absolute and may vary from one deposit to another, but at least they give an idea of the order of magnitude of the phenomena involved. It is certainly true that the quantity of oil discharged through a boring that taps a petroleum deposit represents but a small fraction of the crude oil saturating it.

De Chambrier's method, which is described in a small publication, offers the following advantages over ordinary well drilling: It permits the recovery of two or three times as much oil as that already secured from the same deposit by means of boring; it increases to the above extent the value of a concession by permitting one to at least estimate with sufficient accuracy, if not to calculate precisely, the oil reserves still held in the ground; from the economic point of view it offers possibilities in countries where oil deposits appear to have reached the limits of their yield; from the scientific standpoint, it is destined to solve a multitude of problems that have remained obscure heretofore involving the origin of crude oil, its migration, its concentration in the lower strata, the behavior of the natural gas associated with the petroleum and the stratification of the porus rocks.

It is probably that the first mining of petroleum was by means of pits, even before the drilling of wells.

Oil Gushers.

In many cases wells drilled for oil penetrate porous reservoirs that yield at the outset large amounts of oil that flows strongly from the well and is often thrown under high pressure above the derrick floor. Such wells are termed "gushers" in the United States and "spouters" or "fountains" in Europe and Asia. This type of flow is characteristic of oil under high gas pressure. In some cases, the oil is forced out by hydrostatic pressure in the same manner as the flow of artesian water. The gas pressure may force the oil out without being itself discharged to any material extent. Usually both oil and gas come out, the oil being sprayed high into the air with the escape of the gas. When the formation is loosened, sand, gravel and mud are frequently thrown out. Some wells in Mexico throw out gravel particles weighing as much as 3 to 4 pounds. This blowing out of the sand often causes the well to "drill itself in." This is commonly attended by increased production in the early stages of the well's life.

Gushers usually very rapidly diminish in volume due to the decrease in gas pressure and to the rapid exhaustion of the sand in the immediate vicinity of the oil. Some wells that yield only gas at first, gradually are converted into oil wells. For this reason, the wasteful practice of allowing the gas to escape in order to get the oil is still carried out where it has not been made illegal.

The largest oil well in the world is one which came in near Tampico, Mexico, February 10, 1916. It was known as Cerro Azul No. 4 and was drilled by the Pan-American Petroleum and Transport Co. The first twenty-four hours of oil flow yielded 260,000 barrels. In two years it is said to have produced approximately 60 million barrels of oil or about one-half of the total production of oil from Mexico. Its initial pressure was 1,035 pounds per square inch and the gravity of the oil is 21° Baume' and without sediment or water. This well continued to produce at its usual rate during 1918.

In September, 1910, the Mexican Petroleum Co. brought in a well in the Juan Casiano field. It showed on a test that it was capable of giving a daily yield of something more than 100,000 barrels of oil. Pipeline connections were made, however, but not until more than 1,500,000 barrels of the inflammable product had been burned in order to prevent it from flowing into Lake Tamaihua, thus endangering boats and other property. It was throttled down to a flow of 20,000 barrels a day and for more than eight years it has been giving this yield. It has yielded, up to the present time, more than 65,000,000 barrels of crude petroleum. Accompanying this oil is a gas pressure of 265 pounds per square inch. This natural gas is piped to the top of a hill a mile and a half distant from the well and is there burned in twelve great flares day and night, lighting up the country for a long way around. On account of the lack of transportation facilities, it has not been allowed to flow at its maximum, being restrained to one million barrels per month at this time.

In June, 1921, the Mexican Petroleum Co. again brought in a well twenty-five miles south of the celebrated Cerro Azul No. 4 well above described, which started flowing at the rate of 15,000 barrels per day and quickly increased to 75,000 or 100,000 barrels per day with a pressure of 500 pounds per square inch.

A number of wells in the Saboontchy-Romany oil fields of Russia have given daily yields of from 75,000 to 120,000 barrels for weeks and as much as 7,500,000 barrels in a year.

Another Mexican well at Dos Bocas, south of Tampico, yielded approximately five million barrels within two months.

A well in the Jennings pool in Louisiana, in 1904, is reputed to be the largest gusher in the United States and gave 1,275,000 barrels of oil in four months.

Wells in Texas, California and Rumania have yielded 60,000 to 75,000 barrels of oil per day on the initial production.

The largest wells in the Mid-Continent field were in Butler County, Kansas, where, in the Towanda pool, gushers as large as 25,000 barrels per day, initial production, were struck in 1917.

Wells in the Homer, Louisiana, and El Dorado, Arkansas, district started in originally from 10,000 to 30,000 barrels per day but quickly dropped to 2,000 barrels or less of high grade oil.

PRODUCTION AND DECLINE OF INDIVIDUAL OIL WELLS.

Mid-Continent Field, 1916.

Total number of wells drilled during year	11,240
Total number of dry holes (including gas)	1,970
Total number with gas	475
Total production at end of year	9,270
Average production of this year's producing wells drilled during the year	26 bbls.
Average production of this year's producing wells, including dry holes	21.5 bbls.
Per cent producing at end of year	92.5%
Total number of wells drilled up to end of this year	81,150
Total number of wells drilled and producing at end of this year	43,420
Per cent of wells drilled now productive	53.2%
Average production of all producing wells in field per day, including this year	8 bbls.
Average production of all producing wells drilled, excluding this year	3 bbls.

OIL WELLS DRILLED IN UNITED STATES IN 1917-1918.

DISTRICT	Completed 1917	Completed 1918	Dry 1917	Dry 1918
Pennsylvania	5,435	4,400	985	738
Lima-Indiana	800	793	140	140
Central Ohio	582	605	139	159
Kentucky-Tennessee	1,651	2,191	411	360
Illinois	647	396	151	108
Kansas	3,469	4,671	547	925
Oklahoma-Arkansas	6,717	8,381	1,334	2,116
Texas Panhandle	1,020	,1140	262	625
North Louisiana	472	534	110	105
Gulf Coast	1,562	1,597	639	625
Total	22,355	24,708	4,718	5,901

OIL WELLS IN MEXICO, 1919.

Wells drilled during 1917 producing oil at end of year	70.11%
Wells drilled durign 1918 producing oil at end of year	76.12%

The total number of wells is 1,056, as follows:

Wells located	131
Wells being driven	114
Wells in production	298
Wells not profitable	27
Wells exhausted	64
Wells not producing	422
Total	1,056

OIL WELLS IN MEXICO, 1919

The largest number of productive wells belong to the following companies:

Aguila Company (Lord Cowdray)	55
Mexican Petroleum Company of California	33
The Corona Company	10
Union Petroleum Company, Hispano-Americano	17
The Texas Company of Mexico	10
Mexican Gulf Oil Company	8
Chicholes Oil Company, Ltd	7
Mexican Combustible Co	9
Penn. Mex. Fuel Oil Co	7
Freeport & Mexican Fuel Oil Co	7
Transcontinental Petroleum Co	12
Oil Fields of Mexico	12

DAILY PRODUCTION OF CRUDE OIL BY POOLS (JAN., 1922).

			Barrels
ARKANSAS—			
El Dorado			38,000
CALIFORNIA			337,101
Coalinga	39,592		
Huntington Beach	5,397		
Kern River	21,155		
Lompoc and Santa Maria	14,663		
Los Angeles and Salt Lake	4,065		
Lost Hills-Belridge	10,744		
McKittrick	6,730		
Midway-Sunset	138,773		
Summerland, Watsonville, etc	213		
Ventura County and Newhall	6,249		
Whittier-Fullerton	89,520		
COLORADO			300
ILLINOIS			30,000
INDIANA			4,000
KANSAS			109,412
Augusta	12,968		
Elbing	9,965		
El Dorado	30,592		
Covert-Sellers	3,592		
Florence	25,975		
Greenwood County	4,200		
Peabody	4,680		
Southeastern Kansas and Miscellaneous	17,440		
KENTUCKY			21,000
LOUISIANA			108,280
North Louisiana		99,300	
Caddo, heavy	4,100		
Caddo, light	7,500		
DeSoto and Red River	7,500		
Haynesville	59,700		
Homer	20,500		
South Louisiana		9,500	
Edgerly	500		
Vinton and others	3,500		
Jennings	550		
MONTANA			
Winnett and Cat Creek			3,500
NEW YORK			2,500
OHIO			29,000

DAILY PRODUCTION OF CRUDE OIL BY POOLS (Concluded)

OKLAHOMA			327,459
Washington County	6,620		
Nowata County	6,150		
Osage County	54,625		
Tulsa County	10,274		
Bixby, Bird Creek Jenks, Broken Arrow, Flat Rock, etc.			
Okmulgee County	38,943		
Beggs, Bald Hill, etc.			
Okfuskee County	11,445		
Muskogee and Wagner Counties	5,825		
Creek County	58,405		
Cushing, Shamrock, Glenn, Kiefer, Bristow, etc.			
Pawnee County	10,677		
Jennings and Cleveland.			
Payne County	9,800		
Yale, Quay, etc.			
Kay County—Blackwell, Ponca	5,935		
Garfield and Noble Counties	10,173		
Garber and Billings.			
Carter County	67,004		
Healdton, Hewitt, Fox.			
Cotton and Stephens (Duncan)	31,222		
PENNSYLVANIA			22,000
TEXAS			388,800
Burkburnett	35,000		
Iowa Park, Holliday	5,500		
Electra	11,800		
Eastland County (Ranger)	12,500		
Stephens County (Breckenridge)	51,000		
Commanche, Young, Brown, Coleman, Shackelford	15,700		
Total North Texas		131,500	
East Texas		165,000	
Corsicana, Mexia, Wortham..			
Total South Texas		32,300	
Goose Creek	11,000		
Humble	6,800		
Hull	14,500		
Damon Mound	2,600		
Sour Lake	4,700		
West Columbia	42,700		
Orange	11,700		
Saratoga	2,000		
Pierce Junction	8,000		
WEST VIRGINIA			22,500
Cabin Creek, etc.			
WYOMING			77,500
Salt Creek	40,000		
Grass Creek	4,000		
Elk Basin	3,000		
Big Muddy	5,600		
Pilot Butte	200		
Rock River	7,000		
Lost Soldier	7,280		
Mule Creek	3,870		
Osage	6,550		
CANADA			
Eastern			
Northwest			
MEXICO			500,000
Panuco			
Topila			
Tamaulipas			
Chihuahua			

PRICES OF PETROLEUM AND ITS PRODUCTS

June 1, 1921

Crude at Wells

The following prices are those paid by the pipe lines for crude as delivered from the wells, with a comparison for the corresponding period of 1920:

PENNSYLVANIA-OHIO-WEST VIRGINIA

	Per Barrel June 1st, 1921	June 1st 1920
Cabell, West Virginia	$1.81	$3.42
Corning, Ohio	1.90	4.00
Lima	2.08	3.73
McKinney	2.00	....
Pennsylvania	3.00	6.10
Waterloo	1.25	.....
Wooster, Ohio	2.30	4.05
INDIANA-ILLINOIS		
Illinois	2.02	3.77
Indiana	2.13	3.63
Plymouth, Ill	1.15	3.63
Princeton, Ind	1.77	3.77

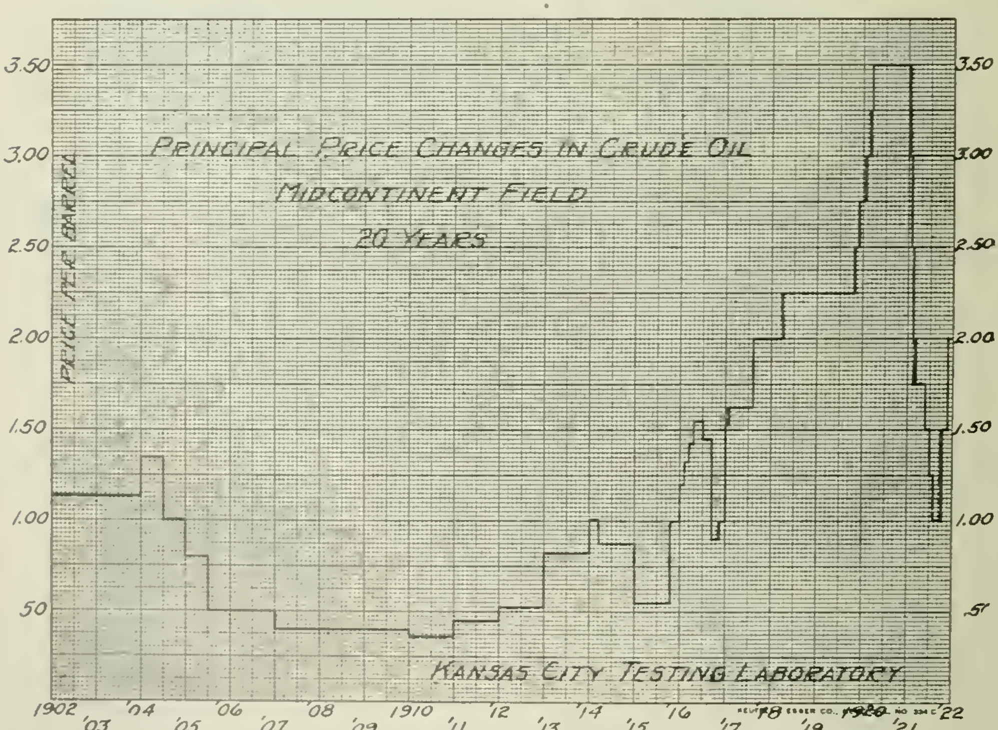


Fig. 18—Chart Showing Principal Price Changes of Crude Oil in Twenty Years.

PRICES OF PETROLEUM AND ITS PRODUCTS (Continued)

Crude at Wells.

	June 1st, 1921	June 1st, 1920
KENTUCKY-TENNESSEE		
Ragland	1.25	1.75
Somerset, light, 38 gravity and above	1.80	4.00
32 to 38 gravity	1.60	4.00
OKLAHOMA-KANSAS		
Healdton	1.00	2.75
Mid-Continent	1.50	3.50
Wlters and Beaver Creek	1.00	....
WESTERN KENTUCKY		
Wester Kentucky	1.28	......
LOUISIANA AND ARKANSAS		
Bull Bayou, 38 gravity and above	1.40	3.15
32 to 34.9° gravity	1.25	3.00
35 to 37.9°	1.30	3.05
heavy, below 32	.25	2.00
Caddo, 38 gravity and above	1.75	3.50
35 to 37.9° gravity	1.65	3.40
32 to 34.9° gravity	1.60	3.35
heavy	1.00	2.50
Crichton, light	1.25	3.00
DeSoto	1.65	3.40
El Dorado, 35 gravity and above	0.70	....
33 to 34.9° gravity	0.60	....
below 33° gravity	0.50	....
Homer, 36 gravity and above	1.50	3.25
35 to 35.9° gravity	1.40	3.15
32 to 34.9° gravity	1.35	3.10
below 32° gravity	1.00	1.75
Pine Island	1.00	2.50
NORTH TEXAS AND NORTH CENTRAL TEXAS		
Burkburnett	$1.50	$3.50
Corsicana, light	1.25	3.00
Heavy	.75	1.75
Electra	1.50	3.50
Henrietta	1.50	3.50
Moran	1.50	3.50
North Central Texas	1.50	3.50
Petrolia	1.50	3.50
Ranger	1.50	3.50
Stephens	1.50	3.50
Strawn	1.50	3.50
Thrall	1.50	3.50
GULF COAST		
Batson	1.00 @ 1.25	3.00
Dayton	1.25	3.00
Edgerly	1.00	3.00
Goose Creek	1.00 @ 1.25	3.00
Hull	1.00	3.00
Humble	1.00 @ 1.25	3.00
Jennings	1.00	3.00
Markham	1.00	3.00
Saratoga	1.00	3.00
Somerset	1.50	3.00
Sour Lake	1.00 @ 1.25	3.00
Spindletop	1.00 @ 1.25	3.00
Vinton	1.00 @ 1.25	3.00
West Columbia	1.00 @ 1.25	3.00

PRICES OF PETROLEUM AND ITS PRODUCTS (Continued)

Crude at Wells.

	June 1st, 1921	June 1st, 1920
WYOMING		
Big Muddy	1.00	2.25
Elk Basin	1.50	2.60
Grass Creek	1.50	2.60
Greybull	1.50	2.85
Lance Creek	1.45	2.25
Mule Creek	.80	.....
Rock Creek	1.10	....
Salt Creek	1.10	2.50
Torchlight	1.50	2.85
CALIFORNIA		
San Joaquin Valley and Whittier-Fullerton Fields—		
14° to and including 17° gravity	1.35	1.48
18° gravity	1.36	1.49
19° gravity	1.38	1.51
20° gravity	1.41	1.54
21° gravity	1.45	1.58
22° gravity	1.50	1.63
23° gravity	1.56	1.69
24° gravity	1.63	1.76
25° gravity	1.71	1.84
26° gravity	1.80	1.93
27° to and including 27.9° gravity	1.90	2.03
28° gravity to and including 28.9° gravity	2.00	2.13
29° gravity to and including 29.9° gravity	2.10	2.33
30° gravity to and including 30.9° gravity	2.20	2.33
31° to and including 31.9°	2.30	2.43
32° to and including 32.9°	2.40	2.53
33° to and including 33.9°	2.50	2.63
34° to and including 34.9°	2.60	2.73
35° gravity and above	2.70	2.83

Prices for each increase in gravity of 1 full degree above 26° gravity up to and including 34.9° gravity, 10c per barrel additional.

Mexican Crude

	12–14°	19–21°
Texas points	$0.90	$1.50
CANADA		
Oil Springs	$2.55	$2.83
Petrolia	2.48	2.58

Add 52½c per barrel to each grade to include allowance by government to producers.

Road and Paving Materials

ROAD OILS.—Following are prices per gallon in tank cars 8,000 gallons minimum f. o. b. place named:

New York, 45% asphalt (at terminal)	$0.06½	$0.13
New York, 65% asphalt (at terminal)	.06	.13
New York, binder (at terminal)	.07	.13½
New York, flux (at terminal)	.06½	.14
New York, liquid asphalt (at terminal)	.08	.10
Chicago, 40-50% asphalt	.06	.08
Chicago, 60-70% asphalt	.06¼	.08½
Dallas, 40-50% asphalt	.10	.07
Dallas, 60-70% asphalt	.13	.08
Dallas, 75-90% asphalt	.13	.10
San Francisco, binder, per ton	15.00	12.25

ASPHALT.—Price per ton in packages (350-lb. bbls. or 425-lb. drums) and in bulk, in carload lots:

	Package	Bulk
New York (Bayonne, N. J.)	$28.00	$16.00
Boston	.....	.....
Chicago	28.50	21.00
San Francisco	21.50	15.00
Dallas	35.00	27.00
Seattle	27.50	.....
Denver	.....	50 @ 70
Minneapolis	.....	25.93
Baltimore	40.00	.....
Los Angeles at factory	22.15	15.00
Montreal	28.00	21.00
Atlanta	33.00	.....
Detroit (petroleum asphalt)	24.50	20.00
Cincinnati	37.50	31.00
Maurer, N. J. (asphalt)	27 @ 38	.....
Maurer, N. J. (asphaltic cement)	29 @ 36	25 @ 31

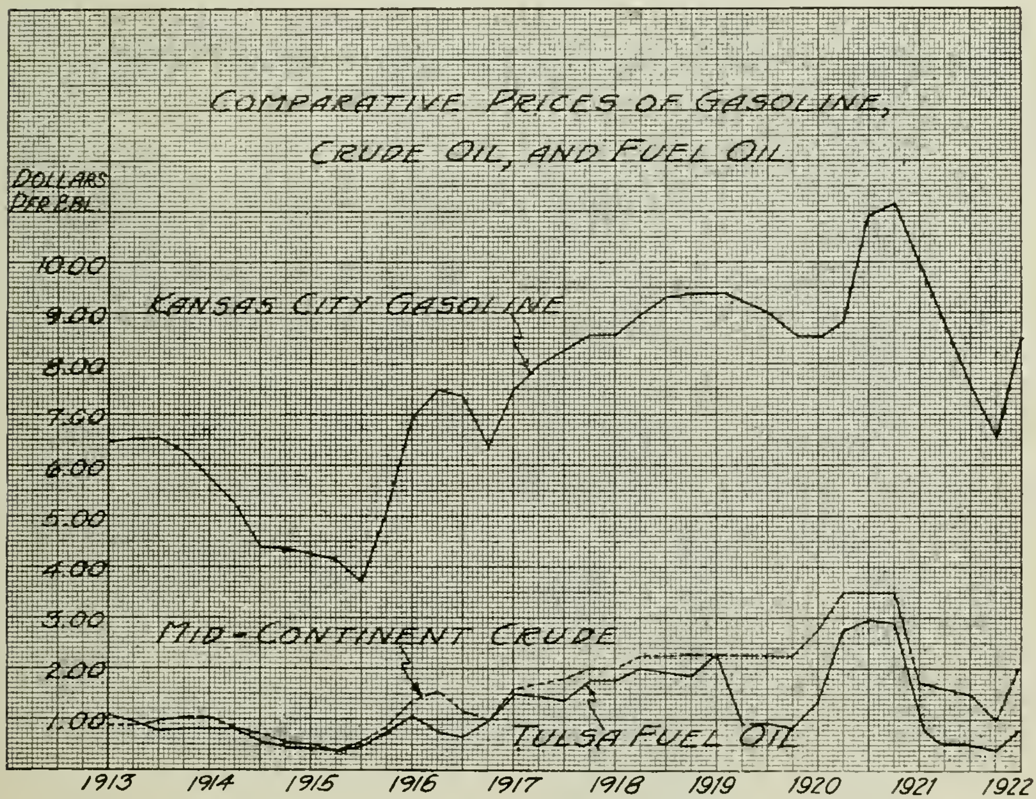


Fig. 19—Chart Showing Price Changes of Gasoline, Crude Oil and Fuel Oils.

PRICE OF CRUDE PETROLEUM COMPARED WITH OTHER RAW COMMODITIES.

JANUARY

	1913	1914	1915	1916	1919	1920	1921	1922
Crude Petroleum, bbl. (mid-continent)	$0.83	1.03	.55	1.20	2.25	3.00	3.50	2.00
Bituminous Coal, per ton (Pittsburg dist.)	$1.30	1.30	1.15	1.25	2.35	2.35	2.75	2.25
Steel Billets, per ton (Pittsburg)	$29.00	20.00	19.00	33.00	43.50	45.00	43.50	30.00
Copper-Electrolytic, cts. per lb. (New York)	17.00c	14.12	13.75	23.62	2..00	19.25	13.25	13.12
Zinc, per lb., St. Louis	7.10c	5.10	5.95	17.75	6.75	9.10	5.55	4.70
Lead, per lb., New York	4.35c	4.10	3.70	5.90	5.62	8.75	5.00	4.54
Rubber, per lb., Para, N. Y	$1.11	.73	0.75	0.86	0.60	0.49	0.18	0.23
Cotton, per lb., N. O	12.50c	12.88	7.75	12.19	29.00	40.25	15.00	16.00
Wool, Cleaned, Boston	$0.72	0.56	0.66	0.76	1.65	2.30	1.05	0.90
Wheat, Hard, Chicago	$1.11	0.96	1.41	1.28	2.41	2.65	1.98	1.15
Corn, Chicago	$0.50	0.62	0.72	0.75	1.41	1.49	0.68	0.48
Sugar, N. Y	3.48c	3.29	4.04	4.58	7.28	13.04	5.52	4.11

PRICES OF PETROLEUM AND ITS PRODUCTS
January 3, 1922

REFINED PRODUCTS.
(Tank Car Quotations at Refineries)

Gasoline and Naphtha

	Per Gal. Cts.
NORTH TEXAS	
56–57, 450 end point	12½
58–60, 437 end point (new navy)	13½
60–61, 400 end point	15
OKLAHOMA	
80–86 grav. casinghead	12
66–68 grav. blend	14½
50–52, 450 end point	13
56–57, 450 end point	14
60–61, 400 end point	16
62–63, 365 end point	16½
64–66, 365 end point	17
58–60, 140 I. B. P. @ 428 E. P	15
60–62, blend 435 end point	14
58–60, blend 440@450 E. P	13½
74–76, absorpt. gasoline, 300 end pt.	14
PENNSYLVANIA	
Painters' Naphtha	18
54 gravity	16
56 gravity	17
58 gravity	17½
60 gravity, S. R	20¼
62 gravity, S. R	21
64–66 gravity	21¾
68 gravity, S. R	22½
64 gravity, blend, f. o. b. W.Va	18
68–70 gravity blend	18
66–68 gravity blend, 450 E. P	20
68–70 gravity blend, 420 E. P	20½
60–62 gravity blend	17

Burning Oils

OKLAHOMA	
42–44 water white kerosene	2
NORTH TEXAS	
40–41 prime winter	2
42–44 water white	2½
PENNSYLVANIA	
45 prime white	6½
45 water white	6½
46 water white	7
47 water white	7½
48 water white	8½
300 mineral seal	7½

Fuel and Gas Oil

BAYONNE	
28–36 degrees	6
24–28 degrees	5¼
18–20 degrees	5
14 plus	4
NORTH TEXAS	
34–36 gas oil	2
32–34 gas oil	2
30–32 gas oil	2
24–28 fuel, per bbl	80

Fuel and Gas Oil

	Per Gal. Cts.
PENNSYLVANIA	
36–40 fuel oil	4¾
38-42 gravity	5
OKLAHOMA	
32–36 gas oil, f. o. b. group 3, Okla.	2½
24–26 fuel oil, bbl	50
35–37 gas oil, straw	2¼
Road oil, 50 @ 60 asphalt	5½
45–50 asphalt	5

Neutral Oils

OKLAHOMA	
100 visc., No. 2 color	5½
200 visc., No. 3 color	14
160 visc., No. 4 color	10½
200 visc., No. 4 color	12¾
200 visc., No. 5 color	12
PENNSYLVANIA	
200 visc., No. 3 color	18½
180 visc., No. 3 color	16½
150 visc., No. 3 color	14½
SOUTH TEXAS	
75 visc., No. 2 color, unfil. pale	4
100 visc., No. 2 color, unfil. pale	5
150 visc., No. 2½ color, unfil. pale	10
200 visc., No. 3 color, unfil. pale	18
300 visc., No. 3 color, unfil. pale	19
500 visc., No. 4 color, unfil. pale	20
750 visc., No. 4 color, unfil. pale	25
70 visc., No. 1½ color, filtered pale.	....
100 visc., No. 1½ color, filtered pale.	....
150 visc., No. 1½ color, filtered pale.	....
200 visc., No. 2 color, filtered pale.	....
300 visc., No. 2 color, filtered pale.	....
500 visc., No. 2½ color, filtered pale.	....
750 visc., No. 2½ color, filtered pale.	....
200 visc., No. 5½ color, red oil	12
300 visc., No. 5½ color, red oil	14
500 visc., No. 6 color, red oil	19

Natural

WEST VIRGINIA	
30 degrees, carloads	24
29 degrees, carloads	25
28 degrees, carloads	26

Cylinder Stocks

PENNSYLVANIA	
600 steam refined	10
650 steam refined	15
600 filtered E	15
600 filtered D	18
OKLAHOMA	
600 steam refined	4
650 steam refined	....

Wax

OKLAHOMA	
122–124 white cr. sc. N. Y., carloads.	2½

Oxidized Asphalt

Asphalt f. o. b. N. J. refinery	$23.00
F. a. s. New Orleans in cont	23.00

PRICES OF PETROLEUM AND ITS PRODUCTS
June 1, 1921

Petrolatums
(Prices Per Pound in Barrels, Carloads)

Snow White	12	.....
Lily Cream	9	.....
Cream Petrolatum Jelly	7	.....
Amber	5	.....
Dark Amber	4½	.....
Veterinary	3	.....
Dark Green	2½	.....

Heavy White Mineral Medicinal Oil

	Gallon	
880-885 specific gravity	$1.15	......
865-870 specific gravity	1.10	......
Ex. Russian crude oil, 885-890 sp. gr., in bbls. to arrive	1.85	$2.00

GASOLINE AND KEROSENE SERVICE STATION PRICES

Place	Gasoline	Kerosene	Place	Gasoline	Kerosene
Augusta, Maine	....	17c	Little Rock, Ark	18	8
Bartlesville, Okla	21.4	9.8	Memphis, Tenn	25	14
Beaumont, Tex	23	13	Miami, Fla	28	17
Buffalo, N. Y	28	15	New Orleans, La	23.5	14
Butte, Mont	30	15	New York City	29	14
Calgary, Canada	41.5	26	Oklahoma City, Okla	18	8
Montreal, Canada	38	21.5	Omaha, Neb	22.5	11¼
Toronto, Canada	40	23	Philadelphia, Pa	27	13
Winnipeg, Can	42	24	Pittsburgh, Pa	27	14
Casper, Wyo	23	14.5	Portland, Ore	28	17.5
Chicago, Ill	22	10.5	Portland, Me	....	15
Cincinnati, Ohio	25	14	Providence, R. I	....	15
Columbus, Ohio	25¾	14	St. Louis, Mo	20.1	10.2
Dallas, Tex	18	8	Salt Lake City, Utah	29	16.5
Denver, Col	24	17	Seattle, Wash	28	17.5
Harrisburg, Pa	...	..	Topeka, Kan	20.4	9.8
Houston, Tex	18	8	Tulsa, Okla	18	8
Joplin, Mo	18	12.3	Washington, D. C	25	11
Kansas City, Mo	18	9.5	Wichita, Kan	21.5	10

PRICE SCHEDULE FOR CALIFORNIA CRUDE OIL 1919

Gravity	Price	Gravity	Price
14 to 17.9	$1.23	35 to 35.9	$1.57
18 to 18.9	1.24	36 to 36.9	1.59
19 to 19.9	1.25	37 to 37.9	1.62
20 to 20.9	1.27	38 to 38.9	1.65
21 to 21.9	1.29	39 to 39.9	1.68
22 to 22.9	1.31	40 to 40.9	1.71
23 to 23.9	1.33	41 to 41.9	1.75
24 to 24.9	1.35	42 to 42.9	1.77
25 to 25.9	1.37	43 to 43.9	1.80
26 to 26.9	1.39	44 to 44.9	1.83
27 to 27.9	1.41	45 to 45.9	1.86
28 to 28.9	1.43	46 to 46.9	1.89
29 to 29.9	1.45	47 to 47.9	1.92
30 to 30.9	1.47	48 to 48.9	1.95
31 to 31.9	1.49	49 to 49.9	1.98
32 to 32.9	1.51	59 to 50.9	2.01
33 to 33.9	1.53	51 to 51.9	2.04
34 to 34.9	1.55	52 to 52.9	2.07

HIGHEST AND LOWEST PRICES OF CRUDE PETROLEUM OF PENNSYLVANIA GRADE, 1859-1918, PER BARREL

	HIGHEST		LOWEST	
Year	Month	Price	Month	Price
1859	September	$20.00	December	$20.00
1860	January	20.00	December	2.00
1861	January	1.75	December	.10
1862	December	2.50	January	.10
1863	December	4.00	January	2.00
1864	July	14.00	February	3.75
1865	January	10.00	August	4.00
1866	January	5.50	December	1.35
1867	October	4.00	June	1.50
1868	July	5.75	January	1.70
1869	January	7.00	December	4.25
1870	January	4.90	August	2.75
1871	June	5.25	January	3.25
1872	October	4.55	December	2.67½
1873	January	2.75	November	.82½
1874	February	2.25	November	.62½
1875	February	1.82½	January	.75
1876	December	4.23¾	January	1.47½
1877	January	3.69⅜	June	1.53¾
1878	February	1.87½	September	.78
1879	December	1.28¾	June	.62⅛
1880	June	1.24⅜	April	.71¼
1881	September	1.01¼	July	.72½
1882	November	1.37	July	.49¼
1883	June	1.24¾	January	.83¼
1884	January	1.15⅝	June	.51¼
1885	October	1.12⅝	January	.68
1886	January	.92¼	August	.59¾
1887	December	.90	July	.54
1888	March	1.00	June	.71⅜
1889	November	1.12½	April	.79½
1890	January	1.07⅝	December	.60¾
1891	February	.81⅜	August	.50
1892	January	.64⅛	October	.50
1893	December	.80	January	.52⅞
1894	December	.95¾	January	.78½
1895	April	2.60	January	.95¼
1896	January	1.50	December	.90
1897	March	.96	October	.65
1898	December	1.19	January	.65
1899	December	1.66	February	1.13
1900	January	1.68	November	1.05
1901	January, September	1.45	May	.80
1902	December	1.54	January, February, March	1.15
1903	December	1.90	Jan., Feb., Mar., Apr., May, June, July	1.50
1904	January	1.85	July, December	1.50
1905	October	1.61	May	1.27
1906	April, May, June, July	1.64	Jan., Feb., Mch., Apr., Aug., Sept., Oct, Nov., Dec.	1.58
1907	March to December, incl	1.78	January	1.58
1908	No change	1.78	No change	1.78
1909	January, February, March	1.78	December	1.43
1910	January	1.43	June to December, incl	1.30
1911	December	1.35	January to December	1.30
1912	December	2.00	January	1.35
1913	March to December, incl	2.50	January	2.00
1914	January to March, inclusive	2.50	September to December, incl	1.45
1915	December	2.25	April to August, incl	1.35
1916	December	2.85	January	2.25
1917	August 22, December 30	3.75	January 2 to 5, incl	2.85
1918	February 8, December 31, incl	4.00	January 1 to February 8, incl.	3.75

MID-CONTINENT CRUDE OIL MARKET

Date	Field	Price
	1902	
Dec.	Neodesha	$1.12
	1903	
Jan.	South Neodesha	1.15
Apr.	South Neodesha	1.16
May	South Neodesha	1.14
July 1	South Neodesha	1.16
	North Neodesha	.96
	Bartlesville	.94
	Corsicana light	1.10
	Corsicana heavy	.60
July 23	South Neodesha	1.18
	North Neodesha	.98
	Bartlesville	.96
	Corsicana light	1.12
Sep. 28	South Neodesha	1.20
	North Neodesha	1.00
	Bartlesville	.98
	Corsicana light	1.14
Sep. 30	South Neodesha	1.22
	North Neodesha	1.02
	Bartlesville	1.00
	Corsicana light	1.16
Oct. 8	South Neodesha	1.24
	North Neodesha	1.04
	Bartlesville	1.02
	Corsicana light	1.18
Oct. 11	South Neodesha	1.26
	North Neodesha	1.06
	Kansas Humboldt heavy	.60
	Bartlesville	1.04
	Corsicana light	1.20
Oct. 26	South Neodesha	1.30
	North Neodesha	1.10
	Bartlesville	1.08
	Corsicana light	1.26
Nov. 20	South Neodesha	1.35
	North Neodesha	1.15
	Bartlesville	1.13
	Corsicana light	1.29
Dec. 2	South Neodesha	1.37
	North Neodesha	1.17
	Bartlesville	1.15
	Corsicana light	1.31
Dec. 9	South Neodesha	1.38
	North Neodesha	1.18
	Kansas Humboldt, heavy	.60
	Bartlesville	1.16
	Corsicana light	1.32
	Corsicana heavy	.60
Dec. 29	South Neodesha	1.36
	North Neodesha	1.16
	Kansas Humboldt heavy	.60
	Corsicana light	1.27
	Corsicana Heavy	.55
	Bartlesville	1.14
	1904	
Jan. 1	South Neodesha	$1.36
	North Neodesha	1.16
	Bartlesville	1.14
	Kansas heavy	60
	Corsicana light	1.27
	Corsicana heavy	.55
Feb. 12	South Neodesha	1.31
	North Neodesha	1.11
	Bartlesville	1.15
	Kansas heavy	.55
	Corsicana light	1.02
	Corsicana heavy	.40
	1904	
Mch. 1	South Neodesha	1.28
	North Neodesha	1.08
	Bartlesville	1.12
	Corsicana light	.99
Mch. 4	South Neodesha	1.25
	North Neodesha	1.05
	Bartlesville	1.09
	Corsicana light	.96
Mch. 12	South Neodesha	1.22
	South Neodesha	1.02
	Bartlesville	1.06
	Corsicana light	.93
Mch. 29	South Neodesha	1.19
	North Neodesha	.99
	Bartlesville	1.03
	Corsicana light	.90
Apr. 8	South Neodesha	1.16
	North Neodesha	.96
	Bartlesville	1.00
	Corsicana light	.87
Apr. 29	South Neodesha	1.13
	North Neodesha	.93
	Bartlesville	.97
	Corsicana light	.84
June 7	South Neodesha	1.08
	North Neodesha	.88
	Bartlesville	.92
	Corsicana light	.81
June 17	South Neodesha	1.03
	North Neodesha	.83
	Bartlesville	.87
	Corsicana light	.78
July 9	South Neodesha	.95
	North Neodesha	.75
	Bartlesville	.95
	Kansas heavy	.50
	Corsicana light	.73
July 13	South Neodesha	.88
	North Neodesha	.68
	Bartlesville	.88
	Kansas heavy	.47
	Corsicana light	.70
Aug. 12	Corsicana light	.80
	Corsicana heavy	.45
Sep. 1	South Neodesha	.90
	North Neodesha	.70
	Bartlesville	.90
	Kansas heavy	.49
	Corsicana light	.85
	Corsicana heavy	.50
Oct. 18	South Neodesha	.87
	North Neodesha	.67
	Bartlesville	.87
	Kansas heavy	.46
Dec. 16	South Neodesha	.82
	North Neodesha	.67
	Bartlesville	.82
	Kansas heavy	.41
Dec. 29	South Neod sha	.80
	Bartlesville	.80
	Corsicana light	.80
	Corsicana heavy	.50
	1905	
Jan. 1	Kansas heavy	.41
	South Neodesha	.80
	Bartlesville	.80
	Corsicana light	.80
	Corsicana heavy	.50

MID-CONTINENT CRUDE OIL MARKET (Continued)

Date	Field	Price
	1905	
Jan. 5	Kansas heavy	.36
	South Neodesha	.77
	Bartlesville	.77
	Corsicana light	.82
Jan. 11	Kansas heavy	.31
	South Neodesha	.72
	Bartlesville	.74
	Corsicana heavy	.45
Jan. 31	Kansas heavy	.50
	South Neodesha	.70
	Corsicana heavy	.50
Mch. 25	South Neodesha	.68
Apr. 12	South Neodesha	.66
Apr. 18	South Neodesha	.61
Apr. 25	South Neodesha	.57
May 27	South Neodesha	.53
	Corsicana light	.81
June 17	South Neodesha	.50
Sep. 12	Corsicana light	.83
	Corsicana heavy	.50
Sep. 16	Corsicana light	.85
Sep. 19	Corsicana light	.87
Sep. 28	Kansas heavy	.35
	South Neodesha	.51
	Corsicana light	.89
Oct. 20	South Neodesha	.52
	Corsicana light	.91
Nov. 11	Kansas heavy	.35
	South Neodesha	.52
	Corsicana light	.89
	Corsicana heavy	.50
	1906	
Jan. 1	Kansas	.52
	Corsicana light	.89
	Corsicana heavy	.50
Apr. 25	Kansas fuel	.35
	Corsicana light	.91
	Corsicana heavy	.52
July 28	Kansas	.50
	Corsicana light	.89
	Corsicana heavy	.50
Aug. 2	Kansas	.48
	Corsicana light	.87
	Corsicana heavy	.48
Aug. 9	Kansas fuel	.32
	Kansas	.45
Aug. 15	Kansas fuel	.29
	Kansas	.42
	Corsicana light	.89
	Corsicana heavy	.50
Aug. 28	Kansas	.39
	1907	
Jan. 1	Kansas 32°	.39
	Kansas heavy	.26
	Corsicana light	1.00
	Corsicana heavy	.60
	Henrietta	.60
Feb. 11	Kansas 32°	.40
	Kansas heavy	.27
	Corsicana light	1.02
Feb. 26	Corsicana heavy	.65
Mch. 9	Kansas 32°	.41
	Kansas heavy	.28
Mch. 21	Corsicana heavy	.70
Dec. 1	Corsicana light	1.00
	1908	
Jan. 1	Kansas 42°	.41
	Corsicana light	1.00
	Corsicana heavy	.70
	1908	
Mch. 30	Henrietta	.75
	Corsicana light	.85
	Corsicana heavy	.65
Apr. 24	Henrietta	.70
	Corsicana light	.82
	Corsicana heavy	.60
June 1	Henrietta	.65
	Corsicana light	.75
	Corsicana heavy	.55
June 10	Henrietta	.60
	Corsicana light	.72
	Corsicana heavy	.50
	1909	
Jan. 1	Kansas	.41
	Kansas heavy	.28
	Corsicana light	.01
	Corsicana heavy	.47
	Henrietta	.89
	1909	
Mch. 13	Corsicana heavy	.50
	Henrietta	.50
Apr. 27	Corsicana heavy	.53
	Henrietta	.53
July 22	Kansas	.35
	1910	
Jan. 1	Kansas light	.35
	Kansas heavy	.28
Mch. 17	Kansas light	.38
	Kansas heavy	.30
May 23	Corsicana light	.60
Sep. 2	Corsicana light	.58
	Corsicana heavy	.53
	Caddo light	.40
	Kansas light	.40
Sep. 20	Kansas heavy	.40
Nov. 14	Kansas heavy	.42
	Corsicana light	.55
	Corsicana heavy	.50
	1911	
Jan. 2	Kansas	.44
	Caddo light	.44
	Caddo heavy	.44
	Corsicana light	.55
	Corsicana heavy	.50
Mch. 14	Caddo light	.50
May 2	Kansas	.46
	Caddo light	.55
	Caddo heavy	.50
June 14	Kansas	.48
	Caddo light	.60
Aug. 9	Caddo heavy	.40
Sep. 15	Kansas	.50
	Caddo light	.62
	1912	
Jan. 1	Kansas-Oklahoma	.53
	Caddo light	.62
	Caddo heavy	.40
	Corsicana light	.55
	Corsicana heavy	.50
Jan. 15	Kansas -Oklahoma	.55
Jan. 18	Caddo light	.65
Jan. 18	Caddo light	.65
Jan. 26	Kansas-Oklahoma	.57
Jan. 27	Caddo light	.69
Feb. 1	Corsicana light	.60
	Electra-Henrietta	.60
Feb. 5	Kansas -Oklahoma	.60
Feb. 7	Caddo light	.72

MID-CONTINENT CRUDE OIL MARKET (Continued)

Date	Field	Price
	1912	
Mch. 20	Corsicana light	.65
	Corsicana heavy	.55
Apr. 9	Kansas-Oklahoma	.63
Apr. 16	Kansas -Oklahoma	.64
	Electra-Henrietta	.65
May 7	Kansas-Oklahoma	.66
May 17	Kansas-Oklahoma	.68
May 20	Caddo light	.77
	Corsicana light	.70
	Electra-Henrietta	.70
June 17	Kansas-Oklahoma	.70
	Caddo light	.80
	Electra-Henrietta	.70
June 17	Kansas-Oklahoma	.70
	Caddo light	80
	Caddo heavy	.60
	Corsicana light	.75
	Electra-Henrietta	.75
Sep. 10	Corsicana heavy	.60
Oct. 25	Corsicana heavy	.65
Nov. 7	Kansas-Oklahoma	.73
Nov. 9	Caddo light	.83
	Caddo heavy	.68
Nov. 14	Corsicana light	.80
	Electra-Henrietta	.80
Nov. 27	Kansas-Oklahoma	.76
Dec. 12	Kansas-Oklahoma	.78
	Caddo light	.88
Dec. 14	Corsicana light	.85
	Corsicana heavy	.70
	Electra-Henrietta	.85
Dec. 16	Kansas-Oklahoma	.80
Dec. 17	Caddo light	.91
	Caddo heavy	.81
Dec. 24	Kansas-Oklahoma	.83
Dec. 26	Corsicana light	.88
	Electra-Henrietta	.88
	1913	
Jan. 1	Kansas-Oklahoma	.83
	Caddo 38° up	.91
	Caddo 35-37.9°	.81
	Caddo 32-34.9°	.76
	Caddo heavy	.70
	Corsicana light	.88
	Corsicana heavy	.70
	Electra	.88
	Henrietta	.88
Jan. 7	Caddo 38° up	.93
	Caddo 35-37.9°	.83
	Caddo-32-34.9°	.78
Jan. 9	Corsicana light	.90
	Electra	.90
	Henrietta	.90
Jan. 29	Corsicana light	.95
	Electra	.95
	Henrietta	.95
Feb. 1	Caddo 38 up	.98
	Caddo 35-37.9°	.88
	Caddo 33-34.9°	.83
Apr. 7	Corsicana light	.80
July 7	Kansas -Oklahoma	.93
July 10	Caddo 38° up	1.05
	Caddo 35-37.9°	.95
	Caddo 32-34.9°	.90
	Corsicana light	.85
July 24	Electra	1.00
	Henrietta	1.05
July 21	Kansas-Oklahoma	.98
July 19	Kansas-Oklahoma	1.03

Date	Field	Price
	1913	
Aug. 21	Caddo 38° up	1.05
	Caddo 35-37.9°	.95
	Caddo 32-34.9°	.90
Aug. 25	Corsicana light	1.05
	Electra	1.05
	Henrietta	1.05
	1914	
Jan. 1	Kansas-Oklahoma	1.03
	Caddo 38	1.05
	Caddo 35-37.9°	.95
	Caddo 32-34.9°	.95
	Caddo heavy	.70
	Electra heavy	1.05
	Henrietta	1.05
	Corsicana light	1.05
	Corsicana heavy	.80
Feb. 2	Kansas-Oklahoma	1.05
Mch. 2	Corsicana heavy	.70
Mch. 26	Healdton	.70
Apr. 4	Caddo heavy	.60
Apr. 8	Kansas-Oklahoma	1.00
	Corsicana heavy	.65
Apr. 10	Kansas-Oklahoma	.95
Apr. 13	Kansas-Oklahoma	.90
	Electra	.95
	Henrietta	.95
	Corsicana light	.95
	Corsicana heavy	.60
	Healdton	.60
Apr. 15	Kansas-Oklahoma	.85
Apr. 16	Caddo heavy	.60
Apr. 20	Electra	.85
	Henrietta	.85
	Corsicana light	.85
	Corsicana heavy	.50
	Healdton	.50
Apr. 27	Kansas-Oklahoma	.80
Apr. 30	Kansas-Oklahoma	.75
May 5	Corsicana	.75
	Electra	.75
	Henrietta	.75
July 9	Caddo 38°	1.00
	Caddo 35-37.9°	.90
	Caddo 32-34.9°	.85
July 15	DeSoto	.95
Aug. 8	Caddo 38°	.95
	Caddo 35-37.9°	.85
	Caddo 32-34.9°	.80
	Caddo heavy	.45
Aug. 12	DeSoto	.85
Aug. 13	Caddo 38°	.85
	Caddo 35-37.9°	.75
	Caddo 32-34.9°	.70
Sep. 12	Kansas-Oklahoma	.65
Sep. 14	Caddo 38°	.80
	Caddo 35-37.9°	.70
	Caddo 32-34.9°	.65
	DeSoto	.80
Sep. 22	Kansas-Oklahoma	.55
	Electra	.65
	Henrietta	.65
	Corsicana light	.65
Oct. 6	Electra	.60
	Henrietta	.60
	Corsicana light	.60
Nov. 13	Electra	.55
	Henrietta	.55
	Corsicana	.55

MID-CONTINENT CRUDE OIL MARKET (Continued)

Date	Field	Price
	1915	
Jan. 1	Kansas-Oklahoma	.55
	Caddo 38° up	.80
	Caddo 34-37.9°	.70
	Caddo 32-34.9°	.65
	Caddo heavy	.45
	DeSoto	.80
	Electra	.55
	Henrietta	.55
	Corsicana	.55
	Healdton	.50
Feb. 8	Healdton	.30
Feb. 16	Electra	.45
	Henrietta	.45
	Corsicana light	.45
	Corsicana heavy	.40
Feb. 18	Kansas-Oklahoma	.40
	Caddo 38° up	.70
	Caddo 34-37.9°	.60
	Caddo 32-34.9°	.55
	DeSoto	.70
Mch. 3	DeSoto	.60
Mch. 24	Caddo 38° up	.60
	Caddo 34-37.9°	.50
	Caddo 34-32.9°	.45
	Caddo heavy	.35
	DeSoto	.70
Aug. 2	Kansas-Oklahoma	.50
Aug. 4	Kansas	.55
	Electra	.55
	Henrietta	.55
	Corsicana light	.55
Aug. 6	Electra	.60
	Henrietta	.60
	Corsicana light	.60
	Corsicana light	.60
	Thrall	.55
	Strawn	.55
Aug. 11	Kansas-Oklahoma	.60
Aug. 11	Kansas-Oklahoma	.60
Aug. 13	Electra	.65
	Henrietta	.65
	Corsicana light	.65
	Thrall	.60
	Strawn	.60
Aug. 19	Kansas-Oklahoma	.65
Aug. 21	Kansas-Oklahoma	.75
	Electra	.70
	Henrietta	.70
	Corsicana light	.70
Aug. 26	Electra	.75
	Henrietta	.75
	Corsicana light	.75
	Thrall	.65
	Strawn	.65
Aug. 27	Caddo 38° up	.65
	Caddo 34-37.9°	.55
	Caddo 34-32.9°	.50
	Caddo heavy	.45
	DeSoto	.55
	Crichton	.45
Sep. 11	Kansas-Oklahoma	.80
	Thrall	.70
	Strawn	.70
Sep. 15	Caddo 38° up	.70
	Caddo 34-37.9°	.60
	Caddo 32-34.9°	.55
	Caddo heavy	.45
	DeSoto	.60
	Electra	.80
	1915	
Sep. 15	Henrietta	.80
	Corsicana light	.80
	Crichton	.50
	Thrall	.75
	Strawn	.75
Sep. 23	Caddo 38° up	.75
	Caddo 34-37.9°	.65
	Caddo 32-34.9°	.60
	Caddo heavy	.50
	DeSoto	.65
Sep. 28	Healdton	.35
	Crichton	.55
Oct. 6	Caddo 38° up	.80
	Caddo 34-37.9°	.70
	Caddo 32-34.9°	.65
	Caddo heavy	.55
	DeSoto	.70
	Crichton	.60
Oct. 11	Healdton	.40
Oct. 13	Kansas-Oklahoma	.90
Nov. 13	Kansas-Oklahoma	1.00
Nov. 15	Electra	1.00
	Henrietta	1.00
	Corsicana light	1.00
	Corsicana heavy	.55
	Healdton	.55
	Thrall	.95
	Strawn	.95
	Moran	.95
Nov. 18	Caddo 38° up	.90
	Caddo 34-37.9°	.80
	Caddo 32-34.9°	.75
	Caddo heavy	.65
	DeSoto	.80
	Crichton	.70
Nov. 20	Caddo 38° up	1.00
	Caddo 34-37.9°	.90
	Caddo 32-34.9°	.85
	Caddo heavy	.75
	DeSoto	.90
	Crichton	.80
Dec. 14	Kansas-Oklahoma	1.20
	Henrietta	1.20
	Corsicana light	1.20
	Corsicana heavy	.60
	Healdton	.60
	Thrall	1.05
	Strawn	1.05
	Moran	1.05
Dec. 17	Caddo 38° up	1.10
	Caddo 34-37.9°	1.00
	Caddo 32-34.9°	.95
	DeSoto	1.00
	Caddo heavy	.80
	Crichton	.85
Dec. 28	Caddo 38° up	1.20
	Caddo 34-37.9°	1.10
	Caddo 32-34.9°	1.00
	Caddo heavy	.80
	DeSoto	1.10
	1916	
Jan. 1	Kansas and Oklahoma	1.20
	Healdton	.60
	Corsicana heavy	.60
	Corsicana light	1.20
	Electra	1.20
	Henrietta	1.20
	Thrall	1.05
	Strawn	1.05

MID-CONTINENT CRUDE OIL MARKET (Continued)

Date	Field	Price
	1916	
Jan. 1	Moran	1.05
	Crichton	.85
	DeSoto	1.10
	Caddo 32-34.9°	1.05
	Caddo 34-37.9°	1.10
	Caddo 38° up	1.20
	Caddo heavy	.55
Jan. 7	Healdton	.75
	Corsicana heavy	.67
Jan. 21	Healdton	.60
	Corsicana heavy	.70
	Corsicana light	1.25
	Electra	1.25
	Henrietta	1.25
Jan. 25	Crichton	.90
	DeSoto	1.15
	Caddo 32-34.9°	1.10
	Caddo 35-37.9°	1.15
	Caddo 38° up	1.25
	Caddo heavy	.80
Jan. 26	Kansas-Oklahoma	1.30
Jan. 27	Healdton	.75
	Corsicana heavy	.75
	Corsicana light	1.30
	Electra	1.30
	Henrietta	1.30
	Thrall	1.30
	Strawn	1.40
	Moran	1.30
	Crichton	.95
Jan. 28	Caddo 32-34.9°	1.15
	Caddo 35-37.9°	1.20
	Caddo 38° up	1.30
	Caddo heavy	.85
Feb. 2	Caddo heavy	.90
Mch. 4	Kansas-Oklahoma	1.40
Mch. 6	Corsicana light	1.40
	Electra	1.40
	Henrietta	1.40
	Thrall	1.40
	Strawn	1.40
	Moran	1.40
Mch. 11	Kansas-Oklahoma	1.45
	Crichton	1.00
	DeSoto	1.30
	Caddo 32-34.9°	1.25
	Caddo 34-37.9°	1.30
Mch. 13	DeSoto	1.35
Mch. 13	Caddo 32-34.9°	1.30
	Caddo 34-37.9°	1.35
Mch. 27	DeSoto	1.45
	Caddo 32-34.9°	1.40
	Caddo 34-37.9°	1.45
June 15	Crichton	.90
June 24	Crichton	.80
	Caddo 38° up	1.40
	Caddo heavy	1.00
Mch. 14	Healdton	.80
	Corsicana light	1.45
	Electra	1.45
	Henrietta	1.45
	Strawn	1.45
	Thrall	1.45
	Moran	1.45
Mch. 14	Kansas-Oklahoma	1.55
Mch. 15	Corsicana light	1.50
	Electra	1.50
	Henrietta	1.50
	1916	
Mch. 15	Thrall	1.50
	Strawn	1.50
	Moran	1.50
	Crichton	1.05
July 15	Crichton	.70
	Caddo 32-34.9°	1.30
	Caddo 35-37.9°	1.35
July 24	Kansas-Oklahoma	.45
	Healdton	.65
	Corsicana heavy	.65
	Corsicana light	1.40
	Electra	1.40
	Henrietta	1.40
	Thrall	1.40
	Strawn	1.40
	Moran	1.40
July 29	Crichton	.65
	Kansas-Oklahoma	1.35
	Caddo 38° up	1.35
July 31	Healdton	.60
	Corsicana heavy	.55
	Corsicana light	1.30
	Electra	1.30
	Henrietta	1.30
	Thrall	1.30
	Strawn	1.30
	Moran	1.30
Aug. 1	Kansas-Oklahoma	1.25
	Caddo 32-34.9°	1.20
	Caddo 35-37.9°	1.25
Aug. 2	Healdton	.50
	Corsicana heavy	.45
	Corsicana light	1.20
	Electra	1.20
	Henrietta	1.20
	Thrall	1.20
	Strawn	1.20
	Moran	1.20
	DeSoto	1.35
	Caddo 32-34.9°	1.10
	Caddo 35-37.9°	1.15
Aug. 7	Kansas-Oklahoma	1.15
	Corsicana light	1.10
	Electra	1.10
	Henrietta	1.10
	Thrall	1.10
	Strawn	1.10
	Moran	1.10
Aug. 8	DeSoto	1.25
	Caddo 32-34.9°	1.10
	Caddo 35-37.9°	1.05
	Caddo 38° up	1.25
Aug. 12	Kansas-Oklahoma	1.05
	Corsicana light	1.00
	Electra	1.00
	Henrietta	1.00
	Thrall	1.00
	Strawn	1.00
	Moran	1.00
Aug. 12	Healdton	.45
	Corsicana heavy	.40
	Corsicana light	.90
	Electra	.90
	Henrietta	.90
	Thrall	.90
	Strawn	.90
	Moran	.90
	DeSoto	1.15

MID-CONTINENT CRUDE OIL MARKET (Continued)

Date	Field	Price
	1916	
Aug. 12	Caddo 32-34.9°	.90
	Caddo 35-37.9°	.95
Aug. 15	Kansas-Oklahoma	.85
	DeSoto	1.05
	Caddo 32-34.9°	.80
	Caddo 35-37.9°	.85
Aug. 16	Corsicana heavy	.30
	Corsicana light	.80
	Electra	.80
	Henrietta	.80
Aug. 16	Thrall	.80
	Strawn	.80
	Moran	.80
Aug. 17	Kansas-Oklahoma	.75
	Corsicana light	.75
	Electra	.75
	Henrietta	.75
	Thrall	.75
	Strawn	.75
	Moran	.75
	DeSoto	.95
	Caddo 32-34.9°	.70
	Caddo 35-37.9°	.75
	Caddo heavy	.65
Aug. 26	Crichton	.60
	DeSoto	.90
	Caddo 32-34.9°	.60
	Caddo 35-37.9°	.65
Aug. 29	Crichton	.55
	DeSoto	.85
	Caddo 32-34.9°	.55
	Caddo 35-37.9°	.60
Dec. 2	Kansas-Oklahoma	.00
	Healdton	.45
	Corsicana heavy	.45
	Corsicana light	1.00
	Electra	1.00
	Henrietta	1.00
	Thrall	1.00
	Strawn	1.00
	Moran	1.00
	Caddo 32-34.9°	.85
	Caddo 35-37.9°	.90
	Caddo 38° up	1.00
	Caddo heavy	.63
Dec. 4	Crichton	.90
Dec. 12	Kansas-Oklahoma	1.10
Dec. 13	Healdton	.50
	Corsicana heavy	.50
	Corsicana light	1.10
	Electra	1.10
	Henrietta	1.10
	Thrall	1.10
	Strawn	1.10
	Moran	1.10
	Crichton	1.00
	DeSoto	1.00
	Caddo 35-37.9°	1.00
	Caddo 38° up	1.10
Dec. 14	Crichton	1.10
	Caddo 32-34.9°	.95
	Caddo 35-37.9°	1.10
	Caddo 38° up	1.20
	Caddo heavy	.73
Dec. 18	Kansas-Oklahoma	1.20
Dec. 19	Healdton	.60
	Corsicana heavy	.55
	Corsicana light	1.20
	Electra	1.20

Date	Field	Price
	1916	
Dec. 19	Henrietta	1.20
	Thrall	1.20
	Strawn	1.20
	Moran	1.20
	Crichton	1.20
	DeSoto	1.20
	Caddo heavy	.78
Dec. 23	Kansas-Oklahoma	1.40
	Healdton	.70
	Corsicana heavy	.63
	Corsicana light	1.30
	Electra	1.30
	Henrietta	1.30
	Thrall	1.30
	Strawn	1.30
	Moran	1.30
Dec. 27	Crichton	1.20
	Caddo 32-34.9°	1.15
	Caddo 35-37.9°	1.20
	Caddo 38° up	1.30
	Caddo heavy	.88
Dec. 28	Kansas-Oklahoma	1.50
Dec. 29	Healdton	.75
	Corsicana heavy	.70
	Corsicana light	1.40
	Electra	1.40
	Henrietta	1.40
	Thrall	1.40
	Strawn	1.40
	Moran	1.40
	Crichton	1.30
	DeSoto	1.30
	Caddo 32-34.9°	1.25
	Caddo 35-37.9°	1.30
	Caddo 38° up	1.40
	1917	
Jan. 3	Kansas-Oklahoma	1.60
	Corsicana light	1.50
	DeSoto	1.40
Jan. 4	Healdton	.80
	Corsicana light	1.60
	Corsicana heavy	.75
	Electra	1.50
	Thrall	1.50
	Strawn	1.50
	Moran	1.50
	DeSoto	1.50
	Caddo 32-34.9°	1.35
	Caddo 35-37.9°	1.40
	Caddo 38° up	1.50
	Caddo heavy	.98
Jan. 6	Kansas-Oklahoma	1.30
	Corsicana light	1.70
	Caddo 32-34.9°	1.45
	Caddo 35-37.9°	1.50
	Caddo 38° up	1.60
	Caddo heavy	1.08
Jan. 8	Healdton	.85
	Corsicana heavy	.80
	Corsicana light	1.80
	Electra	1.50
	Henrietta	1.60
	Thrall	1.60
	Strawn	1.60
	Moran	1.60
Jan. 12	Kansas-Oklahoma	1.40
Jan. 13	Corsicana light	1.90
	Healdton	.90
	Electra	1.70

MID-CONTINENT CRUDE OIL MARKET (Concluded)

Date	Field	Price
	1917	
Jan. 13	Henrietta	1.70
	Thrall	1.70
	Strawn	1.70
	Moran	1.70
Jan. 23	Crichton	1.10
	DeSoto	1.60
	Caddo 32-34.9°	1.55
	Caddo 35-37.9°	1.60
	Caddo 38° up	1.70
Mch. 9	DeSoto	1.75
	Caddo 32-34.9°	1.65
	Caddo 35-37.9°	1.70
	Caddo 38° up	1.80
	Caddo heavy	.95
Mch. 14	Caddo heavy	1.00
Mch. 17	Caddo 32-34.9°	1.75
	Caddo 35-37.9°	1.80
	Caddo 38° up	1.90
	DeSoto	1.80
Aug. 1	Healdton	.95
	Corsicana heavy	.85
Aug. 7	Healdton	1.05
	Corsicana light	1.95
Aug. 15	Kansas-Oklahoma	1.60
Aug. 16	Healdton	1.10
	Corsicana heavy	.90
	Electra	1.90
	Henrietta	1.90
	Thrall	1.90
	Strawn	1.90
	Moran	1.90
Aug. 20	Kansas-Oklahoma	2.05
	Healdton	1.10
	Corsicana light	2.05
	Electra	2.00
	Henrietta	2.00
	Thrall	2.00
	Strawn	2.00
	Moran	2.00
Aug. 22	DeSoto	1.90
	Caddo 32-34.9°	1.85
	Caddo 35-37.9°	1.90
	Caddo 38° up	2.00
	Crichton	1.50
	1918	
Mch. 16	Healdton	1.45
	Corsicana heavy	1.40
Mch. 19	Kansas-Oklahoma	2.25
Mch. 20	Corsicana light	2.25
	Electra	2.25
	Henrietta	2.25
	DeSoto	2.15
	Caddo 38° up	2.25
	Caddo 35-37.9°	2.15
	Caddo 32-34.9°	2.10
	Caddo heavy	1.25
	Crichton	1.75
Aug. 12	DeSoto	2.25
	Caddo 38° up	2.25
	Caddo 35-37.9°	2.25
	Caddo 35-34.9°	2.25
	Caddo heavy	1.55
	1919	
Mch. 21	Healdton	1.20
	Corsicanan heavy	1.05
	Caddo below 32°	.75
June	Homer	2.25
Oct. 4	Burkburnett	2.00
	Henrietta	2.25
Nov. 21	Healdton	1.35
Nov. 20	Corsicana light	2.50
	Kansas-Oklahoma	2.50
	Electra	2.50
Dec. 2	Henrietta	2.50
	Strawn	2.50
	Moran	2.50
Dec. 19	Healdton	1.85
	DeSoto	2.40
	Caddo 38° up	2.50
	Caddo 35-37.9°	2.40
	Caddo 32-34.9°	2.25
	Caddo heavy	1.00
	Hewitt	1.75
Dec. 22	Healdton	2.00
	Kansas-Oklahoma all grades	2.75
	Electra	2.75
	Henrietta	2.75
	Moran	2.75
	Thrall	2.75
	Brukburnett	2.75
	Corsicana light	2.75
	Corsicana heavy	1.30
	Strawn	2.75
	Ranger	2.75
	Desdemona	2.75
	Caddo 38° up	2.75
	Caddo 35-37.9°	2.65
	Caddo 32-34.9°	2.50
	Caddo heavy	1.25
	DeSoto	2.65
	Crichton	2.25
	Homer	2.50
	Burkburnett	2.75
	Ranger	2.75
	Hewitt	2.75
	Crichton crude	2.25

PETROLEUM PRODUCTION CONDITIONS IN MEXICO.

(Roy H. Flamm in U. S. Commerce Reports.)

Mexico's Increasing Contribution to World's Oil Supply.

A comparison of the following figures of oil production in Mexico, in the United States and in the world since 1901 indicates the phenomenal growth of this industry in Mexico. While in 1913, Mexico furnished but one-fifteenth of the world's supply of oil, in 1920 it furnished nearly one-fourth. The production in the table below is given in barrels of 42 gallons each:

Production of Oil Since 1901.

Years	Mexico	United States	Total World Production
1901	10,345	69,620,529	167,434,434
1902	40,200	88,766,916	182,006,076
1903	75,375	100,461,337	194,879,669
1904	125,625	117,080,960	218,204,391
1905	251,250	134,717,580	215,292,167
1906	502,500	126,493,936	213,415,360
1907	1,005,000	166,095,335	264,245,419
1908	3,932,900	178,527,355	285,552,746
1909	2,713,500	183,170,874	298,616,405
1910	3,634,080	209,557,248	327,937,629
1911	12,552,798	220,449,391	344,174,355
1912	16,558,215	222,935,044	352,446,598
1913	25,696,291	248,446,230	383,547,399
1914	26,235,403	265,762,535	403,745,342
1915	32,910,508	281,104,104	427,740,129
1916	40,545,712	300,767,158	461,493,226
1917	55,292,770	335,315,601	506,702,902
1918	63,828,326	355,927,716	514,729,354
1919	87,072,955	377,719,000	544,885,000
1920	163,540,000	443,402,000	688,474,251

Potential and Actual Production of Oil.

The above statistics show the world's actual production of oil in 1920 to have been approximately 688,000,000 barrels. The potential production in Mexico during 1920, according to Mexican official figures, was nearly 800,000,000 barrels. By the term "potential production" is meant the amount of oil that would be produced if each well were permitted to flow without restraint. This estimate of the Mexican government is undoubtedly too high, as it fails to take into consideration the failing wells and has been based on the initial production of large gushers which quickly settle down to a flow of only one-half or two-thirds of their initial production. Conservative estimates as of August 1, 1921, give about 1,500,000 barrels as the daily potential capacity of existing wells. The actual production, based on statistics of the oil movement, amounts to 600,000 barrels daily. The daily potential production of the fields fluctuates greatly, as new wells are being constantly developed and salt water encroachments show up frequently without warning.

The Mexican wells flow continuously under their own pressure, wells often coming in with an initial flow of more than 100,000 barrels daily, under a water and gas pressure as high as 1,085 pounds to the square inch, but averaging between 300 and 800 pounds. Pumps are never required as the wells produce under their own pressure until exhausted. There is no "oil sand" (in our use of the term) found in the producing fields of Mexico, although recent borings in the "Tehuantepec-Tabasco" region indicate the presence of oil-bearing sands. A notable characteristic of Mexican oil is the great heat of the oil produced, the temperature ranging from 90° to 181°F (32° to 83°C). The average temperature at the Ebano fields is 105°F and that of the salt water and oil of the Dos Bocas is 165°F. The temperature of the oil is of great importance from an economic viewpoint, in that it decreases the viscosity of the oil and permits it to flow more freely. Since viscosity retards the movement of oil in the containing formation, the heat is of importance as a factor in determining the rate of daily production. In most of the producing fields of Mexico large amounts of gas are present under considerable pressure, but very little attempt has been made to divert the gas to economic usefulness.

Mexican oil, because of its low gravity, is of low gasoline content, averaging from 5% to 16%. American oil, averaging a higher gravity, produces 20% to 40% gasoline, besides kerosene, lubricating oils, paraffin, etc. One authority averages Mexican oil as composed of about 9% naphtha, 10% illuminants, 50% to 75% fuel and the remainder lubricants, paraffin, asphalt, etc.

An average of 300 wells produced in Mexico during 1920 approximately 164,000,000 barrels of oil, or an average actual daily production of 1,800 barrels per well. From January 1 to May 1, 1921, the Mexican Government reports 42 new wells completed with a daily potential production of 828,728 barrels. During the week ending September 4, 1921, nine wells were completed in Mexico with a daily actual production of 140,000 barrels.

Geographical Division and Production of American Wells.

The oil wells of the United States may be geographically divided into the following fields:

	Number of producing wells.
Appalachian	109,000
Lima-Indiana	42,000
Illinois	16,800
Mid-Continent	78,360
Gulf Coast	1,840
Rocky Mountains	1,070
California	9,490
Total	258,560

The approximate daily production per well averages 4.9 barrels. With but few exceptions the wells in the United States must be pumped from the time they are "brought in."

Oil Producing Areas of Mexico.

The known oil-producing areas of Mexico may be divided into three main regions, as follows: Panuco River region, Tampico-Tuxpan or "South Fields" region, and the Tehuantepec-Tabasco region.

In the Panuco River region the Ebano field is situated 40 miles west of Tampico. The oil from this field has a very high percentage of asphaltum and averages about 12° Be′ (0.986 specific gravity). The Panuco field, comprising the productive areas between the Tamesi and Panuco rivers, is 20 to 30 miles southwest of Tampico and the Topila field is situated a few miles east of the Panuco. Both the Panuco and Topila production is a heavy viscous oil of from 10° to 15° Be′, the deposits being found at approximately 2,200 feet. These fields have been noted for the relatively few failures in drilling. From the east end of the Topila field to the west end of the Panuco field (a distance of 17 miles) is an undrilled gap of nearly 3 miles, which is being closed by exploitation. From this Panuco-Topila district there has been produced to date 130,000,000 barrels of oil, or 20% of Mexico's total output and there is a present daily production of 130,000 barrels. From the Ebano field there has been produced to date 24,000,000 barrels of oil, or 3½% of Mexico's total output. Today there is a daily production of 4,000 barrels. While there is a general salt water table below which no oil will be found, neither of these fields has been finally delineated by dry holes and there is good reason to believe that they will be extended.

Developments in the Tampico-Tuxpan or "South Fields" region have been made upon a long, narrow strip of productive territory running in a north and south direction from Dos Bocas to Alamo. This strip has been developed to a length of about 40 miles and to a width of about 1 mile. Local elevations and variations in structure make some portions of the strip more productive than others, but over the entire 40 miles it is remarkably uniform. The oil from this territory averages from 19° to 21° Be′ (0.9395 to 0 9271 specific gravity). This region has produced 492,446,170 bbls. of oil or 75% of Mexico's output and is now producing daily at the rate of nearly 400,000 bbls. The various sectors or pools of the "South Fields" regions have been given various names. A short description of each of the various sectors or pools of this region follows:

Dos Bocas—This is the most northern pool of the area. The first large well was brought in in 1908 with an initial flow according to its owners of more than 100,000 bbls. daily. After catching fire and running wild for three months, the well turned to hot salt water and is not now productive. Many well versed oil men believe Dos Bocas was a "gasser" as it burned without smoke.

Tepetate-Chinampa—This pool has produced more than 100,000,000 bbls. of oil, but production is only obtained from this pool at this time by stripping. The salt water table started at 2,175 feet and rapidly rose to 1,800 feet. The average depth of the wells was 2,000 feet.

Casiano Pool—The famous Juan Casiano well No. 7 was completed in this pool in 1910, flowing continuously for 10 years and produced 85,000,000 bbls. of oil. Contrary to a popular belief this pool is not a part of the Chinampa pool from which it is separated by volcanic dikes.

Amatlan-Naranjos-Zacamixtle—This district has produced nearly 120,000,000 bbls. of oil up to July 1, 1921, at which time it was estimated to contain a reserve of 50,000,000 bbls. The salt water table began at 2,150 feet at the northern end and rose to 1,660 while on the southern end in Lower Amatlan the salt water has reached the 1,800 foot level. Amatlan is being intensely developed by a score of operators, both old line companies and independents and will probably not have a long life. The average depth of wells in this area is 1,900 feet.

Toteco—This pool was not drilled until early in 1921. The fee title to the pool is held partly by the Huasteca Petroleum Co. The International and Mexican Gulf Companies hold leasehold rights on the remainder. The average depth of wells is 1,800 feet.

Cerro Azul and Juan Felipe—The most famous well in this area is the Huasteca Petroleum Co.'s No. 4 brought in in 1916, and which has produced 60,000,000 bbls. The Juan Felipe area is held by some authorities to be separate from Cerro Azul, being cut off by a well defined basalt dike. One well in the Juan Felipe boundaries now shows the extraordinary pressure of 1,080 pounds, and has not been exploited due to the more convenient location of the Cerro Azul wells belonging to the same American company.

Potrero del Llano and Atazan—The Potrero del Llano well was completed in 1910 and produced 94,000,000 bbls. of oil before it went to salt water in 1918. By strategic drilling and pinching in oil wells a considerable production has been developed since 1918 and it is being maintained. The average depth of wells in this district is 2,000 feet.

Cerro-Viejo—This large property, lying south of Cerro Azul and adjoining Potrero del Llano, is just beginning to be drilled. It belongs to the Huasteca Petroleum Co. and the Aguila Co. Indications point to its overlying a separate pool which, judged by surface indications, will equal any of the larger pools. It contains a small well at a shallow depth which was drilled in 1878. The recent drilling has encountered oil at the 1,600-foot level.

Tierra Blanca and Chapapote Nuenz—This is a non-competitive pool controlled by the Huasteca Petroleum Co., the first well having been completed in May, 1921, with a potential production of 75,000 barrels per day.

Tanhuijo and Tierra Amarilla—Drilling has been deferred in this district because of the greater production of wells to the west, which produce lighter oils.

Molino Pool—One well has been drilled in this pool at 2,710 feet, producing a heavy viscous oil of 11° Be'. While exceptionally heavy, the oil from this well has been discharged successfully under the well pressure through a pipe line to a pumping station at a distance of 20 kilometers.

Alamo—This pool is controlled by the Penn.-Mex. Fuel Co. Approximately 35,000,000 barrels of oil have been produced, consisting of two distinct grades. Salt water has seriously invaded the pool and stripping has been resorted to.

Furbrero—This area is located about 40 miles southwest of Tuxpan. The oil found is of very high grade, being 24° Be', but the yield has not been large and the district is not now producing. Between Alamo and Furbrero are some of the best indications of oil pools in Mexico on lands which are largely taken up by American companies. South of Furbrero, at Pahuatatempa and Vega, are extensive seepages, although no development has yet been undertaken in this region.

In the Tehuantepec-Tabasco region, the Tabasco-Chiapas field is noted for the quality of its oil, which has a paraffin base, is very light, and contains a large proportion of illuminating oils. Exploitation of this field promises to become active after having been dormant since 1917. The Isthmus of Tehuantepec field produces an oil of from 25 to 32° Be' and is characterized by the short productivity and the shallow depth to oil. Operations in this field have not been of great importance in the past few years. Oil is found at a depth of 500 to 600 feet.

The following table shows all of the Mexican oil fields discovered up to June 1, 1921, with the date of discovery, number of wells drilled number of productive wells and the production of these wells:

Number and Production of Wells in Mexican Oil Fields.

REGION AND FIELDS	Year Discovered	No. of Wells Drilled	No. of Wells Productive	Production Total	Production Present Averages Daily
Panuco, Topila, Ebano fields:					
Panuco	1910	218	112	121,000,000	127,000
Topila	1910	75	18	8,539,000	3,500
Ebano	1910	71	38	22,400,000	4,000
Total		364	168	151,939,000	134,500
South Fields:					
Tepetate and Upper Chinampa	1910	28	17	126,874,000	(o)
Lower Chinampa and Amatlan	1913	89	43	141,566,000	240,000
Zacamixtle	1920	10	8	12,039,000	50,000
Toteco	1921	3	3	1,000,000	30,000
Cerro Azul	1916	6	2	59,002,364	60,000
Potrero del Llano & Alazan	1910	21	11	115,650,000	(o)
Tanhuijo & Tierra Amarilla	1919	39	21	500,000	(v)
Alamo	1913	9	6	35,803,806	15,000
Molino	1917	2	1	11,000	500
Total		207	112	492,446,170	395,500
Tehauntepec region	1904	220	54	7,000,000	....
Miscellaneous		...	...	500,000	200
Grand total		791	334	651,885,170	530,200

oSa t water.
vAbandoned.

Explanation of Mexican Gushers.

Mr. E. de Golyer, geologist, in a paper read before the Society of Automotive Engineers is quoted as follows:

"We have been so impressed with the unprecedented size of some of the Mexican gushers and by their continued production of large quantities of petroleum over long periods of time without any appreciable decline in the amount of production, that we have perhaps overestimated the total amount of petroleum to be accrued from any single pool. The explanation of the great gushers seems to lie in the very great porosity of the rock in which the petroleum occurs. It collects in a network of caves and channels previously dissolved out of a bed of thick limestone. This condition allows the petroleum to move about very freely while still underground. Furthermore, the petroleum generally lies over water under an artesian head, and as a consequence the field pressure is largely hydrostatic rather than gas pressure, which, in most fields is the expulsive force causing the oil to flow. The result of these conditions is deposits of petroleum which can be exhausted with a single well, whereas a deposit of the same size under different conditions of occurrence would require hundreds if not thousands of wells to exhaust it."

Salt Water Invasion.

No salt water has yet appeared in the Cerro Azul and Toteco fields. In all other fields some of the wells have been damaged or destroyed by the encroachment of salt water. An unwarranted impression as to the significance of the invasion of salt water in the various Mexican fields has recently been created by articles appearing in the press. The wells now producing oil in Mexico are doing so under a great hydrostatic pressure, the flow of oil continuing until exhausted, and the salt water then following the oil to the surface. The "salt water menace" so-called, does not usually appear until after vast quantities of oil have been taken from a pool and the exhaustion of one pool has no more bearing on an unconnected virgin pool than does the exhaustion of a sector in the United States condemn a sector not yet developed.

The other fields of Mexico will continue to give oil for a considerable time to come, but such production probably will be increasingly smaller from the peak of 1920-21. Many of the wells now being developed in the Amatlan pool show tendencies to develop salt water more rapidly than heretofore. This condition may be accounted for, in a measure, because the producers in competing pools have been forcing production to the limit in order to get out as much oil as possible before a rival concern drains the pool. The extensively developed pools in the South fields region have been pulled on by every pipe line and storage available in the region in a wild scramble to get the oil to the surface and they are now witnessing the inevitable result—a rapid exhaustion of the pools and the early appearance of salt water. Even after a pool has apparently been drained, substantial amounts of oil may be produced by "pinching in" the wells. This consists in closing the flow valve, creating a back pressure and permitting the oil to flow through a smaller aperature; the water, as the heavier material, going to the bottom. This process is repeated so long as clear oil can be made to flow. Pinching in or stripping was resorted to after the Chinampa pool was drained and is now being done to Alamo and Potrero and will be resorted to in Zacamixtle and Amatlan.

Estimation of Mexican Fields.

The following recent estimate of the Mexican fields has been made by Messrs. L. G. Huntley and Stirling Huntley, prominent American geologists:

Estimating the life of Cerro Azul and Tierra Blanca, with an estimated reserve of 200,000,000 bbls. at 1,000 days (on the assumption that they produce at the combined rate of 200,000 bbls. per day after the Amatlan pool is drained) at the time of their being finally flooded, they in their turn should strip 10,000 bbls. or more per day each from wells on the crests. This reserve will be partly sold to other companies and therefore will probably be pulled on much faster than this. While it is impossible to say how long this stripping can go on, there is good evidence that such wells will be long lived, as they are probably fed by oil working up the flanks of the structure over the entire former producing area. Much of this oil must have been cut off by the sudden flooding of the pools and will now be largely available to such strategic wells as those mentioned. This will allow one to estimate that after all the Southern pools have been flooded there will still be a production in the Mexican fields of 250,000 bbls. per day at the end of 1,000 days from July 1, 1921 (December 1, 1924) on the assumption that the new drilling in the Panuco River field increases production.

This alone is sufficient to be a considerable factor in the oil market, particularly the fuel oil market. Meanwhile it can be assumed that the prospecting will have probably extended the producing areas in the Panuco River district and those to the south and west of the Alamo. In the latter region there are good indications that there will be found pools of relatively light oil in sand and limestone formations above the Tamasopa, as well as in the latter formation itself. In the case of the probable pools yielding from reservoirs above the Tamasopa, these will undoubtedly have smaller wells producing over a longer period of time in comparison with the large Tamasopa wells to the north. It is even possible, if later and higher prices warrant it, that this region will see pumps installed for the first time in Mexico.

"The present reserves in producing pools may be shown as follows:

	Barrels
Amatlan Zacamixtle	50,000,000
Cerro Azul-Toteco	150,000,000
Tierra Blanca	50,000,000
Total	250,000,000

"In addition to the above reserves are the Panuco River pools which have not been limited and seem capable of considerable extension.

"These amounts disregard later recoveries from the same areas through stripping wells. as the factor used in the calculations was derived from the data in the Tepetate-Chinampa area, which excludes later recoveries. Early in 1921, before the market decline, the daily production was:

	Barrels
Panuco River fields	145,000
Amatlan-Naranjos-Zacamixtle	400,000
Cerro Azul and Toteco	30,000
Alamo	10,000
Total	585,000
Less Amatlan, in 125 days will lower production to	185,000

"But this disregards oil reserves from various sources, which may therefore be added and summarized, giving the following estimated possible production by fields after Amatlan goes to sea water:

	Barrels
Panuco River fields	145,000
Tepetate-Chinampa (stripping)	10,000
Naranjos-Amatlan-Zacamixtle (stripping)	20,000
Cerro Azul (3 companies)	140,000*
Tierra Amarilla (stripping)	10,000
Potrero Alazon (stripping)	10,000
Alamo (stripping)	7,000
Tierra Blanca (noncompetitive)	60,000**
Total	402,000

*Probably greater on account of the sales to other companies.
**Depending on company's. policy.

Operations in Panuco and Topila.

The American consul at Tampico has observed that production operations in the Panuco and Topila fields are somewhat different in character than in the Southern fields, in that part of them are conducted by individuals and small companies or aggregations of individuals; whereas the major part of development work in the Southern fields is conducted by large corporations which not only drill the wells but construct refineries, pipe line, pumping stations, and loading terminals, and ship the oil by their own tank steamers. Thus they conduct all the operations of production and marketing and the matter of cost price or value at the well concerns them but little. Many of these companies also have valuable properties in the Panuco district. Shipments of Panuco oil have been practically confined to such companies. Lately much activity has been noted among independent producers (confined largely to the Panuco field) finding outlets for their product through brokers and as a result, something resembling a trading market has been formed and a value for the different oils established.

Formerly the big producing pools of Mexico were controlled in most cases by a single company and neither fear of having their property drained by a rival nor competition operated to force production by the individual companies. From the standpoint of conservation of the oil supply, such an arrangement was desirable for a minimum amount of oil was wasted through over-production and insufficient storage. At the present time, the heavy producing pools, particularly in the South fields region, are in most instances being pulled on by competing companies with little regard to conservation of the supply.

Exploration of New Fields.

George Otis Smith, director of the United States Geological Survey, puts the proved area of Mexican oil lands at about 10,000 square miles, with resources of 4,500,000,000 bbls. and the potential output of unproved territory at 1.250,000,000 bbls.; a total estimate of 5,750,000,000 bbls. or a supply adequate for 45 years at the 1920 rate of exports. A greater part of the unproven territory in the known oil zones is already in the hands of the large corporations. The exhaustion of the Amatlan pool will mark the passing of the independent operator in the South fields region to a considerable extent. The Panuco River region has always been essentially a small man's field. The enormous reserves of petroleum lands situated in the producing regions held by the Mexican Petroleum Co. (Doheny) and the Aguila Co. (British) allow these companies to regard the intrusion of salt water in their present wells with a certain degree of equanimity. The Royal Dutch Shell interests control nearly 400 square miles of valuable fee-simple and leasehold oil lands. The Mexican Petroleum Co. has obtained a 40 year lease on nearly 800,000 acres in the Tampico district on land which shows extensive oil seepages. This addition increases greatly the life of the extensive properties already owned by this company. The Marland Oil Co. of Mexico has extensive holdings of undeveloped lands in Mexico, including 280,000 acres in the Tuxpan-Tampico area, 65,000 acres in the Tabasco-Chiapas region and large concessions in Lower California and Sonora.

Increasing attention is now being given to exploration or "wildcatting" in various parts of Mexico for the discovery of oil. Geological conditions indicate that other petroleum fields of great importance will be discovered in Mexico, and that such discoveries will be of a petroleum of a much better quality than that now being produced. A report of the Mexican Petroleum Section of the Department of Commerce, Industry and Labor, places the zone of possible production in the Gulf States at more than 80,000,000 acres and in Lower California at about 18.000,000 acres. Of this immense area, only about 10,000,000 acres have been investigated which illustrates the scope offered for wildcat operations in Mexico. The combined area of the fields now being exploited in Mexico does not exceed 1,200 square miles.

Exploitation has now extended into the districts of Tlacalulu and Cobos. The Tlacalulu district is in an oil bearing formation, situated in the extreme southeast corner of the State of San Luis Potosi, 50 miles southwest of Tampico. The Cobos district lies directly across the Gonzales River from Tuxpan and extends southwest for 50 miles. It is regarded as a determined field and exploitation is going on. Exploration is particularly active in the Isthmus of Tehuantepec and in the region south of Vera Cruz. Many seepages occur in this region. The Tabasco district is the oldest oil field in Mexico, the oil produced being of 32° Be' but former production was in such small amounts that competition with the richer Panuco and South fields was impossible. Extensive leasing is under way and actual development again in progress, principally by the Royal Dutch-Shell interests, although the Standard Oil and Mexican Gulf companies are active. The Grijalva River is being deepened at Frontera, which city is to be the port of the Tabasco field.

Possibilities in Scattered Regions.

The discovery of what is believed to be extensive petroleum deposits on some islands in the Gulf of California has been announced. These islands are close to the shore of Sinaloa, due west of Hermosillo, and the deposit is thought to extend to the mainland of Lower California. The proximity of these areas to the producing areas of the State of California, the probability that portions of Lower California and Sonora are underlaid by a counterpart of the producing horizon of the California fields in the United States, the evidence of petroleum on the surrounding waters and the continued extension of the California fields southward leads to the belief that these areas on the west coast will yet produce petroleum in commercial quantities.

Explorations are being carried on in other parts of Mexico as follows: Durango, in the neighborhood of Mapimi; Oaxaxa, near Puerto Angel; Colima, in the vicinity of Santa Rosalia and of Manzanillo; Chihuahua, in the vicinity of Casas Grandes, Guzman, Trinidad, Santa Maria, and southwest of Ojinaja; Coahuila, at Ubalde, near Piedras Negras, and Nuevo Laredo; Chiapas, in the Departments of Palenque and Mezcalapa; San Luis Potosi in the Valles district; Jalisco in the vicinity of Lake Chapala, and in various parts of Yucatan. On September 1, 1921, there were 240 strings of drilling tools in operation throughout Mexico as follows:

FIELDS	Dlg.	Der.	Loc.	Ttl.
Panuco	24	10	11	45
Topila	3	2	5	10
South Fields	64	19	48	131
Wildcat	19	11	24	54
Total	110	42	88	240

While the cost of drilling wells in Mexico is high, there are other costs which precede drilling and which amounts to a considerable figure. These include the cost of prospecting by highly-paid geologists, the expenses of negotiating the purchase and lease of oil territory, the amount paid for the properties if purchased, or the rentals if leased, the very substantial recording and stamp fees encountered in Mexico, the expense of perfecting title (which is considerable, due to the successive divisions of the land) the cost of clearing the land, the construction of roads and water lines, materials for transporting supplies through the jungles, and many other items of expense peculiar to operations in Mexico.

ACTUAL PRODUCTION BY COMPANIES IN MEXICO.

COMPANIES	1918 Bbls.	1917 Bbls.
Cia. Pet. La Victoria	....	1,574
Topila Petroleum Company	....	2,000
Cia. Mex. Pet. del Golfo	....	29,993
National Oil Company	....	753,589
Panuco Petro. Maat. (Royal Dutch)	2,748	....
Cia. Exp. de Pet. La Universal	3,075	....
Hispano Mexicana (Tex. Mex. Fuel)	4,226	873
Mexico y Espana	5,459	29,625
Mexican Oil Company	3,490	288,770
Cia. Pet. Monterrey	25,021	24,958
Chijoles Oil Ltd. (R. Dutch)	25,266	1,515
Oil Fields of Mexico	29,906	34,689
Vera Cruz Mexico (S. O. N. J.)	51,716	360,258
La Petrolera Poblana	91,311	32,871
Cia. Mex. de Combustible (Pierce O l)	300,064	60,852
La Corona (Royal Dutch)	337,603	740,576
Transcontinental de Petroleo (S. O. N. J.)	382,029	119,315
Panuco Bost. Oil (Atlan. Ref.)	531,511	828,067
Tampascas Oil Company	578,478	174,924
Internat. Pet. (J. H. Hamm'd)	609,733	619,828
Cia. Pet. Tal. Vez. (So. O. & T.)	1,152,063	989,561
Tex. Co. of Mex. (Texas Co.)	1,279,746	2,315,433
Cia. Mex. de Petroleo (Mex. Pet. of Calif.)	1,445,976	1,125,702
Cia. Mex. de Pet. La Libertad (Island O. & T.)	1,550,869	....
Mex. Gulf Oil (Gulf Oil Co.)	1,728,190	1,160,794
Cortez Oil Corp. (Port Lobos Pet. Corp.)	2,161,775	....
East Coast Oil (So. Pac. Co.)	3,457,235	3,143,220
Freeport & Mex. F. O. Corp. (Sinclair Gulf)	4,119,654	4,076,982
Penn. Mex. Fuel Co. (South Penn. Oil)	6,854,080	4,129,296
Cia. Mex. de Pet. El Aguila (Mex. Eagle Oil)	16,910,646	16,922,322
Huasteca Pet. Co. (Mex. Pet. of Delaware)	20,186,459	17,325,171
Totals	63,828,329	55,292,758

PIPE LINES IN MEXICO.

The pipe lines in Mexico on November 30, 1919, with the name of the owners and the capacity of the pipe lines are as follows:

OWNERS	No.	Total Lengths, Meters	Daily Capacity, Cubic Meters
Freeport & Mexican Fuel Oil Corporation	3	4,750	7,950
Cia. Transcontinental de Patroleo	11	20,743	40,131
Tampascas Oil Co	1	1,470	1,590
National Petroleum Corporation	1	350	5,724
National Oil Co	3	10,985	2,880
Oil Fields of Mexico Co	1	88,950	1,590
New England Fuel Oil Co	3	2,276	14,000
Standard Oil Co	3	8,953	6,930
Cortez Oil Corporation	7	78,603	48,472
Cia. de Petrolio La Corona	4	68,188	9,641
Mexican Gulf Oil Co	4	113,276	11,144
East Coast Oil	6	44,843	11,888
Texas Co. of Mexico	7	49,534	17,195
Mexican Oil Co	1	2,707	1,590
Cia. Mexicana de Combustible	2	6,499	3,338
El Aguila S. A.	29	421,498	79,876
Cia. Mexicana de Petroleo	1	11,260	138
Huasteca Petroleum Co	5	362,724	7,950
Tampico Oil Ltd	1	8,500	318
Penn. Mex. Fuel Co	6	62,367	41,657
Panuco Boston Oil	1	1,380	1,145
Cia. Regiones Pet. Mexicanas	1	1,357	4,190
Cia. Terminal de Lobos	1	812	11.400
Pierce Oil Corporation	1	2,463	1,590
Cia. Mex. de Oleoductos Imperio	1	1,213	5,540
La Atlantica Cia	1	2,674	9,000
Cia. Terminal Union S. A	2	875	10,000
Cia. de Fomento del Sureste	1	1,100	1,000
Cia. Metrolopitana de Oleoductos	6	40.570	19,302
Total,	113	1,420,920	377,169

The number of storage tanks in Mexico January 1, 1920, with the name of the owners, the capacity of the tanks, are as follows:

	TO TO DEC. 31, 1919		CONSTRUCTED DURING 1919	
	No.	Capacity, Cubic Meters	No.	Capacity, Cubic Meters
Freeport & Mexican Oil Corp	4	26,234	1	5,962
Cia. Transcont. de Pet. S. A	20	153,420	2	17,598
English Oil Co	1	1,590	.	....
Tampascas Oil Co	1	3,180	.	....
National Petrol. Corp	1	8,745	.	....
Interocean Oil Co	2	17,488	..	....
Hispana Mex. S. A	1	8,745	1	5,961
Cia. Pet. Tal. Vez	1	3,180	..	......
National Oil Co	4	34,980		....
Oil Fields of Mexico	9	28,303	.	....
New England Fuel Oil Co	4	35,980	1	8,744
Standard Oil Co	23	212,800	.	....
Cortez Oil Corporation	6	52,470	4	33,980
Cia. de Pet. La Corona	37	345,467	4	21,218
Topila Pet. Co	1	5,962	..	....
Mexican Gulf Oil Co	76	91,031	5	31,409
Chijoles Oil (Ltd.)	3	3,180	..	....
Producers Terminal Corp	4	34,976	..	....
East Coast Oil Co	18	129,572	..	....
Felix de Martino Diaz	1	8,745	1	8,745
Texas Co. of Mexico	17	118,400	12	20,150
Mexican Oil Co	2	4,212	..	....
Cia. Mex. de Combustible	8	41,914	..	....
El Aguila S. A	374	4,501,900	2	11,925
Cia. Mexicana de Pet	16	96,089	..	......
Huasteca Pet. Co	129	1,169,951	..	......
Tampico Oil Ltd	5	12,918	..	......
Penn. Mex. Fuel Co	17	148,665	..	......
Eureka Pet. Co. S. A	...	....	3	3,968
Panuco Boston Oil Co	3	17,806	..	....
Cia. Terminalde de Lobos	5	43,720	3	25,232
Pierce Oil Corporation	114	111,722	..	....
La Atlantica Cia	..	....	5	42,533
Ferrocarril Interoceanico	1	8,745	..	....
North American Dredging Co	1	5,962	..	....
Cia. de Fomento del Sureste	2	17,490	..	....
Cia. Metrop. de Oleoductos	4	34,980	4	34,980
	915	7,540,531	48	272,406

OIL TANKERS IN USE JUNE, 1921, HANDLING MEXICAN PETROLEUM.

Name of Tanker	Barrels Capacity,
HUASTECA PETROLEUM CO.	
La Habra	68,200
I. C. White	54,000
E. L. Doheny	61,200
C. E. Harwood	30,800
Sunshine	67,100
Solana	63,200
C. Anderson	79,500
San Joaquin	60,600
Tamaha	72,100
G. G. Henry	64,100
Caloric	58,600
Franklin K. Lane	66,900
E. Walker	66,400
Montana	64,300
G. W. Barnes	60,600
C. A. Canfield	61,400
Cerro Ebano	74,000
H. G. Wylie	39,700
Mendocino	54,300
J. Macy	77,400
J. M. Danziger	61,300
Norman Bridge	39,600
Mantilla	53,100
Wm. Green	66,400
Wyneric	38,700
Nora	95,800
Oyleric	53,500
Ario	73,200
MEXICAN GULF OIL CO.	
Gulf Oil	50,400
Shenango	25,300
Gulf Trade	65,700
Currier	46,000
Gulfstar	72,900
Gulflight	32,200
Ligonier	30,000
Oural	19,500
Agwisea	78,700
FREEPORT & MEXICAN FUEL OIL CORP.	
Darden	53,200
Farnum	32,100
Tamesi	20,400
Madrone	55,400
Panuco	25,800
J. M. Cudahy	69,200
E. R. Kemp	44,500
Hardcastle	34,200
Hugenot	61,600
A. E. Watts	64,800

Name of Tanker	Barrels Capacity,
MEXICAN EAGLE OIL CO., LTD.	
War Shikari	49,000
War Begum	49,100
War Rance	52,200
San Florentine	67,600
San Leon	50,500
San Dunstano	68,800
Camden	60,900
Anomia	41,400
San Lorenzo	81,800
San Narario	82,500
British Maple	58,600
San Tiburcio	62,000
War Glackwar	49,500
Bloomfield	43,300
El Cano	45,700
San Silvestro	7,500
San Zotico	49,600
San Ubaldo	46,500
Grenella	46,200
San Teodore	57,400
San Fernando	18,300
Kekoskee	47,600
San Geronimo	108,200
San Ricardo	49,100
Borgestad	36,600
San Patricio	107,500
TRANSCONTINENTAL PETROLEUM CO.	
Comet & Brg. 82	47,200
Princeton	19,500
H. H. Rogers	51,600
Caloria	37,200
Gedania	31,900
Corning	20,300
H. M. Flagler	23,300
Glenpool	48,000
Baytown	20,700
C. M. Everest	53,100
Geo. H. Jones	61,000
Baton Rouge	46,500
James McGee	68,400
Sandtows 1-2	38,200
Wm. G. Warden	51,900
F. W. Weller	41,200
W. Jennings	97,800
F. Q. Barstow	103,700
Zoppot	106,000
Bradford	58,200
Chinampa	63,600
Richconcal	62,900
Bostwick	77,300
J. D. Rockefeller	72,500

OIL TANKERS IN USE JUNE, 1921, HANDLING MEXICAN PETROLEUM (Concluded)

Name of Tanker	Barrels Capacity.
EAST COAST OIL CO.	
F. Sulphur 6	38,500
Torres	51,000
F-Sulphur 1	21,500
Gladsbye	47,500
Topila	52,200
PENN. MEX. FUEL OIL CO.	
Mattole	64,500
Standard	119,300
NEW ENGLAND FUEL OIL CO.	
Radiant	24,300
Socony 90	18,300
Gen. Pettibone	8,300
Socony 85	23,800
Perfection	14,900
M. P. 7	17,700
Chagres	9,800
LA CORONA PETROLEUM CO.	
Utacarbon	53,000
Alabama	26,600
William Isom	28,800
Lucellum	42,100
Ar. Von Gwinner	28,800
NATIONAL OIL CO.	
Katherine	17,300
W. A. Ibsen	31,200
P. J. Reilly	27,100
Daugherty	26,200
TEXAS COMPANY	
Pennsylvania	56,300
Texas	58,800
Occidental	58,900
Harvester	60,500
Sucrosa	52,300
Shenandoah	65,500
Maricopa	35,000
Yorba Linda	66,200
Reaper	64,000
Louisiana	25,900
Belridge	68,300
NATIONAL PETROLEUM CORP.	
Newona	22,200
Lancarville	19,100
Danville	31,000
PIERCE OIL CORPORATION	
Mexicana	21,400
Hampton Roads	42,400

Name of Tanker	Barrels Capacity.
FRANCE & CANADA OIL TRANSPORT CO.	
Swiftarrow	43,800
Swiftsure	41,300
Winapie	18,000
INTEROCEAN OIL CO.	
Aztec	51,300
Pinthis	8,600
ISLAND OIL & TRANSPORT CORP.	
Uncas	44,200
Sabine Sun	70,700
Clement Smith	72,000
Massassoit	45,000
S. B. Hunt	69,000
Nelson	43,800
Crowe	29,500
Hahira	67,700
Muskogee	62,700
Liberty Minguas	48,300
Warden	48,000
Trontolite	61,200
TALVEZ OIL CO.	
Sunset Una	14,800
CIA. REFINADORA DEL AGWI	
Baldhill	62,100
Remulus	48,300
Agwison	71,800
Hadnot	65,300
Chestnut Hill	43,600
Mevania	66,500
Baldbutte	62,400
Chestersun	75,900
Hoven	66,600
Agwiworld	68,900
Hulaco	67,300
Agwimoon	72,200
CORTEZ OIL CORPORATION	
Donnell	105,300
S. L. Fuller	71,700
Japan Arrow	86,000
Halsey	64,200
W. M. Burton	71,900
Devolente	64,900
Tonawanda	28,200
Coalinga	74,900
Montebello	76,000
Laramie	56,500
INTERNATIONAL PETROLEUM CO.	
De Soto	55,700
W. C. Teagle	108,500
J. Worthington	79,500
Mottole	64,600
Rapidan	78,300
Chas. Pratt	102,800

RECORD OF ALL MEXICAN OPERATIONS TO DATE—1919

Prepared by Mexican Petroleum Department, Secretary of Industry.
1 Cubic Meter = 6 29 Barrels.

DRILLED BY	Locations	Drilling Feb. 28, 1919	Producing	Potential Daily Production in Cubic Meters	Abandoned	Total No. of Wells
La Universal	...	1	1	511.00	...	2
Mexico y Espana	...	...	1	626.00	...	1
La Libertad	...	...	1	8,000.00	...	1
Cantabros en Panuco	...	1	...	....	1	2
La Nacional	...	1	...	....	...	1
Panuco Tamesi	1	...	...	....	...	1
Alamo de Panuco	1	...	...	....	1	2
Tux. Ozuluama	...	2	...	....	...	2
Pet. Maritima	...	...	...	....	1	1
Preeport & Mex.	1	4	7	5,794.90	2	14
Esfuerzo Tampiqueno	...	...	...	....	1	1
El Caiman	...	...	...	....	1	1
Panuco Valley	2	...	1	66.77	...	3
Southern Co	...	...	1	800.00	...	1
Expl. Topila	...	...	1	160.00	...	1
La Transatlantica	1	...	...	....	...	1
Panuco Mahuaves	...	...	...	....	1	1
Lluvia de Oro	...	1	...	....	...	1
Esfuerzo Nacional	1	...	...	....	1	2
Vado Oil Fields	...	...	...	....	1	1
La Victoria	...	...	1	6.00	...	1
Transcontinental	3	3	12	15,804.04	7	24
R. A. Mestres	3	...	...	....	...	3
English Oil Co	...	2	4	1,444.00	4	10
El Espino	...	1	...	....	...	1
Pedro Irisari	...	...	1	8.00	...	1
Tampascas Oil	...	1	5	713.00	1	7
National Pet	...	1	...	....	...	1
Gulf Coast Corp	1	...	4	22.96	1	6
Los Perforadores	...	...	2	319.00	...	2
Hispana Mexicana	...	...	1	1,600.00	2	3
Tal Vez, S. A	1	...	2	1,155.00	...	3
Monterrey, S. A	...	...	1	16.00	...	1
International Pet	2	4	3	6,661.22	8	17
Orbananos et al	1	...	...	....	...	1
Margenes del Pam	...	1	...	....	...	1
Panuco Topila	...	...	1	80.00	...	1
El Fenix, S. A	...	...	...	....	1	1
Las Dos Estrellas	1	...	...	....	...	1
Productora de Pet	...	1	1	238.50	1	3
National Oil Co	1	...	4	598.90	1	6
Mex. National Oil	1	...	...	....	2	3
Zaleta Mar Oil Co	...	...	...	....	1	1
La Herradura	...	...	...	....	1	1
Continental Mex	...	...	1	1,500.00	1	2
El Indio	...	1	...	....	...	1
La Oaxaquena	...	...	...	....	1	1
Oil Fields of Mex	1	1	12	60.37	23	37
New England Fuel	...	...	4	3,900.02	...	4
La Oriental Mex	1	...	...	....	...	1
La Esperanza	...	1	...	....	...	1
Abastecedora	1	1	...	....	1	3
Panuco Excelsior	...	...	1	190.00	...	1
Adrian Petroleum	1	2	1	5,000.00	...	4
Cortez Oil Corp	2	...	2	804.38	1	5
Inglesa Explot	...	1	...	....	1	2
Tantoyuca y Anexas	...	2	...	....	...	2
A. P. Wiechers	5	...	...	....	...	5
Mex. Pet. del Golfo	...	...	1	95.45	1	2
La Corona S. A	...	4	10	8,095.42	12	26
Byrd et al	...	2	...	....	...	2
Oro Mexicano	...	...	...	....	1	1
La Bonanza	...	...	1	16.00	...	1
Am. Fuel Oil	...	...	2	802.95	...	2

RECORD OF ALL MEXICAN OPERATIONS TO DATE—1919—Continued.

DRILLED BY	Locations	Drilling Feb. 28, 1919	Producing	Potential Daily Production in Cubic Meters	Abandoned	Total No. of Wells
Topila Petroleum	...	...	1	63.60	...	1
Mexican Gulf	2	2	8	22,370.50	8	20
Tampico Panuco	3	2	...	....	3	8
Chijoles Oil	...	...	7	154.33	...	7
American Inter	...	...	1	4.77	7	8
Hispano Amer	1	...	...	....	...	1
East Coast Oil	...	1	17	4,561.06	9	27
Soria y Socios	...	1	...	....	...	1
Texas Co. of Mex	2	3	10	17,072.19	2	17
Mexican Oil Co	1	...	3	639.98	...	4
Smith's Oil Co	...	...	...	....	1	1
Pan American Oil	...	1	2	875.00	...	3
Orillas de Panuco	...	1	...	....	...	1
Nuevo Leon	...	1	1	15.90	...	2
Mex. de Combust	1	...	9	5,051.62	6	16
Hispano Cubana	...	...	1	397.00	...	1
M. C. Anderson	...	...	2	22.25	...	2
Piedras Devel. Co	...	...	...	....	1	1
Lt Seventeen Co	1	...	2	6.40	...	3
Punta Arena y Anex	...	...	...	....	1	1
Comercio de Peubla	...	...	...	....	1	1
La Argentina	1	...	...	....	1	2
Mexico Fuel Oil	1	1	5	367.13	2	9
Hidalgo Oil Co	...	1	...	....	...	1
El Nayarit	...	...	1	2,000.00	...	1
Financiera de Pet	1	...	...	....	...	1
Mex. Development	...	...	...	....	1	1
El Azadon, S. A	...	1	...	....	1	2
La Concordia	...	...	1	....	...	1
Nueva Bonanza	...	...	...	....	1	1
El Aguila, S. A	32	18	55	20,590.18	284	389
Aamiahua Pet	2	1	...	....	4	7
Mex. Pet. Co. Cal	21	1	33	2,497.65	36	91
Huasteca Pet. Co	3	11	4	48,553.70	19	36
Tuxpam Pet. Co	...	1	...	....	...	1
Mundacadiz, S. A	...	1	...	....	...	1
Juan Casiana Tux	1	...	...	....	...	1
Harry Hummel	...	...	...	....	2	2
La Tolteca	1	...	...	....	...	1
Tampico Oil Ltd	1	...	4	47.00	4	9
Tampico Oil Co	...	...	...	....	1	1
Penn. Mex. Fuel	4	22	7	13,969.35	13	26
La Equidad	...	1	...	....	...	1
Espana, S. A	1	...	...	....	...	1
Pet. de Tepetate	6	...	2	21,462.86	1	9
Consolidata de Pet	...	1	...	....	...	1
Eugenio F. Ruiz	...	1	...	....	...	1
Seguranza, S. A	...	2	...	....	1	3
La Giralda	...	...	2	160.05	...	2
La Meridional	1	...	1	494.52	...	2
Tampiquena-San Javier	...	1	...	....	...	1
Tex. Mex. Fuel Oil	...	...	1	400.00	...	1
Nacional de Petr	...	1	...	....	...	1
Mexican Premier	...	1	...	....	...	1
Eureka	1	...	1	1,072.00	...	2
Panuco Tuxpan	...	...	1	223.00	...	1
Sun Oil Co	1	...	1	127.20	...	2
Petrolera Poblana	...	...	1	2,400.00	...	1
La Comercial	2	...	1	5.00	...	3
Panuco Boston	...	...	2	1,113.00	...	2
Regiones Pet Mex	...	...	4	3,465.10	...	4
Puebla en Panuco	1	2	...	....	1	4
Allison W. Smith	1	...	...	....	...	1
Rodolfo H. Rader	1	...	...	....	...	1
Capuchinas Oil	...	1	...	....	1	2
Fomento de Chapala	1	...	...	....	...	1

RECORD OF ALL MEXICAN OPERATIONS TO DATE—1919—(Concluded)

DRILLED BY	Locations	Drilling Feb. 28, 1919	Producing	Potential Daily Production in Cubic Meters	Abandoned	Total No. of Wells
Mexican Sinclair	1	5	4	2,951.00	1	11
Pet. Agric. Mex. San Jose	1	1	...	....	...	2
Scottish Mex. Oil	...	...	...	....	5	5
Los Brujos	...	...	...	....	2	2
Catopico Oil Co	1	...	...	....	...	1
Dos Banderas Oil	...	1	...	....	...	1
Clipton & Smith	1	...	...	....	...	1
Freggs Oil Co	...	...	...	....	1	1
Hidalgo Petrol. Co	...	1	...	....	...	1
W. H. Miliken	...	...	1	3.18	...	1
Ohio Mex. Oil	...	...	1	795.00	...	1
Producers Oil Co	1	1	2	1,224.30	...	4
Rio Vista	...	...	...	....	1	1
Sims & Bowser	...	...	1	79.50	1	2
Spanish Mex. Oil	...	1	...	....	...	1
J. W. Sloan	...	1	...	....	...	1
J. R. Sharp	...	...	1	39.75	...	1
Tampico Banking	...	...	2	2.24	...	2
Tampico Fuel Oil	...	...	1	127.20	...	1
Boston Mex. Leasing	...	...	1	12,720.00	...	1
H. McKeever	...	1	...	....	...	1
Mex. Tex. Pet	...	...	...	....	1	1
Tamesi Pet. & Asph	...	...	...	....	2	2
Gobiorno de la Fed	...	...	4	3.86	5	9
Fom. del Sureste	...	1	...	....	...	....
Totals	132	109	244	253,217.93	513	1056

LARGE PRODUCERS OF KANSAS—WITH PRODUCTION.

DAILY PRODUCTION IN 1918

NAME	Augusta, Barrels	El Dorado, Barrels	Outside, Barrels	Total, Barrels
Carter Oil Co	154	6,799	......	6,945
Carter & S. W. Oil Co	......	9,445	......	9,426
Magnolia Petrol. Co	3,126	......	......	3,108
Mid-Kansas Oil Co	2,108	......	......	2,196
Prairie Oil & Gas Co	747	47	......	773
Tidal Oil Co	......	1,073	......	1,027
Cosden Oil & Gas Co	1,562	......	......	1,562
Empire Gas & Fuel Co	12,041	31,376	......	43 419
Gypsy Oil Co	......	18,812	......	18,811
Monitor Oil & Gas Co	1,539	......	......	1,535
Oklahoma Prod. & Ref. Co	220	31	......	253
Producers Oil Co	83	......	......	80
C. B. Shaffer	......	1,502	......	1,594
Sinclair Oil & Gas Co	......	1,940	......	1,320
Totals	21,580	71,025	......	92,607
All other companies	1,613	14,643	13,000	29,256
	23,193	85,668	13,000	121,863

LARGE PRODUCERS IN CALIFORNIA.

OPERATOR	Per Cent Total Oil	Proved Land, Acres	No. of Wells
Associated Oi Co	9.1	7,347	1,708
Doheny (various companies)	7.3	4,286	348
General Petroleum Corporation	4.3	2,584	400
Honolulu Consolidated Oil Co	1.3	2,701	35
A. T. & S. F. Ry. (oil subsidiaries)	4.0	3,097	12
Shell Co. of California	6.8	2,442	236

CASINGHEAD GASOLINE MANUFACTURERS.

Name	Address	Plant
	CALIFORNIA	
American Gas Co	1005 Central Bldg., Los Angeles	Santa Maria
Calumet Oil Co	517 I. W. Hellman Bldg	Fillmore
Fellows Gasoline Co	Los Angeles	Fellows
Gilmore, A. F. Co	700 Van Nuys Bldg., Los Angeles	Los Angeles
Hurley Smith Co	339 Consol. Realty Bldg., Los Angeles	Brea
Hurley Smith Co	339 Consol. Realty Bldg., Los Angeles	near Sherman Jct.
La Habra Gasoline Co	339 Central Realty Bldg., Los Angeles	Brea
La Habra Gasoline Co	339 Central Realty Bldg., Los Angeles	Maricopa
La Habra Gasoline Co	339 Central Realty Bldg., Los Angeles	Taft
Olig Crude Oil Co	2827 LaSalle Ave., Los Angeles	Fellows
Olinda Gasoline Co	Van Nuys Bldg., Los Angeles	Olinda, Orange Co.
Pacific Gasoline Co	501 I. W. Hellman Bldg., Los Angeles	Brea
Purity Gasoline Co	339 Consol. Realty Bldg., Los Angeles	Bicknell
Rancho La Brea Oil Co	908 Merch. Natl. Bank Bldg., Los Angeles	Los Angeles
Richfield Oil Co	933 Van Nuys Bldg., Los Angeles	Maricopa
Sunset Gasoline Co	932 Van Nuys Bldg., Los Angeles	Taft
Union Oil Co. of California	Union Oil Bldg., Los Angeles	Avila
Union Oil Co. of California	Union Oil Bldg., Los Angeles	Brea
Union Oil Co. of California	Union Oil Bldg., Los Angeles	Maltha
Union Oil Co. of California	Union Oil Bldg., Los Angeles	Oleum
Union Oil Co. of California	Union Oil Bldg., Los Angeles	Santa Paula
Union Oil Co. of California	Union Oil Bldg., Los Angeles	San Pedro
Ventura Refining Co	458 S. Spring St., Los Angeles	Fillmore
Wilshire Oil Co	2455 E. Market St., Los Angeles	Fellows
Honolulu Consol. Oil Co	120 Market St., San Francisco	Kern Co.
New Pa. Petroleum Co	Santa Maria	Santa Maria
	COLORADO	
Midwest Refining Co	First National Bank Bldg., Denver	Salt Creek, Wyo.
	DELAWARE	
Leonard Oil Co	901 Market St., Wilmington	Cherry Grove, Pa.
	ILLINOIS	
Vacuum Oil Co	West Chestnut St., Bridgeport	
Atlas Oil Co	144 S. Wabash Ave., Chicago	Shreveport, La.
Atlas Oil Co	144 S. Wabash Ave., Chiacgo	Monroe, La.
Royalties Corporation	140 S. Dearborn St., Chicago	Lenapah, Okla.
Central Refining Co	Lawrenceville	Lawrenceville, Ill.
	KANSAS	
Continental Oil & Ref. Co	Independence	Independence
LeJune Oil & Gas Co	Independence	Independence
Roth Gasoline Co	P. O. Box 392, Independence	Elgin, Kan.
	KENTUCKY	
Collier Oil & Gas Co	West Liberty	Cannel City, Ky.
	LOUISIANA	
Standard Oil Co. of Louisiana	Baton Rouge	Northern Louisiana
Assoc. Prod. & Ref. Corp	Shreveport Commercial Bank Bldg	Mansfield, La.
Assoc. Prod. & Ref. Corp	Shreveport Commercial Bank Bldg	Monroe, La.
Central Oil & Gasoline Co	Shreveport	Vivian, La.
	MASSACHUSETTS	
Cabot, Godfrey L	Boston	West Va. and La.
	MISSOURI	
Ajax Gasoline Co	1012 Baltimore Ave., Kansas City	Delaware, Okla.
Atlas Petroleum Co	1012 Baltimore Ave., Kansas City	Jennings, Okla.
Dewey Portland Cement Co	Mutual Bldg., Kansas City	Dewey, Okla.
Diamond Gasoline Co	1012 Baltimore Ave., Kansas City	Jenks, Okla.
Diamond Gasoline Co	1012 Baltimore Ave., Kansas City	Nowata, Okla.
Lake Park Refining Co	324 Rialto Bldg., Kansas City	Bixby, Okla.
Lake Park Refining Co	324 Rialto Bldg., Kansas City	(2) Sapulpa, Okla.
Hale Petroleum Co	921 Commerce Bldg., Kansas City	Neodesha, Kas.
Little Sioux Oil Co	421 Commerce Bldg., Kansas City	Creek Co., Okla.
Osage Gasoline Co	1012 Baltimore Ave., Kansas City	Ochelata, Okla.
	NEW YORK	
Test Oil Co	67 Perry St., Buffalo	Dewey, Okla.
Carter Oil Co	26 Broadway, New York City	
Potter Gas Co	21 E. 40th St., New York City	Shinglehouse, Pa.

CASINGHEAD GASOLINE MANUFACTURERS—Continued.

Name	Address	Plant
	OHIO	
Buckeye State Gas & Fuel Co	Coshocton	near Coshocton
Medina Gas & Fuel Co	P. O. Box 390, Wooster	Mansfield, Ohio
	OKLAHOMA	
Cull nan Oil Association	Ardmore	near Ardmore
Dahlgren, Paul F	227 Masonic Temple, Bartlesville	Bigheart, Okla.
Dahlgren, Paul F	227 Masonic Temple, Bartlesville	Osage Junction
Foster, H. V	202 Masonic Temple, Bartlesville	Bigheart
Foster, H. V	202 Masonic Temple, Bartlesville	Osage Junction
Foster & Davis, Inc	227 Masonic Temple, Bartlesville	Osage, Okla.
Foster & Norwood Oil Co	227 Masonic Temple, Bartlesville	Bigheart
Phillips Petroleum Co	Bartlesville	Washington and Osage Co.
Four Gasoline Co	Bixby	near Bixby
Aurelius-Thomas Gasoline Co.	Box 707, Drumright	Drumright
Ray Flood Gas Co	Drumright	Lawton
Champlin Refining Co	First National Bank Bldg., Enid	near Enid
Peppers Gasoline Co	Rm. 9, First Natl. Bank Bldg., Enid	near Enid
Lawton Refining Co	Lawton	Lawton
Barnes Oil & Gas Co	712 Barnes Bldg., Muskogee	
Boynton Oil & Gas Co	Muskogee	
Motor Gasoline Co	Muskogee	near Muskogee
Seaboard Oil & Gas Co	Muskogee	Okmulgee Co.
Stoutz Bros	Box 1433, Muskogee	near Muskogee
Childers Gasoline Co	Nowata	Nowata
Henderson Gasoline Co	Nowata	near Delaware
All-American Oil & Gas Co	816 Colcord Bldg., Oklahoma City	Healdton field
Triumph Gasoline Co	209 Mercantile Co., Oklahoma City	Okmulgee Co.
Kingwood Oil Co	316 Parkinson Bldg., Okmulgee	Okmulgee, Okla.
Kingwood Oil Co	316 Parkinson Bldg., Okmulgee	Weleetka, Okla.
Okmulgee Prod. & Ref. Co	505 S. Boulder Ave., Okmulgee	Bartlett, Okla.
Okmulgee Prod. & Ref. Co	505 S. Boulder Ave., Okmulgee	Kusa, Okla.
Bluff Gasoline Co	Sapulpa	Sapulpa
Brighton Gasoline Co	Berryhill Bldg., Sapulpa	near Sapulpa
Akin Gasoline Co	503 Exchange Natl. Bank Bldg., Tulsa	Bartlesville
Akin Gasoline Co	503 Exchange Natl. Bank Bldg., Tulsa	Bartlesville
Akin Gasoline Co	503 Exchange Natl. Bank Bldg., Tulsa	Bixby
Benmo Oil Co	420 S. Cheyenne St., Tulsa	Bald Hill
Bixby Gasoline Co	Tulsa	near Bixby
Boynton Gasoline Co	Kennedy Bldg., Tulsa	near Tulsa
Chestnut & Smith Corporation	306 Exchange Natl. Bank Bldg., Tulsa	Okla., Kas. & Texas
Cloco Gasoline Co	401-15 Unity Bldg., Tulsa	Shamrock, Okla.
Clover-Dietz Gas Co	409 Unity Bldg., Tulsa	Mohawk, Okla.
Consumers Oil & Refining Co.	Tulsa	Broken Arrow
Cosden & Co	Tulsa	Stone Bluff
Cosden & Co	Tulsa	Cushing field
Cosden & Co	Tulsa	Garber field
Elliott, W. C	420 Palace Bldg., Tulsa	Sperry, Okla.
Gilliland Oil Co	First National Bank Bldg., Tulsa	Cushing
Gilliland Oil Co	First National Bank Bldg., Tulsa	Shamrock
Gilliland Oil Co	First National Bank Bldg., Tulsa	Oilton
Gilliland Oil Co	First National Bank Bldg., Tulsa	Drumright
Gillilnad Oil Co	First National Bank Bldg., Tulsa	Bigheart
Gilliland Oil Co	First National Bank Bldg., Tulsa	Burkburnett, Tex.
Gilliland Oil Co	First National Bank Bldg., Tulsa	Homer, La.
Highway Oil Refining Corp	207-8-9-10-11 Lynch Bldg., Tulsa	Red Fork, Okla.
Highway Oil Refining Corp	207-8-9-10-11 Lynch Bldg., Tulsa	Jenks
Highway Oil Refining Corp	207-8-9-10-11 Lynch Bldg., Tulsa	Leonard
Highway Oil Refining Corp	207-8-9-10-11 Lynch Bldg., Tulsa	Broken Arrow
Highway Oil Refining Corp	207-8-9-10-11 Lynch Bldg., Tulsa	Okmulgee (2)
Highway Oil Refining Corp	207-8-9-10-11 Lynch Bldg., Tulsa	Beggs (3)
Highway Oil Refining Corp	207-8-9-10-11 Lynch Bldg., Tulsa	Kellyville
Hope Gasoline Co	1005-13 Kennedy Bldg., Tulsa	Turkey Mountain
Hygrade Pet. & Gasoline Co.	1005-13 Kennedy Bldg., Tulsa	Stone Bluff
Hygrade Pet. & Gasoline Co.	1005-13 Kennedy Bldg., Tulsa	(Wagoner Co.)
Hygrade Pet. & Gasoline Co.	1005-13 Kennedy Bldg., Tulsa	Bird Creek pool
Hygrade Pet. & Gasoline Co.	1005-13 Kennedy Bldg., Tulsa	Avant (Osage Co.)
Hygrade Pet. & Gasoline Co.	1005-13 Kennedy Bldg., Tulsa	Hogshooter pool
Hygrade Pet. & Gasoline Co.	1005-13 Kennedy Bldg., Tulsa	(Bartlesville)

CASINGHEAD GASOLINE MANUFACTURERS (Continued)

OKLAHOMA

Name	Address	Plant
Hygrade Pet. & Gasoline Co.	1005-13 Kennedy Bldg., Tulsa	Sedan, Kas.
Indian Gasoline Co	538-9 Kennedy Bldg., Tulsa	Osage Co., Okla.
Jefferson Gasoline Co	Tulsa	Cushing field
Kadashen Gasoline Co	501 Palace Bldg., Tulsa	
Liquefied Petroleum Gas Co	10th floor Kennedy Bldg., Tulsa	Chelsea, Okla. (3)
Livingston Refiners Corp	Tulsa	Bixby
McMan Oil & Gas Co	Drew Bldg., Tulsa	Burkburnett, Tex.
Magna Oil & Ref. Co	Kennedy Bldg., Tulsa	
Midco Gasoline Co	Midco Bldg., Tulsa	Adair, Okla.
Midco Gasoline Co	Midco Bldg., Tulsa	Dewey
Midco Gasoline Co	Midco Bldg., Tulsa	Oilton
Mileage Gasoline Co	201-2 Kennedy Bldg., Tulsa	Bartlett, Bald Hill, Red Fork
Moon Gasoline Co	Tulsa	Bixby field
Nowata Oil & Ref. Co	206-8 Cheyenne Ave., Tulsa	
Oil State Gasoline Co	407 Kennedy Bldg., Tulsa	Jenks & Beggs
Oklahoma Central Oil Co	Tulsa	
Okla. Petrol. & Gasoline Co	First National Bank Bldg., Tulsa	Bixby, Broken Arrow, Chelsea, Cleveland, Glenn Pool, Haywood, Spur, Jenks, Mohawk, Wateva, Standard Spur, Stone Bluff.
Okla. Prod. & Ref. Corp	O. P. & R. Bldg., Tulsa	
Old Dominion Oil Co	810-13 Mayo Bldg., Tulsa	Yale, Okla.
Olsan Bros	Tulsa	Broken Arrow
Pleasant Hill Oil Co	318-9 Cent. Natl. Bank Bldg., Tulsa	Drumright
Revere Oil Co., Ltd	213½ S. Boston St., Tulsa	
Samallen Oil Co	502 Exchg. Natl. Bank Bldg., Tulsa	Bixby Dewey, Bartlesville
Sapulpa Refining Co	Sapulpa	Drumright
Scaw Oil Co	Tulsa	Tulsa field
Sinclair Oil & Gas Co	Sinclair Bldg., Tulsa	
Stebbins Oil & Gasoline Co	Box 1970, Tulsa	Inola and Boynton
T. B. Gasoline Co	First National Bank Bldg., Tulsa	Nowata field
Tidal Gasoline Co	602 S. Cheyenne S7., Tulsa	Delaware, Nowata Ochelata, Drumright
Totem Gasoline Co	Tulsa	Jenks
Triangle Pet. & Gas. Co	Tulsa	near Bixby
Tulsa Gasoline Co	Bank of Commerce Bldg., Tulsa	Glen Pool
Victor Gasoline Co	Tulsa	Cushing field
Walker, P. G., Jr	307 Cosden Bldg., Tulsa	Boynton
Western Oil Corporation	504 Cosden Bldg., Tulsa	Burkburnett, Tex.
Harris, W. A. and J. A	Wagoner, Okla	Wagoner

PENNSYLVANIA

Name	Address	Plant
Bradford Oil & Gasoline Co	287 Congress St., Bradford	Bell's Camp
Gilmore Gasoline Co	Bradford	Gilmore, Pa.
Gilmore Gasoline Co	Bradford	Wafferty Hollow
Jefferson Gasoline Co	43 Main St., Bradford	Limestone, Ohio
Kane Gasoline Co	101 Main St., Bradford	Kane, Pa.
Pennsylvania Gasoline Co	9 Main St., Bradford	Bradford, Pa.
Pennsylvania Gasoline Co	9 Main St., Bradford	Bolivar, B. Y
Sloan & Zook Co. of Ohio	101 Main St., Bradford	Carrollton, Ohio
Stroud, B. B. Co	130 Main St., Bradford	Coleville, Pa.
Warren Gasoline Co	101 Min St., Bradford	Eldred, Pa.
Vogt, C. J	Bruin, Pa	Bruin, Pa.
Johnson & Dunlap	Chicora, Pa	Chicora, Pa.
Highland Oil Co.	Clarion, Pa	
Home Gas Co	Clarion, Pa	
Jane Oil Co	Emlenton, Pa	Emlenton, Pa.
Barte & Snow	Karns City, Pa	Butler Co. Pa.
Crawford Oil & Gas Co	Meadville	Friendly, W. Va.
Casinghead Gas Co	Oil City	Oil City
Sun Company	Finance Bldg., Philadelphia	
Guffey-Gillespie Oil Co	Union Bank Bldg., Pittsburgh	Billings, Okla.

CASINGHEAD GASOLINE MANUFACTURERS (Concluded)

Name	Address	Plant
	PENNSYLVANIA	
Hope Natural Gas Co	424 Sixth Ave., Pittsburgh	West Virginia
Imperial Oil & Gas Prod. Co.	1106 Union Bank Bldg., Pittsburgh	Hannahdale, W.Va.
Laughner, E. E	1107 Standard Life Bldg., Pittsburgh	near Ambridge, Pa.
Manufacturers Light & Heat Co.	248 Fourth Ave., Pittsburgh	West Virginia
Ohio Fuel Oil Co	2017 Farmers Bank Bldg., Pittsburgh	West Virginia
Penn. Mex. Fuel Co	424 Sixth Ave., Pittsburgh	Tuxpan, Mex.
Showalter, J. B	Pittsburgh	Butler Co., Pa.
Transcontinental Oil Co	Benedum-Trees Bldg., Pittsburgh	
Wayne Naphtha Co	308 Columbia Bk. Bldg., Pittsburgh	near Waynesburg, Pa.
Haskell, H. H	Pleasantville	Venango and Warren County, Pa.
Deerlick Oil Co	Russell	
Wolcott Gas Co	Shinglehouse	Shinglehouse, Pa.
Tidioute Refining Co	Tidioute	Warren Co., Pa.
Warren Oil Co., of Pa	Warren, Pa	Henrys Mills, Pa.
Henry Farm Oil Co	Warren, Pa	Warren
Pavania Oil Co	Warren, Pa	
Sayre, J. J	West Sunbury	Forest Co., Pa.
	TEXAS	
DeSoto Gasoline Co	P. O. Box 929, Beaumont	Goss, La., Muskogee and Wann, Okla.
Higgins Oil & Fuel Co	Beaumont	Caddo, La.
Lone Star Gas Co	Fallas	Petrolia, Tex.
Panhandle Refining Co	1412 Royal St., Dallas	
Phoenix Oil Co	411 F. & M. Bank Bldg., Ft. Worth	Erath Co., Tex.
Higgins Oil & Fuel Co	Scanlan Bldg., Houston	Daddo Field, La.
Humble Oil & Ref. Co	Coggan Bldg., Houston	Iowa Park, Healdton, Okla.
Bartles & Jones	P. O. Box 84, Ranger	Ranger District
Ranger Gulf Corp	Ranger	Burkburnett, Tex.
Grayburg Oil Co	Box 1097, San Antonio	Somerset, Tex.
Internat'l Petroleum Co	234 Bedell Bldg., San Antonio	White Point, Tex.
	UTAH	
Utah-Wyoming Consol. Oil Co.	McIntyre Bldg., Salt Lake City	Byron, Wyo.
	WEST VIRGINIA	
Transylvania Oil & Gas Corp.	Day and Night Bldg., Huntington	Lawrence Co.
O'Brien, Wm	New Cumberland—same	
Petterson Bros. Co	Parkersburg	Elizabeth, W.Va.
Robert Bros	Parkersburg	Burning Spring, W. Va.
McKelvy Oil & Gas Co	Sisterville	West Virginia
LaSalle Oil & Gas Co	93 11th St., Wheeling	Jefferson Co.
Penn.-Ky. Oil & Gas Ref. Corp.	City Bank Bldg., Wheeling	Hancock Co., W.Va.
	WYOMING	
Enalpac Oil & Gsa Co	Casper	Mineral Wells, Desdemona and Burkburnett, Tex.

STANDARD OIL CO. (N. J.) AND SUBSIDIARIES CONSOLIDATED GENERAL BALANCE SHEET.

DEC. 31, 1918.

Assets.

Total value of plant, stable and floating equipment (less depreciation)		$249,827,931.92
Stock in other companies		23,009,449.64
Government bonds and other investment securities	$ 93,452,369.77	
Inventories of merchandise	160,505,280.15	
Accounts receivable	151,320,085.90	
Cash	13 201,851.66	
		418,479,587.48
Total assets		$691,316,969.04
Less accounts payable	$116,816,714 77	
Marine insurance reserves	11,957,228.46	
		128,773,943.23
Net value		$562 543,025.81

Nominal Liabilities.

Capital stock	$ 98,338,300 00
Reserve for annuities	492,315.84
Surplus including reserve for working capital	463,712,409.97
	$562,543,025 81

STATEMENT OF EARNINGS AND DIVIDENDS FOR THE YEARS 1912-1918 INCLUSIVE, WITH INCOME AND WAR TAXES DEDUCTED FROM THE EARNINGS OF THE YEAR ON WHICH SAME WERE CALCULATED. (S. O. Co.)

Year	Earnings Before Deducting Federal Taxes	Federal Taxes Paid and Accrued	Earnings After Deducting Federal Taxes	Dividends Paid
1912	$35,397,717.37	289,830.33	$35,107,887.04	19,667,660
1913	46,168,955 06	7,085.57	45,691,869.49	*59,002,980
1914	31,898,849.62	341,215.45	31,457,634.17	19,667,660
1915	61,396,922.73	619,679.39	60,777,243.34	19,667,660
1916	72,426,692.36	1,634,633.19	70,792,059.17	19,667,660
1917	105,785,858 91	25,019,916.97	80,765,941.94	19,667,660
1918	101,611,113 84	†44,330,359.15	57,283,784.69	19,667,660

*Under "Dividends paid" for the year 1913 there is included the distribution of $10 per share made from repayments by former subsidiaries of cash which had previously been advanced by this company.

†1918 taxes subject to adjustments.

BY-PRODUCT COKE PLANTS IN UNITED STATES AND CANADA (BENZOL PRODUCERS).

OWNER OR OPERATOR	LOCATION	Coal Used	Coke Made
Calhoun Gas Co	Battle Creek, Mich	36,000	25,300
Ford Motor Co	Detroit, Mich	864,000	622,000
Semet-Solvay Co	Detroit, Mich	1,343,300	1,009,000
Michigan Light Co	Flint, Mich	96,400	67,500
Michigan Light Co	Kalamazoo, Mich	43,800	30,700
Michigan Alkali Co	Wyandotte, Mich	94,000	65,800
Minnesota Steel Co	Duluth, Mich	600,000	450,000
Zenith Furnace Co	Duluth, Minn	200,000	144,000
Minnesota By-Products Coke	St. Paul, Minn	380,000	273,600
Laclede Gas Light Co	St. Louis, Mo	320,000	240,000
Camden Coke Co	Camden, N. J	360,000	252,000
Seaboard By-Product Coke Co	Jersey City, N. J	340,500	255,350
Seaboard By-Product Coke Co	Jersey City, N. J	681,000	510,700
Semet-Solvay Co	Buffalo, N. Y	386,000	289,500
Empire Coke Co	Geneva, N. Y	146,000	102,200
Solvay Process Co	Syracuse, N. Y	65,000	45,000
Dominion Iron & Steel Co	Sydney, N. S	720,000	518,400
Dominion Iron & Steel Co	Sydney, N. S	1,664,000	1,198,080
Nova Scotia Steel & Coal Co	Sydney Mines	159,000	110,000
Dover By-Products Coke Co	Canal Dover, Ohio	120,000	87,600
United Furnace Co	Canton, Ohio	280,000	204,400
Cleveland Furnace Co	Cleveland, Ohio	450,000	337,500
River Furnace Co	Cleveland, Ohio	1,300,000	949,000
American Steel & Wire Co	Cleveland, Ohio	1,150,000	839,500
Hamilton Otto Coke Co	Hamilton, Ohio	240,000	168,000
Ironton Solvay Coke Co	Ironton, Ohio	432,000	270,000
National Tube Co	Lorain, Ohio	1,320,000	963,600
Portsmouth Solvay Coke Co	Portsmouth, Ohio	770,000	559,900
Toledo Furnace Co	Toledo, Ohio	560,000	408,800
Brier Hill Steel Co	Youngstown, Ohio	520,000	397,600
Republic Iron & Steel Co	Youngstown, Ohio	1,020,000	744,600
Youngstown Sheet & Tube Co	Youngstown, Ohio	1,300,000	949,000
Youngstown Sheet & Tube Co	Youngstown, Ohio	650,000	474,500
Steel Co. of Canada	Hamilton, Ont	342,000	260,400
Algoma Steel Co	Sault Ste. Marie, Ont	285,000	217,000
Algoma Steel Co	Sault Ste. Marie, Ont	681,000	510,700
Philadelphia Suburban Gas & Electric Co	Chester, Pa	125,000	87,500
Carnegie Steel Co	Clairton, Pa	4,000,000	2,800,000
Carnegie Steel Co	Clairton, Pa	800,000	560,000
Semet-Solvay Co	Dunbar, Pa	280,000	173,600
Carnegie Steel Co	Farrell, Pa	830,000	581,000
Allegheny By-Products Coke Co	Glassport, Pa	260,000	195,000
Jones & Laughlin Steel Co	Hazelwood, Pa	2,000,000	1,300,000
Cambria Steel Co	Johnstown, Pa	529,200	338,888
Cambria Steel Co	Johnstown, Pa	1,529,500	1,223,700
Bethlehem Steel Co	Lebanon, Pa	887,000	638,000
Bethlehem Steel Co	Steelton, Pa	375,000	270,000
Bethlehem Steel Co	Steelton, Pa	516,000	371,500
Lehigh Coke Co	South Bethlehem, Pa	2,400,000	1,920,000
Providence Gas Co	Providence Gas Co	240,000	172,800
Memphis Gas & Electric Co	Memphis, Tenn	59,000	41,300
Seattle Lighting Co	Seattle, Wash	48,600	29,200
Fairmount By-Products Co	Fairmount, W. Va	....	....
LaBelle Iron Works	Follansbee, W. Va	610,000	445,300
National Tube Co	Benwood, W. Va	270,000	189,000
Northwestern Iron Co	Mayville, Wis	320,000	230,400
Milwaukee Coke & Gas Co	Milwaukee, Wis	732,000	549,000
Northwestern Iron Co	Mayville, Wis	197,000	147,000
Chattanooga Coke & Gas Co	Chattanooga, Tenn	173,000	124,000

PETROLEUM PRODUCING COMPANIES OF TEXAS FOR 1921.

The following producing companies, partnerships and individuals operating in the state of Texas, by their sworn statements have reported to the Oil & Gas Department of the Railroad Commission, their gross oil production and value of same for the months of January, February and March, 1921.

Total production was 22,693,414.47 bbls. and the sales value of same, $48,032,959.11.

Number of companies, partnerships and individuals that have reported to date 680 as against 709 for the last quarter of 1920.

The Humble Oil & Refining Co. of Houston for the first quarter of 1921 was first in production, 3,766,622 bbls., value $6,943,956. The Texas Co. was second in value, $5,404,692 and third in production, 2,608,512 bbls. The Gulf Production Co. third in value, $5,026,030 and second in production, 2,783,376 bbls.

For the last quarter 1920, the Texas Co. was first in production, 4,072,104 bbls, value $12,805,648. Gulf Production Co. was second, 2,742,108 bbls., value $8,661,216. Humble Oil & Refining Co. was third with 2,954,747 bbls., value $8,213,768.

Total production in the last quarter of 1920 was 23,689,504 bbls. valued at $76,168,108.

Company	Location
Acorn Oil Co.	Beaumont
American Texas Oil Co.	Somerset
Apple, C. B.	Wichita Falls
Apple, S. A., E. Dunlap & Sykes	Ardmore, Okla.
Apple, Dunlap & Claude Bell	Ardmore, Okla.
Arcade Oil Co.	Beaumont
Arkansas-Texas Co.	Little Rock, Ark.
American Refining Co.	Wichita Falls
Andover Texas Oil & Drilling Co.	Wellsville, N. Y.
Armstrong, Jas. R.	Wichita Falls, N. Y.
Adams Oil Co.	Wichita Falls, N. Y.
Ashley & Ashley	McKinney
Atlantic Oil Co.	Philadelphia, Pa.
Argonaut Oil Co.	Fort Worth
Associated Oil Co.	Wichita Falls
Amalgamated Oil Co.	Houston
A No. 1 Oil Co.	Lawton, Okla.
Ada Belle Oil Co.	Independence, Kas.
Adams, D. C.	Aurora, Mo.
Ajax Oil Co.	Dallas
Arizona-Braden Oil Co.	Dallas
Anna Belle Oil Co.	Fort Worth
American Oil Engineering Corporation	Fort Worth
Alico Oil Co.	Tulsa, Okla.
All-American Oil & Gas Co.	Oklahoma City, Okla.
American Consolidated Oil Co.	Oklahoma City, Okla.
Antilley, J. H.	Sour Lake
Altex Petroleum Co.	New York City, N. Y.
Arkansas Natural Gas Co.	Pittsburgh, Pa.
Allies Oil Co.	Wichita Falls
Benton, Mrs. Bessie Y.	Houston
Breckenridge Crude Oil Syndicate	Breckenridge
Block 31 Oil Syndicate	Breckenridge
Broderick, A. J.	New York City, N. Y.
Bashara, M. J.	Wichita Falls
Barkley & Meadows	Wichita Falls
Burnett-Van Cleave Oil Co.	Wichita Falls
Wm. Bartlett Co.	Electra
Bell Bros. & McDonald	Eastland
Birkeland, K. B.	Humble
Baker Oil Co. of Houston	Houston
Burgess, Burgess, Chrestman & Brundidge	Dallas
Bradley Co.	Fort Worth
Burk Venus Oil Co.	Dallas
Brock Lundy Oil Co.	Bowie
Buchanan, S. R.	Batson
Bullington, Orville	Wichita Falls
Bell Burke Oil Co.	Waco
Brooks & Strong	Breckenridge
Bass Petroleum Co.	Houston
Birkeland, K. B.	Minneapolis, Minn.
Buffalo-Texas Oil Co.	Buffalo, N. Y.
Burk Noel Oil Co.	Wichita Falls
Bell Burke Oil Co.	Waco
Big Four Oil Co.	Wichita Falls
Belen Oil Co.	Belen, N. M.
Burkburnett Oil Co.	Custer City, Okla.
Geo. Beggs Oil Co.	Fort Worth
Bowers & Witherspoon	Palestine
Beverly Oil Co.	Wichita Falls
Bryan Oil Corporation	Wichita Falls
Big Pool Oil Co.	Wichita Falls
Bailey-Winkler Oil & Gas Co.	Breckenridge
Burk-Mack Oil Co.	Sheridan, Ind.
Breckenridge Production Co.	Breckenridge
Blue Bonnet Petroleum Co.	San Antonio
Brinkley Petroleum & Refining Co.	Wichita Falls
Biggs Oil & Gas Co.	McKinney
Bass & Dillard	Wichita Falls
Bexata Oil Co.	San Antonio
Bowen Olympic Oil Co.	New York City, N. Y.
B. B. Oil Co.	Electra
Bessley, Lincoln & McDonald	Electra
Brooks Producing Co. No. 1	Wichita Falls

PETROLEUM PRODUCING COMPANIES OF TEXAS FOR 1921. (Continued)

Company	Location
Brown & Co., Inc	Dallas
B. O. O. G. Oil Co	Iowa Park
Barkley, T. G	Sour Lake
Bankers & Merchants Petroleum Co	Fort Worth
Belle City Oil Co	Wichita Falls
Big 4 Consolidated Oil Co	El Paso
Big John Oil Co	Beaumont
Bower & Dillard	Wichita Falls
Brown, Geo. I	San Antonio
Buckeye Development Co	Columbus, Ohio
Burney, I. H	San Antonio
Castles Oil Co	Corsicana
Chapman, O. H	Waxahatchie
Caldwell Oil Co	Oklahoma City, Okla
Commercial Petroleum Co	San Antonio
Castell Oil Co	Houston
Cooper, Henderson & Martin	Breckenridge
Continental Oil & Refining Co	Tulsa, Okla.
Cactus Oil Co	Fort Worth
Crown Oil & Refining Co	Houston
Corsicana Oil & Refining Co	Corsicana
Clara Oil Co	Wichita Falls
Cornucopia Oil Co	Fort Worth
Centerfield Oil Co	Wichita Falls
C. A. L. Oil Co	Eastland
Connell, W. E	Fort Worth
Cohen & Lebow	Wichita Falls
Christian, W. G	Houston
Crescent Oil Co	Wichita Falls
Cezreaux & Martin	Humble
Craven Oil & Refining Co	Jakehamon
Clint Woods Oil Corporation	Wichita Falls
Consolidated Oil Co	Cisco
Crosbie, T. S	San Antonio
Crystal Oil Corporation	Denver, Colo.
Crosbie, J. E	Tulsa, Okla.
Comanche Northern Oil Co	Fort Worth
Chappell Oil Co	Denver, Colo.
Champlin & Winkler (T. & P. Co.)	Thurber
Cheley, W. J	Denver, Colo.
Continental Petroleum Co	Dallas
Considine-Martin Oil Co	San Francisco, Calif.
Central Texas Oil & Gas Association	De Leon
Crowell, L. R	Dallas
Carteret Oil Co	Fort Worth
Caroline Oil Co	Nacogdoches
Central Oil Development Co	Cisco
Chapman, P. A., Jr	Eastland
Consolidated Producing Co	Fort Worth
C. H. R. C. Oil Co	Breckenridge
Cooper-Henderson Oil Co	Breckenridge
Cline Oil Co	Wichita Falls
Camp Oil & Gas Co	Fort Worth
Chenault, N. B	Wichita Falls
Crosbie, J. E	Tulsa, Okla.
Cabiness, C. C	Wichita Falls
Canadian Park Oil Co	Canadian
C. Y. T. Oil Co	Beaumont
Cedar Creek Oil Co	Houston
Clem Oil Co., Inc	Houston
Colorado Oil & Gas Co	Denver, Colo.
Comanche Duke Oil Co	Fort Worth
W. F. Corts Drilling Co	Columbus, Ohio
Cosden Oil & Gas Co	Tulsa, Okla.
Cosa, Aubrey N	Corsicana
Dale-Knotts Oil Co	Wichita Falls
Duggan Oil Co	Dallas
Duke of Dublin Oil Co	Fort Worth
Daniel, W	Wichita Falls
Developers Oil & Gas Co	Wichita Falls
Davis, L. R	Tulsa, Okla.

Company	Location
Deibel Oil Co	Thrall
Dale, E. A. (Perkins lease)	Electra
Dominion Oil Co	Wichita Falls
Danciger, M. O	Wichita Falls
Double Standard Oil Co	Wichita Falls
Dayton Oil Co	Dayton, Ohio
Dennie Roberts Oil Co	Wichita Falls
Duqueane Oil Co	Eastland
Deep Sand Oil & Gas Co	Corsicana
Deshler Oil & Refining Co	Breckenridge
Denver Petroleum Co	Denver, Colo.
Dalso Oil Co	Mineral Wells
Doodlebug Oil Co	Sour Lake
Elm Hill Oil Co	Corsicana
Ellis & Anderson	San Antonio
Ennis Oil & Development Co	Ennis
Economy Oil Co	Fort Worth
Erie Gas & Oil Co	Huntington, Ind.
Eddy Oil Co	Guffey
Eagle Petroleum Co	Houston
Eaton, E. E	Electra
Emerick Oil Co	Wichita Falls
Empire Texas Oil Co	Brocton, N. Y.
Ellis, Thos S	San Antonio
East Batson Oil Co	Batson
Eldorado Oil & Gas Co	Ranger
Empire Gas & Fuel Co	Bartlesville, Okla.
Evangeline Oil Co	Brockton, N. Y.
Elliott, Jones & Co., Inc	San Antonio
Foster, H. V., et al	Bartlesville
Fensland Oil Co	Fort Worth
Ferris-Seay Co	Wichita Falls
Fisher & Gilliland	Wichita Falls
Flynn-Tuttle Oil Co	Electra
Fern Glen Oil Co	St. Louis, Mo.
Frontier Oil Co	San Antonio
Fisher-Parker Oil Co	Wichita Falls
Four & Four Oil Co	Dallas
Franklin, J. M., et al	Wichita Falls
Fox & Lamb Drilling Co	Brownwood
Fidelity Oil Corporation	Louisville, Ky.
Freedman, Alex	Corsicana
Fowler, M	Wichita Falls
Ferguson Wells No. 1 and No. 2	Wichita Falls
Forest Oil Co	Wichita Falls
Fisher, Gates & Co	Wichita Falls
Fiver Rivers Oil & Gas Co	Wichita Falls
Franklin, Wirt	Ardmore, Okla.
Farish & Ireland lease	Houston
Farmer, Robt	Wichita Falls
Ferguson, C. J	Wichita Falls
Foster & Allen lease	Wichita Falls
Foster & Watson	Wichita Falls
Federal Oil Co	Cleveland, Ohio
Freene Oil Co	Wichita Falls
Farquherson Oil Co	Wichita Falls
Findley-Minnick Oil & Gas Co	Benjamin
Forty-One Oil Co	Wichita Falls
Fletcher Oil Co	Wichita Falls
Gulf Production Co	Houston
Gabler & Brannon	Eastland
Gladstone Oil & Refining Co	Fort Worth
Galvez Oil Corporation	New York City
Galloway Consolidated Oil Co	Fort Worth
Gwynn, O. F. (trustee)	Iowa Park
Gilbert Co	Beaumont
Golconda Oil Co., No. 2	Wichita Falls
Gonzales Creek Oil Co	Houston
Goose Creek Oil Corporation	Houston
Gotham Oil Association	Fort Worth
Gatewood Oil Co	Ennis
Glenridge Oil Corporation	St. Louis, Mo.

PETROLEUM PRODUCING COMPANIES OF TEXAS FOR 1921.
(Continued)

Company	Location
Grisdale, J. A.	McIntyre, Iowa
Glasscock Leasing Syndicate	San Antonio
Griswold Oil Co	Wichita Falls
Golden Cycle Oil Co	Dalhart
Gatewood Oil Co	Ennis
Galvez-Burk Petroleum Co	Galveston
Gulf Coast Oil Corporation	Houston
Gates Oil Co	Ardmore, Okla.
Gohlke & Gerard	Wichita Falls
Great States Petrol. Co. of Texas	Dallas
Getzier, W. F.	Burkburnett
Gladiolus Oil Co	Wichita Falls
Gooch & Davis Tract No. 1	Lawton, Okla.
Gooch & Davis Tract No. 2	Lawton, Okla.
Guffey-Gillespie Oil Co	Pittsburgh, Pa.
Golconda Oil Co. No. 1	Wichita Falls
Gilliland Oil Co	Tulsa, Okla.
Godfrey, F. L.	Enid, Okla.
Glenridge Oil Corporation	St. Louis, Mo.
Gallagher & Lawson	Desdemona
Gladys Belle Oil Co	Tulsa, Okla.
Grayburg Oil Co	San Antonio
Grand Duke Oil Co	Fort Worth
Greater Breckenridge Oil Co	Breckenridge
Galena Signal Oil Co. of Houston	Houston
Gutzler & Cottingham	Bluffton, Ind.
Gates, T. M.	Wichita Falls
Guaranty Oil & Gas Co	Breckenridge
Granite Oil Co	Electra
Houston & Welch	Abilene
Hoo Hoo Oil Co	Burkburnett
Herren, H. H.	Breckenridge
Humble Oil & Refining Co	Houston
Hamon, Jake L.	Ardmore, Okla.
Harvey, R. O.	Wichita Falls
Harvey Oil Co	Wichita Falls
Hawkins, W. L.	Wichita Falls
Hefmeir & Deegans	Dallas
Hunt, J. C.	Wichita Falls
Halmack Oil Co	Dallas
Houseman, H. D. Co	Dallas
H[illegible] Oil & Fuel Co	Houston
Hyde, Geo.	Houston
Hill & Jones	Burkburnett
H[illegible]ley & Vrooman	Electra
Hal[illegible]day & Caffell	Beaumont
High-Land Oil & Gas Co	Electra
Houston Oil Co. of Texas	Houston
Helvetia Copper Oil Co	San Antonio
Hub Oil Co	Dallas
Houston Production Co	Houston
Hayman Krupp	New York City
Harrell, Jas. G. (attorney)	Breckenridge
Harrison & Dale	Wichita Falls
H[illegible] Meyers Trust	Wichita Falls
H[illegible] Oil & Gas Co	Marlow
Henderson, F. G.	Nowata
H[illegible] Bros	Brownwood
Hereford Oil Co	Electra
H[illegible] O'Rourke Constr. Co	Dallas
H[illegible] & Wertheimer	Ardmore, Okla.
H[illegible] Krupp	New York City
I[illegible] Oil Co	Fort Worth
Iowa Park Producing Co	Iowa Park
[illegible] Oil Co	Wichita Falls
I[illegible] Oil & Gas Development Co.	Duluth, Minn.
I[illegible] Oil Co	Wichita Falls
I[illegible] Petroleum Co	Plainview
I[illegible] A. G.	Fort Worth
I[illegible] Oil Co	New York City
I[illegible] Oil & Refining Co	Muskogee, Okla.
Ja[illegible] Oil Co	Tulsa, Okla.
Jones, Thos. H.	Cleveland, Ohio
Japhet & Sutherland	Houston
Jones Light Petroleum Co	Pilot Point
John & Jeff Oil Co	Wichita Falls
Julia Oil Co	Sour Lake
Jackson, J. S. (trustee)	Sour Lake
Jackson Co	San Antonio
Jeffers, S. L.	San Antonio
Jefferson Oil Co	Dallas
Kemp-Munger-Allen Oil Co	Wichita Falls
Kein, Frank D.	Wichita Falls
Kerr, T. P.	Corsicana
Koons Dell	Tulsa, Okla.
King Petroleum Co	Wichita Falls
Keoury Mike	Waco
Knotts, F. F.	Wichita Falls
Keen & Woolf Co	Shreveport, La.
Kirby, Harper R.	Austin
Kansas City Petroleum Co	Wichita Falls
Kepley & Bright	Wichita Falls
Kavanaugh Petroleum Co	Houston
Kemp, G. G.	Vernon
Kentucky River Oil Co	Fort Worth
Keystone Drilling Co	De Leon
Kauth Oil Co	Wichita Falls
King Petroleum Co	Milwood, West Va.
Keever & Gordon Oil Co	Sour Lake
Kansas Gulf Co	Chicago, Ill.
Kurz Oil Co	Somerset
Lincoln Oil Co	Electra
Levely-Maxwell Oil Co	Wichita Falls
Lesh Bros. Oil Co	Wichita Falls
LaRue Oil Association	Electra
Long, Taylor & Thomas	Houston
Lou Ellen Oil Co	Denison
Lone Star Gas Co	Dallas
Lowe Oil Co	De Leon
Little Wonder Oil Co	Bowling Green, Ky.
P. J. Lee & Co	Wichita Falls
Le Sil Oil Corporation	Wichita Falls
Lucky Seven Oil Co	Wichita Falls
Lockhart, Parker & Glasscock	Ranger
Landreth, E. A. Co	Breckenridge
Lawton Oil Co	Lawton, Okla.
Lowry Oil Corporation	Muskogee, Okla.
Liberty Petroleum Co	Wichita Falls
Lone Star Oil Co	Burkburnett
Lake Oil Co	Beaumont
Louisiana-Stephens Oil Corporation	Fort Worth
Lake View Oil Co	Sour Lake
Lincoln McDonald Oil Co	Electra
Mahon, P. J. (receiver)	Beaumont
Manhattan Oil & Refining Co.	Wichita Falls
Marathon Oil Co	San Antonio
Martin Oil Co	Beaumont
Mary D. Oil Co	Sherman
Mennis, G. W.	Wichita Falls
Minor Oil Co	Beaumont
Montour Oil Co	Pittsburgh, Pa.
Mooney, L. E. (trustee)	Wichita Falls
McDonald Oil & Gas Co.	New Middleton, Ohio
McDowell, H. B.	El Paso
Mid-Kansas Oil & Gas Co	Findlay, Ohio
Moore & McKinney	Houston.
Mutual Oil Co	LaPorte
Miller, Herbert G.	Eastland
Medina Oil & Gas Co	San Antonio
Mook Texas Co	Fort Worth
Maer & Shappell	Wichita Falls
McDorman, C. R.	Ardmore, Okla.
Montrose Oil Ref. Co	Fort Worth
Montrose Oil Ref. Co	Fort Worth

PETROLEUM PRODUCING COMPANIES OF TEXAS FOR 1921.
(Continued)

Company	Location
McMan Oil & Gas Co.	Tulsa, Okla.
Margay Oil Corporation	Tulsa, Okla.
McBan Oil Co.	Wichita Falls
McAllister & Brown	Wichita Falls
McKenzie Oil Co.	Wichita Falls
Monarch Oil & Refining Co.	Houston
Metropolitan Oil Co.	Houston
Maxon Oil Co.	Wichita Falls
Mary Elizabeth Oil Co.	Dallas
Morris & White	Carbon
Matador Oil & Gas Co.	Quannah
Murphy Oil Co. of Pa.	Thrall
Mesquite Oil Co.	Fort Worth
Meyers, Green, Wilson & Brannon	Wichita Falls
Mitcham & Morrison	Fort Worth
Majestic Oil & Refining Co.	Wichita Falls
McLain Oil & Coal Co.	Columbus, Ohio
McCamey, Geo. B.	Cross Plains
Mildren Oil Co.	Lexington, Ky.
Marnet Oil & Gas Co.	Pittsburgh, Pa.
Moore, Edward T.	Dallas
Martin, G. A.	Humble
Mann & Ilseng (W. L. Mann)	Wichita Falls
Mann-McPahil Oil Co.	Wichita Falls
Mann-Power Oil Co.	Wichita Falls
Mann Oil Co.	Wichita Falls
M. & P. Burke Extension Oil Co.	Lawrence, Kansas
Moore, N. A.	Eastland
Moore, F. L.	Tulsa, Okla.
Madden & Madden	Rising Star
Mahlstedt-Mook Oil Co.	Fort Worth
McNamara Oil Co.	Beaumont
Minutex Oil Co.	Wichita Falls
Mitchell Producing Co.	Fort Worth
Mackenzie Oil Co.	Fort Worth
M & V Tank Co.	Wichita Falls
McGoldrick, E. W.	Batson
Morrissey, Thos. & Heydrick, L. A.	Dallas
Monarch Petroleum Co.	Dallas
Mayfield, Jos. L. Oil Co.	Wichita Falls
McQuaid, M. W.	Fort Worth
Magnolia Petroleum Co.	Dallas
Mack, Theodore	Fort Worth
Markham, John H., Jr. & Tidal Oil Co. (T & P)	Thurber
Nutt, Horace	Austin
New Domain Oil & Gas Co.	Dallas
Northwest Oil & Gas Co.	Wichita Falls
Nineteen Oil Co.	Beaumont
Nortex Drilling & Development Co.	St. Louis, Mo.
Necona Burk Oil Co.	Burkburnett
North American Oil & Ref. Corporation	Oklahoma City, Okla.
Nutt, Horace	Austin
North Texas Oil Co.	Vernon
Norton & Cline	Wichita Falls
Number 77 Oil Co.	Wichita Falls
Northwest Burk Oil & Gas Co.	Lawton, Okla.
Noble, Chas. F.	Wichita Falls
Natural Oil Co.	Wichita Falls
Nineteen Oil & Gas Co.	Wichita Falls
Nortex Drilling Co.	St. Louis, Mo.
Oil Dominion Oil Co.	Houston
Oriental Oil Co.	Dallas
O'Neill, H. A.	Wichita Falls
Odell Oil Co.	Wichita Falls
Oil Development Co.	St. Louis, Mo.
Oktaha Co.	Tulsa, Ok.
Old Colony Oil Co.	Dayton
Owen, Burkett & Wheeler	Mineral Wells
Oil Development Co.	St. Louis, Mo.
Old Colony United Oil Co.	Wichita Falls
Osage Production Co.	Wichita Falls
Otex Oil Co.	Columbus, Ohio
Okla. Prod. & Ref. Corp. of America	Tulsa, Okla.
Okla. Petroleum & Gas Co. of Texas	Tulsa, Okla.
Old Dominion Oil Co.	Wichita Falls
Ohio Fuel Oil Co.	Pittsburgh, Pa.
Plateau Oil Co.	Fort Worth
Planet Petroleum Co.	Fort Worth
Pennok Oil Co.	Tulsa, Okla.
Petroleum Development Co.	Wichita Falls
Primrose Oil Co.	Houston
Placid Petroleum Co.	Wichita Falls
Powell, J. L.	Wichita Falls
Perkins, J. J.	Wichita Falls
Pace, Geo. L.	Dallas
Palmer Oil Co.	Henrietta
Chas. Paggi & Co.	Saratoga
Portland-Texas Oil Co.	Wichita Falls
Paraffine Oil Co.	Beaumont
Pure Oil Co.	Columbus, Ohio
Phillips Bros.	Beaumont
Priddy, W. M.	Wichita Falls
Patton, H. H.	Fort Worth
Pierce Oil Corporation	New York City
Paradox Oil Co.	Wichita Falls
Paine Oil & Refining Co.	Houston
Pioneer Oil Corporation	Wichita Falls
Prairie Oil & Gas Co.	Independence, Kansas
Patton, H. H.	Fort Worth
Panhandle Refining Co.	Dallas
Paris-Wichita Oil Co.	Paris
Pivoto, M. E.	Sour Lake
Pinto Oil Co.	Mineral Wells
Parker, Arthur G.	Eastland
Pippin Oil Co.	Brownwood
P & M Oil Co.	Houston
Pilot Point Oil & Gas Co.	Pilot Point
Pioneer Producing Co.	Wichita Falls
Porter, Works & Hicks	Wichita Falls
Southside Oil Co.	Wichita Falls
Staley, M. L.	Wichita Falls
Shackelford, F. L.	Wichita Falls
Strawn Petroleum Co.	Denver, Colo.
Silb-Erman Oil Co.	Wichita Falls
Schlicher Oil Co.	Sour Lake
Stephens Oil Co.	Sour Lake
San Diego Oil & Gas Co.	Alice
Sankey, John S.	Fort Worth
Speed, C. D.	Corsicana
Seibel Oil Co.	Wichita Falls
Seaystone Oil Co.	Wichita Falls
Simms, E. F. & Co.	Houston
Sink, Jeel	Corsicana
Southern Petroleum & Refining Co.	Houston
Standard Oil Land & Leasing Co.	Beaumont
Sure Pop Oil Co.	Dallas
Sterling Oil Co.	Titusville
States Oil Corporation	Eastland
Swensondale Oil Co.	Fort Worth
Shawmut Petroleum Corp., Inc.	Fort Worth
Shappell, T. O.	Wichita Falls
Stump Oil & Refining Co.	Burkburnett
Saxon Oil Co.	Sour Lake
Slaughter & Hutchinson	Bowie
Smoot, Geo. A.	Wichita Falls
Stull, R. O.	Wichita Falls
Shaffer-Mankin	Dallas
Stella Oil Co.	Beaumont
Spencer Petroleum Co.	Cisco

PETROLEUM PRODUCING COMPANIES OF TEXAS FOR 1921.
(Continued)

Company	Location
Snowden, Geo. M.	Wichita Falls
Sun Co	Beaumont
Stribling, J. C.	Houston
Star-Tex Petroleum Co	Wichita Falls
Sipe-Tex Oil Co	Moody
Security Oil Co	Breckenridge
Schutt, R. K	Wichita Falls
Silirian Oil Co	St. Louis, Mo.
Schram, J. F	Brenham
Simms Oil Co	Dallas
Somerset Oil Co	San Antonio
Sinclair Oil Co	Houston
Sextette Oil Co	Lawton, Okla.
Sixty-Six Oil Co	Wichita Falls
Seventy-Two Oil Co	Wichita Falls
Superior Oil Co	Superior, Wisc.
Scanlon & McCourtie	Dallas
Sioux Oil & Refining Co	Wichita Falls
San Bernard Oil Co	Beaumont
Southwestern Oil Development Co.	Eastland
Swastika Oil Co	Beaumont
Smith-Hess Oil Co	Cisco
Snowden & McSweeney Co	New York City
Seaboard Oil & Gas Co	Muskogee, Okla.
Silk, W. W	Wichita Falls
Streeter-Electra Oil Co	Streeter, N. Dak.
Snider, C. W	Wichita Falls
Standiford Bros	Iowa Park
Sutherland, W. C. & Cox, C. B.	Wichita Falls
Sun Co. (North Texas Division)	Dallas
Skelly Oil Co	Tulsa, Okla.
Southwestern Petroleum Co	Tulsa, Okla.
Stevenson Lease (A. J. Powell)	Waco
Shamrock Oil Co	Wichita Falls
Sutherland Oil Co	Houston
Skinner, E. W. Oil Co	Saratoga
Silver Lake Co	Abilene
Staley, J. A	Wichita Falls
Texas Southern Oil Co	San Antonio
Texola Petroleum Co	Electra
Tarver Oil Co	Dallas
Tolbert, John Oil Co	Midlothian
Texas-Virginia Oil Co	Paris
Texas Oil Corporation	Dallas
Texas Wonder Pools	Wichita Falls
Texmex Oil Co	Fort Worth
Thomas, Mack	Wichita Falls
Texas Standard Oil Co	Houston
Trisler(?), Daniel	Wichita Falls
Texas Chief Oil & Gas Co	Wichita Falls
Triangle Oil Co	Wichita Falls
Texas Blue Bonnet Oil Asso.	Wichita Falls
Thaxton, W. H	Austin
Texas Oil & Drilling Co	Houston
Tidal Western Oil Corp.	Tulsa, Okla.
Texas Co	Houston
Texas Pacific Coal & Oil Co	Thurber
T W P Oil Co	Sour Lake
Texas Oil Producing Co	Dallas
[illegible] Oil Co	Sour Lake
Transcontinental Oil Co	Pittsburgh, Pa.
[illegible] Oil Co	Wichita Falls
Text[illegible] Oil & Refining Co	Wichita Falls
Thompson & McKinnis	Ranger
Texas Buffalo Oil Co	San Antonio
Texas Oil & Land Investment Co.	Fort Worth
Texas Pacific Coal & Oil Co	Thurber
T[illegible] E. D.	Fort Worth
Texas Consolidated Oil Co	Dallas
Texas Electra Co	Columbus, Ohio
Tarrant Oil Co	Cisco
Turnbow Oil Corporation	Houston
Texas Federal Oil Co	Electra
Texas Amalgamated Oil Co	Fort Worth
Thomas, Leon	Wichita Falls
T. Y. Oil Co	Sour Lake
Texas Operating Syndicate	Wichita Falls
Taylor, T. J & Sibley, S. W.	Wichita Falls
Texana Production Co	Fort Worth
Tri-Mutual Oil Development Co.	Rapid City, S. Dak.
Texas Southern Oil & Devel. Co.	San Antonio
United Drilling & Develop. Co.	Wichita Falls
Unity Oil Co	Beaumont
United Petroleum Co	Chicago, Ill.
United Oil & Fuel Co	Philadelphia, Pa.
Union National Oil Co	Houston
Underwriters Prod. & Ref. Co.	Oklahoma City, Okla.
Underwood Drilling Co	Wichita Falls
Universal Drilling & Develop. Co.	Wichita Falls
Universal Texas Oil & Gas Co	Dallas
United Oil Co	Shreveport, La.
Victory Oil Producing Co.	Little Rock, Ark.
Vulcan Oil Co	Tiffin
Van Cleave Oil Trust	Wichita Falls
Volcanic Producing Co	Brenham
Val Verde Oil Co	Del Rio
Valley Oil Co	Petrolia
Vat Oil & Gas Co	Byers
Volunteer Oil Co	Nashville, Tenn.
Venus Oil Co	Denison
Virginia Oil Co	Fort Worth
Vulcan Oil Co (T & P)	Thurber
Williams, J. L	Brownwood
Western Prod. & Drilling Co	Wichita Falls
Wagonner, R. M	Wichita Falls
Wood, Cranfield	Wichita Falls
Western-Keoughhan-Hurst Syndicate	Strawn
Worth Oil Co	Tulsa, Okla.
Wonder Oil Co	Houston
Woods Oil Co	Beaumont
Wood, C. C	Wichita Falls
Wichita Clay Oil Co	Wichita Falls
Wichita Petroleum Co	Wichita Falls
Walker Consolidated Co	Dallas
Wilson Breach Co	Beaumont
Walker, B. S	Breckenridge
Watkins Pool Oil Co	Dallas
Waseco Oil Co	Fort Worth
Waggoner, Abe W. (trustee 3)	Houston
Waggoner, Abe W. (trustee 4)	Houston
Weber, Mark U	Casper, Wyo.
Webb, W. G	Albany
Wichita Burk Oil Co	Wichita Falls
Winner Oil & Gas Co	Wisner, Nebr.
Woodburn Oil Corporation	Philadelphia, Pa.
Witherspoon Oil Co	San Antonio
Wilkoff, B. A. Syndicate	Pittsburgh, Pa.
White, S. V	Wichita Falls
Walker, P. G., Jr	Tulsa, Okla.
Webb Oil Co	Humble
White & Scarbrough	Burkburnett
Woodrow-Lee Trust	Wichita Falls
Wills & Garity	Corsicana
Weona Oil Co	Burkburnett
Western Petroleum Co	Vernon
Wyatt Oil Co	Sour Lake
Webb, W. G	Albany
West Tennessee Lease	Wichita Falls
West Virginia Ranger Oil Co.	Charleston, West Vt.
Webb, J. R	Corsicana
Wichita Southern Oil Prod. Co	Houston

PETROLEUM PRODUCING COMPANIES OF TEXAS FOR 1921.
(Concluded)

Company	Location
Witcher, W. C	Wichita Falls
Westheimer & Daube	Ardmore, Okla.
Welden Oil Co	Houston
Walker Caldwell Producing Co	Dallas
Weber, Howard	Bartlesville, Okla.
Young, Simmons Drilling Co	Wichita Falls
York Production Co	Wichita Falls
Yount-Lee Oil Co	Sour Lake
Young Bros. & Kennedy	Wichita Falls
Y. M. C. A. Block	Breckenridge

PETROLEUM PRODUCING COMPANIES OF OKLAHOMA FOR 1921.

Company	Location
Aaronson, L. E. Z	Tulsa
Abraham, Joe	Bristow
Acme Oil Co	Tulsa
Ackerman, F. T	Tulsa
Advance Oil Co	Fort Worth, Texas
Adams, E. H., et al	Okmulgee
Adams Oil & Gas Co	Washington, D. C.
Aetna Petroleum Co	Pittsburgh, Pa.
Aiken Oil Co	Nowata
Akin Oil Co	Tulsa
Aladdin Oil Co	Tulsa
Albion Oil Co	Tulsa
Alexander-Shakely Petroleum Co	Tulsa
Alluwe Oil Co	Nowata
Almeda Oil Co	Bartlesville
Almy, C. C	Okmulgee
All-American Oil & Gas Co	Oklahoma City
American Gas & Carbon Co	Tulsa
American Oil Co	Oklahoma City
Amerada Petroleum Co	Tulsa
American Oil & Gas Co	
Anderson & Simpson	Ardmore
Anglo-Texas Oil Co	Okmulgee
Apex Oil & Gas Co	Tulsa
Arthur Oil Co	Sisterville, W. Va.
Arm Oil Co	Walters
Argue & Compton	Tulsa
Ashland Oil Co	New York City
Atlas Petroleum Co	Kansas City, Mo.
Atlantic Petroleum Co	Tulsa
Atlantic Petroleum Co	Boston, Mass.
Atlantic Oil Prod. Co	Philadelphia, Pa.
Aubyme Oil & Gas Co	Garber
Ault & Ross	Vinita
Avery, C. S	Tulsa
Acme Oil Corp	Tulsa
Avery Oil & Gas Co	Tulsa
Avon Oil Co	Tulsa
Aztec Oil Co	Houston, Texas
B. Jack Oil Co	Sapulpa
Bagley Oil & Gas Co	Auburn, Nebr.
Banford Oil Co	Tulsa
Banowetz, M. O	Coffeyville, Kas.
Baker Oil & Gas Co	Independence, Kas.
Bass, C. W	Tulsa
Bassett, W. O	Okmulgee
Barber Oil Co	Tulsa
Bartlesville Oil & Gas Co	Bartlesville
Bartles-Johnson Oil Co	Bartlesville
Barbara Oil Co	Okmulgee
Barnsdall Oil Co	Bartlesville
Baughman, R. P	Ponca City
Bay State Oil & Gas Co	Kansas City, Mo.
Baxter, L. W	Tulsa
Beacon Oil Co., et al	Bartlesville
Beatty, E. F	Oil City, Pa.
Bell Oil & Gas Co	Tulsa
Bell Oil & Gas Co	Warren, Pa.
Belvy Oil Co	St. Louis, Mo.
Benmo Oil Co	Tulsa
Berger Oil & Gas Co	Tulsa
Berry, R. H	Tulsa
Best Prod. Co	Okmulgee
Betty, G. Petroleum Co	Cement
Betty Ruth Oil Co	Broken Arrow
Benedum Trees Oil Co	Pittsburgh, Pa.
Big Sioux Oil & Gas Co	Okmulgee
Big Fifty Oil Co	Tulsa
Bigheart Producing & Ref. Co	Tulsa
Biddle Oil Co	Tulsa
Bird Creek Oil & Gas Co	Tulsa
Bird Creek Oil Co	Tulsa
Bird, Gaffney & Simons	Bradford, Pa.
Billy Oil Co	Chelsea
Black, E. L	Henryetta
Black, Geo. E	Pasadena, Calif.
Blackwell Oil & Gas Co	Blackwell, Kas.
Bloch Oil Co	Tulsa
Blue Ridge Oil & Gas Co	Oklahoma City
Boesche, F. E. C	Coffeyville, Kas.
Bolivar Run Oil Co	Tulsa
Bole, Geo.	Tulsa
Bokma Oil Co	Chicago, Ill.
Bradstreet, J. G. & Co	Tulsa
Bradley Oil Co	Tulsa
Braik Oil & Gas Co	Henryetta
Braley, C. A	Kansas City, Mo.
Brann, Jas. (receiver)	Bartlesville
Brandes Oil Co	Nowata
Breene, Frank M	Tulsa
Breener Oil Co	Pawhuska
Breene, Mabel V	Tulsa
Bright, Samuel	Okmulgee
Brilling, Geo. Co	Tulsa
Bridgman Oil Co	Nowata
Bridgman, Welsh & Haner	Muskogee
Briggs, B.	Tulsa
Brown, F. B. & W. H	Bartlesville
Brown Oil & Gas Co	Tulsa
Brundred Oil Corp. of	Oil City, Pa.
Bruner Oil Co	Independence, Kan.
Bucher Petroleum Co	Bartlesville
Burket, J. G	Mineral Wells, Tex.
Burke Hoffeld Oil Co	Tulsa
Bull-Head Oil Co	Ardmore
Bull Dog Oil Co	Tulsa
Burwell, H. B	Broken Arrow
Burton, N. S	Ardmore
Burns, Robt	Tulsa
Burt W. & Lyon M. J	Joplin, Mo.
Butler & Lafferty	Muskogee
Cabin Valley Mining Co	Chelsea
Cala-Belle Oil Co	Cement
Cameron, Mrs. Lillian	Tulsa
Campbell, H. C	Nowata
Campbell, A. P	Wichita, Kan.
Campbell, H. B	Welch
Canada Oil Co	Nowata
Canary & Sinclair	Denver, Colo.
Canary & Canary	Denver, Colo.

PETROLEUM PRODUCING COMPANIES OF OKLAHOMA FOR 1921 (Continued)

Company	Location
Canary, J. D.	Denver, Colo.
Canary, S. C.	Tulsa
Canfield, W. E. & G. W.	Yale
Cappeau, J. P.	Tulsa
Carr, J. M.	Okmulgee
Carr, M. L.	Okmulgee
Carlock & Dexter	Ardmore
Carey Oil & Gas Co	Wellsville, Ky.
Carpenter, I. C.	Morris
Carter Bros	Tulsa
Carter Oil Co	Tulsa
Cassidy, Alice M.	Guthrie
Cash Oil & Gas Co	Nowata
Caswell, Chas. H.	
Catlett-Davis Oil Corp	Tulsa
Celestine Oil Co	Tulsa
Central Union Oil Co	Tulsa
Central Refining Co	Tulsa
Central National Oil Co	Okmulgee
Chamberlain, H. G.	Marietta, Ohio
Chapman, O. H.	Waxahachie, Tex.
Chandler, T. A.	Vinita
Chapman, Fred A.	Ardmore
Chicago Oil Co	Chicago, Ill.
Chief Bigheart Oil & Gas Co	
Childers Gasoline Co	Nowata and Wichita, Kan.
Chinango Oil & Gas Co	New York City
Choctaw Oil Co	Tulsa
Cimarron River Oil & Gas Co.	Oklahoma City
Clark, L. P.	Independence, Kan.
Cleve Oil & Gas Co	Bartlesville
Cline Oil Co	Wichita Falls, Tex.
Clover Oil Co	Tulsa
Clover, Marvin K.	Tulsa
Coe, R. W.	Ardmore
Collins Oil Co	Vinita
Coline Oil Co	Ardmore
Columbia Petroleum Co	Oklahoma City
Commonwealth Oil Co	Warren, Pa.
Commercial Refining Co	Wichita, Kan.
Comotop Oil Co	Tulsa
Compton, et al	Independence, Kan.
Concord Oil Co	Oklahoma City
Congress Oil Co	Kansas City, Mo.
Consumers Oil Co., et al	Okmulgee
Continental Oil Co	Independence, Kan.
Continental Oil Co	Okmulgee
Corner, Akin & Argue	Bartlesville
Corine Oil & Gas Co	Guthrie
Coronado Oil & Gas Co	Cleveland
Corbin Oil & Gas Co	Tulsa
Cosden & Co.	Tulsa
Cosden Oil & Gas Co	Tulsa
[illegible] Oil Co	Okmulgee
Cotton Farm Oil Co	Independence, Kan.
Cotton Belt Petroleum Co	Ardmore
[illegible] Oil Co	Garber
Cowles & Lawton	Nowata
[illegible] Oil Co	Tulsa
Critchlow, W. S.	Ardmore
[illegible] & Davis	Tulsa
[illegible] Davis, et al	Tulsa
[illegible] & Potter	Ardmore
[illegible] Smith & [illegible]	Ardmore
Crown Oil Co	Rochester, N. Y.
[illegible] Capital Oil Co	Okmulgee
[illegible] Oil Co	Independence, Kan.
[illegible] Oil Co	Okmulgee
Cumberland Oil & Gas Co	Muskogee
Curtis & Akin	Tulsa

Company	Location
Cushing Gasoline Co	Tulsa
Cudahy Oil Co	Cleveland, O
D. & S. Oil & Gas Co	Tulsa
Dallas Osage Co	Tulsa
Danciger Oil & Refining Co	Tulsa
Dana Oil Co	Bartlesville
Davis, R. D.	Cleveland
Davis, L. R.	Tulsa
Davis & Younger	Oklahoma City
Daisy Belle Petroleum Co	Ardmore
Dover Oil Co	Bartlesville
Daw Bell Oil Co	Oklahoma City
Day, E. L.	Oklahoma, City
Deep Fork Oil Co	Marietta, O.
Delokee Gas & Oil Co	Bartlesville
Devonian Oil Co	Tulsa
Dekoma Development Co	Tulsa
Deaver, J. J.	Okmulgee
Delmar Oil Co	Bartlesville
DeSoto Gasoline Co	Beaumont, Tex.
Dempsey, J. J.	Oklahoma City
Doneghy Lease	Tulsa
Delco Oil & Gas Co	Tulsa
Dierk Fred H.	Kansas City, Mo.
Dominion Oil Co	Muskogee
Dock Oil & Gas Co	Bartlesville
Done Oil & Gas Co	Tulsa
Douglass Harvey, Atty	Chelsea
Dresser Oil Co	Tulsa
Duffield, L. C. & Co	Caney, Kan.
Duffey, J. B. et al	Tulsa
Dundee Petroleum Co	Tulsa
Dunn Oil Co	Tulsa
Duffield & Howard	Tulsa
Dubbs, E. E.	Indiana Harbor, Ind.
Dubeth & Okla. Oil Co	Dilworth
Eachob, Trumbo & McKay	Muskogee
Eagle Oil & Gas Co	Lyons, Kan.
Eastern Oil Co	Buffalo, N. Y.
Ebling, L. P. & Co	Bartlesville
Echo Oil Co	Tulsa
Edgar Oil Co	Bartlesville
Eddystone Oil Co	Tulsa
Ellis, M.	Tulsa
Elliott & Yensel	Tulsa
Elin Oil Co	Tulsa
Elliott, W. C.	Tulsa
Elmer Oil Co	Elmira, N. Y.
Empire Gas & Fuel Co	Bartlesville
Enid 80 Oil & Gas Co	Enid
Enfisco Oil & Gas Co	Tulsa
English, W. H.	Ponca City
Enterprise Transit Co	
Evidence Oil Co	Caney, Kan.
Exchange Oil & Gas Co	Tulsa
Exchange Oil Co	Tulsa
Eysenbach, O. K., et al	Tulsa
Fagundus Oil Co	Chelsea
Farmer, A. L. & A. E.	Tulsa
Fay Drilling Co	Tulsa
Fee Oil Co	Muskogee
Fever, M. M.	Marietta, O.
Fewel, Green A.	Muskogee
59 Osage Oil Co	Bartlesville
Fitzgerald, J. W.	Bartlesville
Fitzgerald, D. C.	Ardmore
Finance Oil Co., et al	Pawhuska
Flat Rock Oil Co	Tulsa
Flesher Petroleum Co., et al.	Lexington, Ky.
Fort Ring Oil & Gas Co.	Fort Worth, Tex.
Foster, H. V.	Tulsa

PETROLEUM PRODUCING COMPANIES OF OKLAHOMA FOR 1921 (Continued)

Company	Location
Fortuna Oil Co	Dallas, Tex.
Foster Oil Co	Tulsa
Fox Petroleum Co	Ardmore
Fox, W. T	Sapulpa
Franchot, D. W. & Co	Tulsa
Foster & Davis, Inc	Bartlesville
Freese Oil & Gas Co	Okmulgee
Freehold Oil & Gas Co	Pittsburgh, Pa.
Friedman, Louis	Muncie, Ind.
French, M. C	Okmulgee
Fierce, C. A	Bartlesville
Foree Oil Co	Tulsa
Francoma Oil Co	Ponca City
Franklin, Wirt	Ardmore
Fredora Oil & Gas Co	Okmulgee
Funk, A. L	Tulsa
Gadfuy, F. J	Okmulgee
Gardner Oil Co	Tulsa
Gardner & Avery	Tulsa
Galbraith, H. H., et al	Independence, Kan.
Gates Oil Co	Ardmore
Gaffney, H. E	Bradford, Pa.
Gardner Petroleum Co	Tulsa
Garco Oil Co	Enid
Gardner, J. L	Okmulgee
Gamo Oil Co	Claremore
Georgia Petroleum Co	Okmulgee
Getty Oil Co	Los Angeles, Cal.
Getty, Geo. F	Los Angeles, Cal.
Gilmond Oil Corp	Pawhuska
Giddings, F. C., et al	Tulsa
Gilliland Oil Co	Tulsa
Gillespie, F. A	Tulsa
Gillespie, Joe	Coffeyville, Kan.
Gilmer Oil Co	Lamine, Mo.
Gilbert, N. T	Tulsa
Gladstone Oil & Refining Co	Fort Worth, Tex.
Gorton Trust	Cement
Greenwalt, H. L	Okmulgee
Guardian Oil Co	Tulsa
Gypsy Oil Co., J. J. McGraw, et al	Bartlesville
Gypsy Oil Co	Tulsa
Geneva Pearl Oil Co	Ardmore
Gibney, H. J	Bartlesville
Guillot & Hall	Ardmore
Goldie Oil & Gas Co	Kansas City, Mo.
Grimes, Elliott, et al	Tulsa
Guffey-Gillespie Oil Co	Pittsburgh, Pa.
Grimes, Blair, et al	Tulsa
Griffen Refining Co	Tulsa
Gillespie, F. A., et al	Tulsa
Gore, Harry	Tulsa
Gray, W. B	Tulsa
Gnome Oil Corp	Chicago, Ill.
Great Southwestern Petroleum Co	Oklahoma City
Grimes, et al	Tulsa
Halfmoon Oil Co	Dewey
Hillside Oil Co	Muskogee
Heenan, J. A	Ardmore
Harris, T. D	Okmulgee
Hartley & Suggs	Oklahoma City
Heggem & Davis	Tulsa
Hulings, M. C	Tulsa
Hulings, F. W. Tr.	Okmulgee
Hull, J. A	Tulsa
Hennessey, J. E	Okmulgee
Hoge, J. B	Nowata
Hastings, W. T	Marietta, O
Harrington, Wm	Marietta, O
Hamilton & Jack	Dewey
Hamilton W. B	Dewey
Hutchinson, E. A	Muskogee
Hill Oil & Gas Co	Muskogee
Hazel Oil Co	Independence, Kan.
Home Gas Co	Cushing
Howard Duffield & Berlin	Tulsa
Harlin, E. C	Welch
Hummel, C. S	Chelsea
Hazlett, Bradford, et al	
Haley Oil & Gas Co	Tulsa
Hollis, Elsie	Los Angeles, Cal.
Humphreys, E. P	Okmulgee
Harrington, L. F	Tulsa
Houston, H M	Bixby
Harvey Crude Oil Co	Tulsa
Humphreys Petroleum Co., et al	Tulsa
Hummel, Sadie L	Chelsea
Hayner Petroleum Co	Tulsa
Haney, Phil P	Coffeyville, Kan.
Hamill, A. W	Tulsa
Hivick, L. C	Ardmore
Hivick & Slack	Ardmore
Harris, T. D	Okmulgee
Healdton Oil & Gas Co	Marlow
Huckleberry, J. H	Kansas City, Mo.
Haskogee Oil & Gas Co	Haskell
Humble Oil & Gas Co	Houston, Tex.
Hill Oil & Gas Co	Tulsa
Harrington, W. J	Coffeyville, Kan.
Houbert, H. J	Tulsa
Haler, W. T	Oklahoma City
Hughes, R. H	Tulsa
Hane, C. E., Agt	Tulsa
Harris-Strawn Oil Co	Ardmore
Hamon, J. L	Ardmore
Henton, E. L., et al	Chelsea
Henderson Co.	Nowata
Haverhill Petroleum Co	Tulsa
Hamon & Walls	Ardmore
Howard, O. R	Tulsa
H. C. W. Oil Co	Chelsea
H. M. Petroleum Co	Tulsa
Halco Oil Co	Tulsa
Harris Oil & Gas Co	Independence, Kan.
Harris, L. C	Rising Sun, Ind.
Harter Drilling Co	Tulsa
Henry Oil Co	Chicago, Ill.
Henson Prod. Co.	Tulsa
Hojoco Oil Co	Tulsa
Holbeck Oil Co	Ardmore
Huntly Oil Corp	Pittsburgh, Pa.
Hull & Bradstreet	Tulsa
Hutchinson, E. A	Muskogee
Hyman, T. J	Chicago, Ill.
Ideal Oil Co	Ardmore
Imperial Osage Develop. Co	Bartlesville
Interstate Oil & Gas Co	Bartlesville
Indiana Oil & Gas Co	Tulsa
Invincible Oil Co	Fort Worth, Tex.
Indiahoma Refining Co	St. Louis, Mo.
Invader Oil & Refining Co	Muskogee
Independence Oil Co	Independence, Kan.
Indian Territory Illuminating Co	
Indian Petroleum Co	Okmulgee
Iokla Oil & Gas Co	Healdton
Illinois-Kansas Oil & Gas Co	Chicago, Ill.
Illinois Oil Co	Chicago, Ill.
Ideal Royalty Co	Tulsa
Irwin & Miller	Bartlesville

PETROLEUM PRODUCING COMPANIES OF OKLAHOMA FOR 1921 (Continued)

Company	Location
Irwin, John S	Bartlesville
Iron Mountain Oil Co	Tulsa
Jitney Oil Co	Tulsa
Jenson, H. A	Red Fork
Jolly, M. V	Tulsa
Jane Gwinn Oil Co	Tulsa
Jennings, E. H. Bros. Co	Pittsburgh, Pa.
Jay Bee Oil Co	Bartlesville
Johnson Farm Oil Co	Warren, Pa.
Jameson, J. B	Concord, N. H.
Jomack Oil Co	Bristow
Jewell Oil & Gas Co	Lawton
Johnson, Ike	Bartlesville
Josey Oil Co	Oklahoma City
Jennie Oil Co	Chelsea
Johnson Oil Refining Co	Chicago, Ill.
Jennings, R. G. & Lawrence Gas Co	New York City
Jackson, Wise & American Pet. Co	Sapulpa
Jackson, Wise & Bovaird	Sapulpa
Jackson, Wise & Markham	Sapulpa
Johnson, W. J	Pittsburgh, Pa.
Kansas & Gulf Co	Chicago, Ill.
Katheryne Oil Co	Tulsa
Kent Oil Co	Dilworth
Keystone Oil & Gas Co	Independence, Kan.
Kingwood Oil Co	Okmulgee
Knupp, W. J., et al	Warren, Pa.
Keeche Oil & Gas Co	Oklahoma City
Kinkaid, W. R	Delmare
King Carlie Oil & Gas Co	
Kistler, R. P	Tulsa
Kraeer, O. A., & Co	Bartlesville
Karnes, H. E	Independence, Kan.
Kay & Kiowa Oil Co	Tulsa
Karnes, H. E	Independence, Kan.
King, Newbert, Shufflin, et al	Nowata
Kay-Wagoner Oil & Gas Co	Oklahoma City
Kawfield Oil Co	Tulsa
Karns, Ed	Coffeyville, Kan.
King, Frank	
Kistler, et al	Okmulgee
Kanola Oil & Refining Co	Tulsa
Kiefer, B. L	
Kirk, S C	Wooven, O.
Kingsmith Refining Co	Tulsa
Kewanee Oil & Gas Co	Titusville, Pa.
Konkel, W. A	Bluffton, Ind.
Kemp, E. R	Tulsa
Knappenberger, D. L	Sapulpa
Kerull Oil Co	Tulsa
Kansas-Osage Petroleum Co	Bartlesville
Landom, A M	Independence, Kan.
Laurel Oil & Gas Co	Tulsa
Lima Oil & Gas Co	Bartlesville
Lucky Leaf Oil & Gas Co	Blackwell
Lancaster, et al	Tulsa
Larkin, C. L.	Bartlesville
Lovell Dot. L. Gdn	Marietta, O.
Lovell, J. A.	Marietta, O.
Lorley, Chas	Marietta, O.
Limestone Oil & Gas Co	Sapulpa
Lightning Creek Oil & Gas Co	Wellsville, Ky.
Lane Oil Co	Tulsa
Lenore Oil Co.	Ardmore
Larue Oil Co	Bartlesville
Little Fay Oil Co	Tulsa
Livingston Oil Corp.	Tulsa
Lambert Oil & Gas Co	Tulsa
Lawson G. Neely Co	Tulsa
Lake Maramec Oil & Gas Co	Maramec

Company	Location
Lane E.	Nowata
Locol Oil Co	Warren, Pa.
Lucky Tiger Oil Co	Oklahoma City
Lowry Oil Corp	Muskogee
Layton Oil Co	Tulsa
Lucado Oil & Gas Co	Coffeyville, Kan.
Leopold & Brett	Muskogee
Lawrence Gas Co	New York City
Larkin & Reynolds	Bartlesville
Lawton, E. B	Nowata
Lawton, et al	Nowata
Leahy Oil Co	Pawhuska
Link Oil Co	Tulsa
Longfellow, J. M	Bristow
Lasoya Oil Co	Ottawa, Pa.
Lewis Oil Co	Pittsburgh, Pa.
Loett Oil Co	Tulsa
Long Green Oil & Gas Co	Kansas City, Mo.
Lone Star Gas Co	Dallas, Tex.
Lorber, C. C	Cleveland
Lebow, Max	Tulsa
Lahoma Oil & Gas Co	Oklahoma City
Leonard, J. M	Joplin, Mo.
Lincoln Oil & Gas Co	Tulsa
Louvain Oil Co	Bartlesville
Ludlow, Leo	Tulsa
MacMullen, G. W. Co	Tulsa
Magnolia Oil & Refining Co	Tulsa
Mallory, J. F., et al	Tulsa
Marland Refining Co	Ponca City
Mason, D. B	Tulsa
McLaughlin & Co	Tulsa
Melba Oil Co	Tulsa
Minnehoma Oil Co	Los Angeles, Cal.
Mid-Co. Petroleum Co	Tulsa
Milliken, J. F. et al	Tulsa
Mitchell & Marrow	Independence, Kan.
Mitchell, Mark D. & Co	Independence, Kan.
Moran, M.	Tulsa
Montrose Oil & Ref. Co	Fort Worth, Tex.
Mountain State Oil Co	Bartlesville
Mourison & Jackson	Sapulpa
Mudge Oil Co	Pittsburgh, Pa.
Magnolia Petroleum Co	Dallas
Midland Sec. Co	Tulsa
McClintock R. Otis	Tulsa
Murray, Jas. M	Cleveland
Moore Petroleum Co	Tulsa
Merrick F. W	Ardmore
Mid-Southwestern Oil Co	Cement
Midgert Oil & Gas Co	
Monarch Oil & Gasoline Co	Tulsa
McKeys Oil & Gas Co	Ardmore
McBamme, L. W	Gary, Ind.
Markham, John H. Jr., et al	Tulsa
McGraw, Henry	Tulsa
McKinney, J. E	Tulsa
Minshall, E. R	Tulsa
Minshall Oil & Gas Co	Tulsa
Modern Oil Co	Wellsville, N. Y.
Marshall Oil Co	Nowata
McCaskey, J. G. & Wentz, Louis	Ponca City
Moore, Clint	Tulsa
Malou Oil Co	Pittsburgh, Pa.
Midwest & Gulf Oil Corp	Tulsa
McGraw, J. J	Ponca City
McClelland Bros	Okmulgee
McDonnell, J. V	Tulsa
McCann, Wm. L	Oklahoma City
Martin, B. C	

PETROLEUM PRODUCING COMPANIES OF OKLAHOMA FOR 1921 (Continued)

Company	Location
McCoy, S.	Okmulgee
McDougal, D. A.	Sapulpa
McLaine Farm Oil Co.	Tulsa
McCormick, Matt	Nowata
Mooney, D. E.	Ponca City
McCray, W. S.	Tulsa
Miller, G. L.	Ponca City
Mead, C. J.	Kansas City, Mo.
Majestic Oil & Gas Co.	DeQuein, Ill.
Manhattan Oil Co.	Tulsa
Marshall Oil Co.	Tulsa
Martin Mamie Lease	Nowata
McGraw, T. F.	Newkirk
Mid-Kansas Oil & Gas Co.	Findlay, Ohio
Mallory et al	Tulsa
Milroy Petroleum Co.	Duncan
M. O. Oil Co.	St. Louis, Mo.
Marietta Oil Co.	Marietta, Ohio
Maple Leaf Oil Corporation	Bartlesville
Mooney, L. E.	Chelsea
Misener, F. D., et al.	Tulsa
Mooney & Holtxendorff	Claremore
M. T. C. Oil & Gas Co.	Wagoner
McMan Oil & Gas Co.	Tulsa
McFarlin & Chapman	Tulsa
Mutual Oil & Gas Co.	Tulsa
Michihoma Oil & Gas Co.	Muskogee
Midland Oil Co.	Bartlesville
Morton Petroleum Co.	Bartlesville
Mustul Oil Co.	Tulsa
Mohawk Petroleum Co.	Tulsa
Minnehoha Oil Co.	Newasha, Wis.
Mercer Oil Co.	Oklahoma City
Metropolitan Petroleum Co.	Tulsa
Margay Oil Corporation	Tulsa
McKay, M. C., Gdn.	Sapulpa
Mack Oil & Gas Co.	Bartlesville
Myers & Twichel	Okmulgee
Nile Oil Co.	Tulsa
Newblock Oil & Gas Co.	Tulsa
Nancy Oil Co.	Sapulpa
Neal, D. F., & Co.	Cleveland
National Explor. Co.	Tulsa
Noco Prod. Co.	Tulsa
Northrop, C.	Ponca City
New England Oil Co.	Boston, Mass.
North American Oil & Gas Co.	Oklahoma City
National Oil & Development Co.	Okmulgee
Nuco Oil Co.	Indianapolis, Ind.
N. Y. Oil Co.	Tulsa
Nyanza Refining Co.	Ardmore
National Union Oil & Gas Co.	Blackwell
Newman, Wm. C.	Okmulgee
Nolan Lease	Sapulpa
Nowata Oil & Refining Co.	Tulsa
Noble, Chas. F.	Tulsa
Neutadt, Walter	Ardmore
New Haven Oil Co.	Bartlesville
Oregon Oil Co.	Tulsa
Offenbacher Petroleum Co.	Tulsa
Osage Develop. Co.	Bartlesville
Oklahoma Syndicate, Ltd.	Tulsa
Oliphant Petroleum Co.	Pawhuska
Osage Foraker Oil Co.	Tulsa
Oil Issues Co.	Tulsa
Ohio Fuel Oil Co.	Pittsburgh, Pa.
Okla. Penn Oil Co.	Tulsa
Oil State Petroleum Co.	Enid
Okeh Oil & Refining Co.	Okmulgee
Okla. Prod. & Ref. Co.	Tulsa

Company	Location
O'Conner, Martin	Portville, N. Y.
Oklahoma Central Oil Co.	Tulsa
Okliana Oil Co.	Tulsa
Okla. Petroleum & Gasoline Co.	Tulsa
Oklahoma Natural Gas Co.	Tulsa
Oklarado Oil Co.	Okmulgee
Osage Arrow Oil Co.	Ponca City
Osage Nat'l Oil Syndicate	New York City, N. Y.
Osage Indian Oil Co.	
Overton, C. H.	Tulsa
Old Colony Petroleum Co.	Oklahoma City
Osage Prod. & Ref. Co.	Bartlesville
Old Dominion Oil & Gas Co.	Tulsa
Oglesby, Robt.	Tulsa
Oklavania Oil Co.	Tulsa
Owsley, D. L.	Tulsa
Owens, B., Est.	Buffalo, N. Y.
Obins & Weber	Bartlesville
Okla. Natural Gas Co.	Sapulpa
Parmenter, L. C.	Muskogee
Paragon Oil Co.	Tulsa
Panhandle Refining Co.	Dallas, Tex.
Panama Oil Co.	Holdenville
Parks Oil Co.	Chelsea
Patterson, M. P.	
Pauline Oil & Gas Co.	Duncan
Pennhoma Oil Co.	Pittsburgh, Pa.
Paraffine Oil Co.	Beaumont, Tex.
Papoose Oil Co.	Tulsa
Page Chas. Tr.	Sand Springs
Paw Paw Oil Co.	Baltimore, Md.
Painter & Stager et al.	Nowata
Page, W. R.	Tulsa
Petroleum Corp. of America	Okmulgee
Penn Osage Oil Co.	Bartlesville
Periscope Oil Co.	Tulsa
Pensy Oil & Gas Co.	Tulsa
Petroleum Co.	Tulsa
Pennok Oil Co.	Tulsa
Pet. Lock Oil Co.	
Peters-Leahy Oil Co.	Pawhuska
Pennsylvania Oil Co.	Warren, Pa.
Peters, Chas. B.	Pawhuska
Phillips Petroleum Co.	Bartlesville
Phillips Pet. Co. & Skelly Oil Co.	Bartlesville
Phillips Pet. Co. & Gypsy Oil Co.	Bartlesville
Phillips Pet. Co. & Beard Bros.	Bartlesville
Phillips Pet. Co. & A. D. Morton	Bartlesville
Phillips Pet. Co. & Standish Oil Co.	Bartlesville
Phillips, W. G., et al.	Chelsea
Phillips Oil Co.	Chelsea
Phillips & Milam	Chelsea
Phillips, Waite	Tulsa
Phillips, J.	Sapulpa
Phyems, Scott	Chelsea
Phillip King Oil Co.	New Bedford, Mass.
Pierce Oil Corp.	New York City
Pioneer Oil Co.	Tulsa
Pilgrim Petroleum Co.	Tulsa
Pioneer Petroleum Co.	Tulsa
Pine, W. B.	Okmulgee
Planet Petroleum Co.	Fort Worth, Tex.
Plover Drilling Co.	Bartlesville
Plymouth Petroleum Co.	Tulsa
Plew, W. L.	Gary
Planters Oil Co.	Nowata
Polecat Oil Co.	Tulsa
Potomac Oil Co.	Tulsa
Powell & Wasson	Muskogee

PETROLEUM PRODUCING COMPANIES OF OKLAHOMA FOR 1921 (Continued)

Company	Location
Potter Oil Co.	New York City
Pollyanna Oil & Gas Co.	
Ponca Oil Co.	Ponca City
Producers & Refiners Corp.	Tulsa
Preston & Straight	Bartlesville
Probst, Geo. C., et al	Tulsa
Prairie Oil & Gas Co.	Independence, Kas.
Pulaski Oil Co.	Tulsa
Pure Oil Co.	Columbus, Ohio
Quadrangle Oil Co.	Wichita, Kas.
Quaker Oil Co.	Coffeyville, Kas.
Quinlin, G. P.	Tulsa
Quaker Oil & Gas Co.	Tulsa
Raycome Oil & Gas Co.	Orrick, Mo.
Rabbit Foot Oil Co.	
Ramsey Oil Co.	Caney, Kas.
Ranger Oil Corp.	Tulsa
Reliance Oil Co.	
Reynolds, W. G.	
Reliance Oil Co.	Beaumont, Tex.
Reno Oil Co.	Sisterville, W. Va.
Republic Oil & Pipe Line Co.	
Regal Oil Co.	Pittsburgh, Pa.
Rebold, J. H.	Okmulgee
Rebold, J. H., et al	Okmulgee
Red Bank Oil Co.	Denver, Colo.
Relia Oil Co.	Tulsa
Reynolds Oil & Gas Co.	Independence, Kas.
Reed, H. W.	Nowata
Rebold Drill Co.	Okmulgee
Rhode Island Oil Co.	Independence, Kas.
Rhodes Oil Corp.	Tulsa
Rimer, J. J.	Nowata
Riddle, T. L., Est.	Marietta, Ohio
Richards, A. A.	Tulsa
Rice Creek Prod. Co.	Tulsa
Riverland Co.	Tulsa
Rogers, A. H.	Carthage, Mo.
Rood, Foster, Meloy	Bartlesville
Robinson, E. L.	Tulsa
Roberts, C. M.	Okmulgee
Roxana Petroleum Co.	St. Louis, Mo.
Royer, E. H.	Ardmore
Rose City Oil & Gas Co.	Kansas
Rockland Oil Co.	Ardmore
Rockwell Petroleum Corp.	Tulsa
Rose Petroleum Corp.	Okmulgee
R. & M. Oil Co.	Hominy
Rosebud Oil Co.	Muskogee
Roxoline Petroleum Co.	Oklahoma City
Ross, C. H.	Coffeyville, Kas.
Roth Bros.	Independence, Kas.
Roth & Shafter	Independence, Kas.
Ryan, J. B.	Tulsa
Ryan Consolidated Pet. Co.	Bartlesville
Saratoga Oil & Gas Co.	Tulsa
[illegible] Oil Co.	Marietta, Ohio
Savoy Oil Co.	Tulsa
Sanford Oil Co.	Bartlesville
[illegible] M.	New York City
[illegible] Oil Co.	Oklahoma City
[illegible] Oil & Marketing Co.	Tulsa
[illegible] L. S.	Ardmore
[illegible] Home et al	Sand Springs
[illegible] Thomas	Okmulgee
[illegible] S.	Okmulgee
Sapulpa Refining Co.	Sapulpa
[illegible] Oil Co.	Tulsa
[illegible] & R[illegible]	Tulsa
[illegible]	
[illegible] J. C.	Los Angeles, Calif.

Company	Location
Security Oil Co.	Denver, Colo.
Seamans Oil Co.	Oklahoma City
Sellas, Geo.	Chicago, Ill.
Shipley, J. M.	Nowata
Shaffer, Danner & Lawrence Gas Co.	
Shertzer Bros.	Dewey
Shear, M.	Bradford, Pa.
Shear & Marcus Oil Co.	Bradford, Pa.
Shertzer, C. W.	Dewey
Shulthis, A. W.	Independence, Kas.
Showalter & Cutchell	Sapulpa
Shuler, I.	Tulsa
Shamrock Oil Co.	Tulsa
Sheeders Oil & Gas Co.	Pawhuska
Shaffer Oil & Refining Co.	Chicago, Ill.
Sheridan Oil Co.	Tulsa
Shufflin, M. B.	Coffeyville, Kas.
Shaffer-Markin Oil Co.	Dallas, Tex.
Simplex Oil Co.	Okmulgee
Silurian Oil Co.	St. Louis, Mo.
Sitrin, Sam	Tulsa
Silers, Marshall & Co.	Skiatook
Simpson, B. A.	Ardmore
Siaco Oil Co.	New York City
Sinclair Oil & Gas Co.	Tulsa
Skelly, W. G.	Tulsa
Skelly Oil Co.	Tulsa
Skelly Oil Co. et al	Tulsa
Skelly Oil Co. & Gypsy Oil Co. et al.	Bartlesville
Skelton-Moore Oil Co.	Bartlesville
Skiatook Oil & Gas Co.	Copan
Slick, T. B.	Clarion, Pa.
Smith, W. T.	Okmulgee
Smith, W. S., Special	Tulsa
Smith & Cleage	Tulsa
Smith & Weathers	Okmulgee
Smith, H. E.	Marietta, Ohio-Vinita
Smith Oil Syndicate	Tulsa
Smith & Daugherty	Nowata
South Dakota Oil & Gas Co.	
Southwestern Oil Fields Co.	Bartlesville
Southwestern Oil & Gas Co.	Independence, Kas.
Southwestern Petroleum Co.	Tulsa
Southern Oil & Gas Co.	CoffeyVile, Kas.
Spring Oil Co.	Independence, Kas.
Spangler, C. W., et al.	Tulsa
Sperata Oil Co.	Bartlesvile
Spurgin, J. G.	Bixby
Stinson & Matthews	Tulsa
Studebaker, E. H.	South Bend, Ind.
Stephens, C. S.	Coffeyville, Kas.
Stralem, C. I.	New York City
Steyner Oil Co.	Bartlesville
Stut, J. A.	Tulsa
Standish Oil Co.	Bartlesville
Stanford, J. W.	Nowata
States Petroleum Co.	Tulsa
Stebbins Oil & Gas Co.	Tulsa
Stake Oil Co.	Independence, Kas.
Stevens Oil & Gas Co.	Pittsburgh, Pa.
Sterling Oil & Gas Co.	
Stahl, E. S.	Ardmore
Steinberger, C. R.	Tulsa
Sun Gasoline Co.	Tulsa
Sunbeam Petroleum Co.	Tulsa
Surpass Petroleum Co.	Pittsburgh, Pa.
Summit Oil Co.	Bartlesville
Summers, Jack	Haskell
Sweeney, J. F. & Co.	Tulsa

PETROLEUM PRODUCING COMPANIES OF OKLAHOMA FOR 1921 (Concluded)

Company	Location
Swanson et al	Tulsa
Sykes, C. E	Ardmore
Symsor, A. J	Bartlesville
System Oil Co	Tulsa
Taft Oil Co	Independence, Kas.
T. B. Gasoline Co	Tulsa
Terrell Co	Terrell, Tex.
Texas Co	Tulsa
Terriokla Oil & Gas Co	Muskogee
Texas-Oklahoma Invest. Co	Independence, Kas.
Testlog Oil Co	Tulsa
Texas Prod. Co	Independence, Kas.
Test Oil Co	Bartlesville
Thefts, John C	Buffalo, N. Y.
Thompson, R. B. & W. M	Tulsa
Thompson, J. N	Tulsa
Tulman Oil Co	Tulsa
Thompson, Roy B., et al	Tulsa
Thompson, J. L	Gas City, Ind.
Thompson, Wm. O	Gas City, Ind.
Thompson, Welder & Neal	Cleveland
The Hefner Co	Ardmore
Thurvan Oil Co	Bartlesville
Thompson Oil & Gas Co	Tulsa
The Keno Oil Co	Tulsa
Tim Eliza Oil Co	Sapulpa
Tidal Oil Co	Tulsa
Titus, C. W	Tulsa
Tibbens, C. G	Tulsa
Tittle, Mrs. Bertha	Gary, Ind.
Togo Oil Co	Tulsa
Tom Games Oil Co	Ponca City
Traders Oil Corporation	Claremore
Trumbo, A. C	Muskogee
Travis, L. R	Tulsa
Travis, D. R	Tulsa
Transcontinental Oil Co	Pittsburgh, Pa.
Troy Oil & Gas Co	Sapulpa
202 Oil Co	Bartlesville
Tuxedo Oil Co	Tulsa
31 Oil Co	Lawton
32 Oil & Gas Co	Ardmore
25 Oil Co	Tulsa
Turman Oil Co	Okmulgee
Twin States Oil Co	Tulsa
Tyrell, H. C	Tulsa
Twin Hills Oil & Gas Co	Tulsa
Two Rivers Oil & Gas Co	Bartlesville
Twichel, J. A	Okmulgee
Tulsa Interstate Petroleum Co	Tulsa
Union Oil & Gas Co	Tulsa
Upland Oil Co	Tulsa
U. S. Oil & Gas Co	Tulsa
Union Oil Co	Tulsa
Urbana Oil Co	Lawton
Vance, S. E	Tulsa
Victoria Oil Co	Tulsa
Viwell Lease	Sapulpa
Victor Oil Co	Tulsa
Verland Oil & Gas Co	Tulsa
Van Hay Oil Co	Tulsa
Vesta Oil & Gas Co	Kansas City, Mo.
Vensel, F. E	Tulsa
Van Nostrand, H. L., Tr	Claremore
Van Dall Bros	Bartlesville
Van Moss Oil Co	Bartlesville

Company	Location
Van Horn, R. V	Clifton Forge, Va.
Valos, T. K	Chicago, Ill.
Victor Oil Co	Pavilion, N. Y.
Victor Oil Co	Tulsa
Walker, J. W	Mounds
Watkins, F. E	Waurika
Wigwam Oil Co	Tulsa
Wrightsman, C. J	Tulsa
Wrightsman Oil Co	Tulsa
Wrightsman, Edna	Tulsa
Western American Oil Co	Bartlesville
Wilcox, Oswalt & Wilcox	Indianapolis, Ind.
Wilcox, H. E.	Indianapolis, Ind.
Whittier, M. H	Tulsa
Wesely, C. T	Ochelata
Wolverine Oil Co	Tulsa
Weber, Howard	Bartlesville
Warren Oil Co	St. Louis, Mo.
Welsh, M. P., et al	Nowata
Wilkinson, Eugene	Miami
White Rose Oil & Gas Co	Oklahoma City
Ward Oil & Gas Co	Nowata
Wright, J. H	Sapulpa
Walsh Oil Co	Tulsa
Wilcox, H. F	Tulsa
Wilcox Oil Co	Tulsa
Warner-Caldwell Oil Co	Titusville, Pa.
Wagoner Oil & Gas Co	Wagoner
Washington, J. E	Tulsa
Walker, Wm. H	Tulsa
Warren Co	Bartlesville
Woodward et al	Tulsa
Woodward & Reed	Tulsa
Woodward, Geo. E	Tulsa
Woodward & Robertson	Nowata
Woodward & Crenshaw McMorris	Nowata
Whitehall, Donovan, et al	
Whitehall, B. F	Wilkinsburg, Pa.
West Hazlett Oil & Gas Co	Independence, Kas.
Walter Oil Co	Pawhuska
Wah-Shah-She Oil Co	Bartlesville
Winona Oil Co	Tulsa
Wolf, F.	Tulsa
Walker, P. M	Tulsa
Walker, P. G	Tulsa
Wall Oil Co	Tulsa
Warren Petroleum Co	Warren, Pa.
Wettack, Maude T	Nowata
Welsh, J. D	Kansas City, Mo.
Welsh Oil & Gas Co	Stillwater
Wells, N. D	Tulsa
Wertzenberger, D. D	Tulsa
Westheimer & Daube	Ardmore
Whitehall Petroleum Co	Tulsa
Wiser Oil Co	Bartlesville
Wise & Jackson	Sapulpa
Winters Oil Co	Bradford, Pa.
Wilcox, M. A	Dewey
Wooster Oil Co	Okmulgee
Workman Oil & Gas Co	Oklahoma City
Xetloc Oil Co	Denver, Colo.
Yorkhoma Oil Co	Bartlesville
Zaline Oil Co	Muskogee
Zahn, S. A	Tulsa
Zola Oil Co	Tulsa

PETROLEUM REFINERIES IN THE UNITED STATES.

Year	Building	Completed	Daily Capacity
1914	..	176	....
1918	..	267	1,186,155 Bbls.
1919	..	289	1,295,115 Bbls.
1920	99	373	1,530,565 Bbls.
1921	44	415	1,888,800 Bbls.

In the following table, the refining plants are divided into eleven classes for the convenience of those desiring to know the products that are generally manufactured by each refinery:

Complete Plant (Comp.)—Gasoline, kerosene, gas and fuel oils, lubricating oils, paraffin wax, petroleum coke or asphalt, or both coke and asphalt.

Skimming Plant (Skim.)—Gasoline, kerosene, gas and fuel oils.

Skimming and Lube (S. & L.)—Gasoline, kerosene, gas and fuel oils, lubricating oils.

Skimming and Asphalt (S. & A.)—Gasoline, kerosene, gas and fuel oils, asphalt.

Skimming and Coke (S. & C.)—Gasoline, kerosene, gas and fuel oils, coke.

Skimming, Lube and Asphalt (S.-L. & A.)—Gasoline, kerosene, gas and fuel oils, lubricating oils, asphalt.

Skimming, Lube and Coke (S.-L. & C.)—Gasoline, kerosene, gas and fuel oils, lubricating oils, coke.

Wax Plant (Wax)—Gasoline, kerosene, gas and fuel oils, lubricating oils, paraffin wax.

Lube Plant (Lube)—Gas and fuel oils, lubricating oils.

Asphalt Plant (Asphalt)—Distillates, gas and fuel oils, asphalt.

Topping Plant (Top)—Tops, distillates, gas and fuel oils.

PETROLEUM REFINERIES IN THE UNITED STATES.
(Continued)

COMPANY	LOCATION	Daily Capacity	Type of Plant
	ARKANSAS		
Arkansas Prod. & Refining Co	El Dorado	1,000	S
Davis, Abner	El Dorado	250	S
Shipper's Petroleum Co	El Dorado	2,000	S
Union Oil & Pipe Line Co	El Dorado	3,000	S
Arkansas Oil Refining Co	Fort Smith	500	S. & L.
Lion Oil & Refining Co	El Dorado	4,000	S
New Arkansas Petroleum Co	El Dorado	2,000	S
Petroleum Products Co. (Root Refineries)	El Dorado	2,000	S
Jones Bros. & Tatum	El Dorado	1,000	S
Red River Oil & Refining Co	El Dorado	2,000	S
Grison Refining Co	El Dorado	4,000	S
National Petroleum Products Co	El Dorado	1,000	S
Crude Oil Marketing Co	El Dorado	3,000	S
	CALIFORNIA		
Union Oil Co. of California	Avila	17,000	Top
Associated Oil Co	Avon (San Francisco)	22,000	S. & L.
Richfield Oil Co	Bakersfield	3,500	Skim.
Standard Oil Co. (California)	Bakersfield	20,000	S. & A.
Union Oil Co. of California	Brea	10,000	Skim.
Puente Oil Co	Chino	1,300	Skim.
American Petroleum Co	Coalinga	3,600	Top.
Continental Petroleum Refining Co	Coalinga	2,500	Skim.
Shell Co. of California	Coalinga	2,000	Skim.
Standard Oil Co. (California)	El Segundo	35,500	Comp.
American Oilfields Co	Fellows	10,000	Top.
Wilshire Oil Co., Inc	Fellows	5,000	Top.
Ventura Refining Co	Fillmore	4,200	Wax
California-Fresno Oil Co	Fresno	500	Skim.
St. Helens Petroleum Co	Fullerton Field	200	Top.
Associated Oil Co	Gaviota (Santo Barbra)	10,000	Skim.
King Refining Co	Kern River	450	Asphalt
Producers Refining Co	Kern River	150	S. L. & A.
Amalgamated Oil Co	Los Angeles	3,500	Top.
Asphaltum & Oil Refining Co	Los Angeles	600	S. & A.
Gilmore, A. F. Co	Los Angeles	260	Skim.
Richfield Oil Co	Los Angeles	900	Skim.
Turner Oil Co	Los Angeles	1,000	S. L. & A.
Union Oil Co. of California	Maltha	3,000	Skim.
Shell Co. of California	Martinez (San Franc.)	30,000	S. & L.
Union Oil Co. of California	Oleum	22,000	S. L. & A.
Standard Oil Co. (California)	Richmond (San Fran.)	60,000	Comp.
Union Oil Co. of California	San Pedro (L. A.)	12,000	Skim.
Capitol Crude Oil Co	Santa Paula	40	Skim.
Union Oil Co. of California	Santa Paula	800	Skim.
Seager, C. L.	Tulare	150	Skim.
California Oil & Asphalt Co	Vernon	500	Skim.
General Petroleum Corporation	Vernon	20,000	Top.
Gilmore Petroleum Co	Vernon	700	Skim.
Jordon Oil Co	Vernon	600	S. & L.
Pacific American Petroleum Co	Vernon	300	Skim.
Petroleum Lubricants Co	Vernon	200	
Pioneer Paper Co	Vernon	400	Asphalt
Union Sales Corporation	Vernon	4,000	Skim.
Vernon Oil Refining Co	Vernon	1,500	Skim.
Wilshire Oil Co., Inc	Vernon	3,000	Skim.
	COLORADO		
United Oil Co	Florence	1,500	Comp.
Apex Refining Co	Loomis	200	S. & L.
Raven Oil & Refining Co	Rangeley	50	Skim.
	GEORGIA		
Atlantic Refining Co	Brunswick	4,000	S. & L.

PETROLEUM REFINERIES IN THE UNITED STATES.
(Continued)

COMPANY	LOCATION	Daily Capacity	Type of Plant
	ILLINOIS		
Leader Oil Co	Casey	300	S. & L.
Indiahoma Refining Co	East St. Louis	3,500	Skim.
Lubrite Refining Co	East St. Louis	1,000	Lube
Warren Oil Co. of Pennsylvania	Joilet	1,000	Lubr
Central Refining Co. (Indian)	Lawrenceville	4,000	S. & L.
Indian Refining Co	Lawrenceville	13,500	Comp.
The Texas Co	Lockport	4,500	Skim.
Interocean Refining Co	McCook	1,000	Lube
Wabash Refining Co	Robinson	1,000	Comp.
Roxana Petroleum Corporation	Wood River	15,000	Skim.
Standard Oil Co. (Indiana)	Wood River	12,000	Comp.
White Star Refining Co	Wood River	1,000	Skim.
	INDIANA		
Indiana Oil Refining Co	Columbus	700	....
Consolidated Oil Refining Co	East Chicago	2,000	Skim.
Sinclair Refining Co	East Chicago	10,000	Comp.
Service Oil Refining Co	Fairmount	1,200	Skim.
Portland Oil & Refining Co	Portland	500	....
Standard Oil Co. (Indiana)	Whiting	40,000	Comp.
	KANSAS		
The Kanotex Refining Co	Arkansas City	3,000	Skim.
The Lesh Refining Corporation	Arkansas City	2,500	Skim.
Midco Petroleum Co	Arkansas City	4,500	Wax
Augusta Oil Refining Co	Augusta	1,000	Skim.
Harvey Crude Oil Co	Augusta	2,000	Skim.
White Eagle Oil & Refining Co	Augusta	5,000	Skim.
General American Oil Co	Baxter Springs	1,000	Skim.
McWhorter-Chanute Refining Co	Chanute	200	....
Mutual Oil Co	Chanute	1,000	Skim.
Sinclair Refining Co	Chanute	2,000	Skim.
The Uncle Sam Oil Co	Cherryvale	2,400	Skim.
Kansas Oil Refining Co	Coffeyville	2,000	S. & L.
National Refining Co	Coffeyville	4,000	Comp.
Sinclair Refining Co.	Coffeyville	3,500	Wax
Atlas Refining Corporation	El Dorado	1,000	Skim.
El Dorado Refining Co	El Dorado	3,000	Skim.
Fidelity Refining Co	El Dorado	2,500	Skim.
Midland Refining Co	El Dorado	4,000	Skim.
St. Louis Oil & Refining Co	El Dorado	1,500	Skim.
Tri-State Oil & Refining Corporation	El Dorado	1,200	Skim.
Great Western Oil Refining Co	Erie	1,500	Wax
Miller Petroleum Co	Humboldt	2,000	Skim.
Hutchinson Petroleum Co	Hutchinson	1,000	Skim.
Empire Refineries, Inc	Independence	500	Skim.
Kansas City Refining Co	Kansas City	2,500	Skim.
Mo-Kan Refining Co	Kansas City	1,000	Skim.
Sinclair Refining Co	Kansas City	5,000	Skim.
Commonwealth Oil & Refining Co	Moran	800	Skim.
Standard Oil Co. (Kansas)	Neodesha	12,000	S. L. & C.
Chemical Oil & Gas Co	Osawatomie	2,000	Skim.
Vickers Petroleum Co	Potwin	2,000	Skim.
North American Refining Co. (Puritan Refinery)	Rosedale	1,000	S.
The Derby Oil Co	Wichita	1,500	Skim.
Golden Rule Refining Co	Wichita	750	Skim.
Sterling Oil & Refining Co	Wichita	4,000	Skim.
	KENTUCKY		
Producing & Refining Co	Bowling Green	1,000	....
Nena Refining Co.	Campton Junction	800	Skim.
Petroleum Refining Co.	Latonia	1,800	Skim.
Great Southern Refining Co	Lexington	1,500	Skim.
Aetna Refining Co., Inc	Louisville	3,000	Skim.
Dixie Bell Refining Co.	Louisville	1,500	....

PETROLEUM REFINERIES IN THE UNITED STATES. (Continued)

COMPANY	LOCATION	Daily Capacity	Type of Plant
	KENTUCKY		
Stoll Oil Refining Co	Louisville	2,000	S. & L.
Oleum Refining Co	Pryse	1,100	Skim.
Standard Oil Co. (Kentucky)	Riverside (Louisville)	5,000	S. & C.
Massey Refining Co	Scottsville	500	....
Mutual Oil & Refining Co	Winchester	500	....
	LOUISIANA		
Delart Refining Co	Anse La Butte	100	Skim.
Great Southern Prod. & Refining Co	Ardia	2,000	....
Standard Oil Co. of Louisiana	Baton Rouge	40,000	Comp.
Louisiana Petroleum Products Co	Bossier City	3,000	....
Caddo Central Oil & Refining Co	Cedar Grove	3,000	Skim.
Caddo Central Oil & Refining Co	Cedar Grove	3,600	Skim.
Crescent Oil & Refining Co	Cedar Grove	6,000	Skim.
International Oil & Gas Corporation	Cedar Grove	1,000	Lube
Red River Refining Co	Crichton	2,000	Skim.
Mexican Petroleum Corporation of Louisiana	Destrehan	20,000	S. & A.
Louisiana Oil Refining Corporation	Gas Center	5,000	Skim.
New Orleans Refining Co	Good Hope	7,000	S. & A.
General Oil & Refining Co	Homer	......	....
Homer Refining Co	Homer	250	....
Shreveport Prod. & Refining Co	Jewella	3,000	Skim.
Sinclair Refining Co. of Louisiana	Meraux	10,000	S. & A.
Liberty Oil Co., Ltd	New Orleans	1,000	Skim.
General Oil & Refining Co	Oil City	2,000	S. & L.
Island Refining Corporation	Sarpy	10,000	Skim.
Paramount Petroleum Corporation	Sheehan	......	....
Louisiana Oil Refining Corporation	Shreveport	1,800	Skim.
The Texas Co	Shreveport	3,000	Top.
U. S. Producers Refining Co	Shreveport	......	....
Paramount Petroleum Co	Superior	......	....
Calcausieu Oil Refining Co	Westlake	650	Skim.
	MARYLAND		
Interocean Oil Co	Baltimore	1,000	S. & L.
Standard Oil Co. (N. J.)	Baltimore	32,000	Comp.
United States Asphalt Refining Co	Baltimore	3,000	Asphalt
Prudential Oil Corporation	Fairfield	6,000	Comp.
	MASSACHUSETTS		
Massachusetts Oil Refining Co	East Braintree	5,000	S. & A.
Beacon Oil Co	Everett	10,000	Skim.
New England Oil Refining Co	Fall River	20,000	S. & A.
	MINNESOTA		
Pure Oil Co	Minneapolis	1,000	S. & L.
	MISSOURI		
Wilhoit Refining Co	Joplin	1,000	Skim.
North American Oil & Refining Corporation	Kansas City	1,500	Skim.
Ranger Refining & Pipe Line Co	Kansas City	2,000	Skim.
St. Joseph Viscosity Oil Co	St. Joseph	500	Skim.
Standard Oil Co	Sugar Creek	12,000	Comp.
	MONTANA		
Montana Refining Co	Billings	1,000	Skim.
	NEBRASKA		
Nicholas, L. V., Oil Co. (White Eagle)	Omaha	500	....
Omaha Refining Co	Omaha	1,000	Skim.

PETROLEUM REFINERIES IN THE UNITED STATES.
(Continued)

COMPANY	LOCATION	Daily Capacity	Type of Plant
	NEW JERSEY		
Standard Oil Co. (N. J.)	Bayonne	20,000	Comp.
Tide Water Oil Co	Bayonne		
Columbia Oil Co. of New York	Constable Hook	1,000	....
Standard Oil Co. (N. J.)	Jersey City	180,000	Comp.
Standard Oil Co. (N. J.)	Linden		
Barber Asphalt Paving Co	Maurer	3,000	S. & L.
Raritan Refining Corporation	New Brunswick	6,000	......
Vacuum Oil Co	Paulsboro	10,000	Comp.
Warner-Quinlan Co	Warner	2,500	S. & A.
	NEW MEXICO		
Pecos Prod. & Refining Co.	Tucumcari	2,000	....
	NEW YORK		
Standard Oil Co. of N. Y	Brooklyn		
Standard Oil Co. of N. Y	Brooklyn		
Standard Oil Co. of N. Y	Long Island City	23,000	......
Standard Oil Co. of N. Y	Long Island City		
Standard Oil Co. of N. Y	Buffalo	4,000	Comp.
Vacuum Oil Co	Olean	7,000	Comp.
Wellsville Refining Co	Wellsville	1,000	Wax
	OHIO		
Ohio Refining Co	Cincinnati	1,200	Skim.
The Canfield Oil Co	Cleveland	1,000	Wax
Standard Oil Co. (Ohio)	Cleveland	8,400	Comp.
Anderson & Gustafson, Inc	Columbus	400	Skim.
National Refining Co	Findlay	1,000	Comp.
The Pure Oil Co	Heath	3,000	Skim.
The Craig Oil Co	Ironville	1,500	Wax
Solar Refining Co	Lima	6,500	Caomp.
National Refining Co.	Marietta	400	Wax
Paragon Refining Co	Toledo	8,000	Comp.
Standard Oil Co. (Ohio)	Toledo	......	....
Sun Co	Toledo	3,000	Comp.
Rajah Oil & Refining Co.	Youngstown	100	S. & L.
	OKLAHOMA		
Big Diamond Oil & Refining Co	Addington	......	....
Harvey Crude Oil Co	Allen	1,500	Skim.
Arbuckle Refining Co	Ardmore	1,000	Skim.
Cameron Refining Co	Ardmore	3,000	Skim.
Chickasaw Refining Co	Ardmore	7,500	Skim.
Imperial Refining Co	Ardmore	4,000	Skim.
The Pure Oil Co	Ardmore	7,000	Skim.
Bigheart Prod. & Refining Co	Bigheart	2,500	S. & L.
C. H. & W. Oil & Gas Co	Blackwell	......	....
Globe Oil & Refining Co	Blackwell	1,800	S. & L.
Modern Refining Co	Bladkwell	1,000	Skim.
Producers & Refiners Corporation	Blackwell	2,000	Skim.
Transcontinental Oil Co	Boynton	3,000	S. & L.
Illinois Refining Co	Bristow	2,500	Skim.
Carter Oil Co	Cartoco	15,000	Skim.
American Oil & Tank Line Co	Cleveland	1,250	Sk m.
Marland Refining Co	Covington	1,000	Skim.
Anderson & Gustafson, Inc	Cushing	1,500	Skim.
Biery Oil Co	Cushing	1,800	Skim.
Empire Refineries, Inc	Cushing	4,000	Skim.
Illinois Oil Co	Cushing	2,500	Skim.
Inland Refining Co	Cushing	2,500	Skim.
Marigold Oil & Refining Co	Cushing	2,0o0	Skim.
Occident Oil & Refining Co	Cushing	1,200	Skim.
The Pure Oil Co	Cushing	6,500	Skim.
Shaffer Oil & Refining Co	Cushing	6,000	Wax

PETROLEUM REFINERIES IN THE UNITED STATES.
(Continued)

COMPANY	LOCATION	Daily Capacity	Type of Plant
	OKLAHOMA		
Sinclair Refining Co	Cushing	6,500	Skim.
Cyril Refining Co	Cyril	600	Skim.
Constantin Refining Co	Devol	8,000	Skim.
Beaver Petroleum Refining Co	Dilworth	......	Skim.
Tidal Gasoline Co	Drumright	2,500	Skim.
Duncan Refining Co	Duncan	1,000	....
Bolene Refining Co	Enid	2,000	Skim.
Champlin Refining Co	Enid	8,000	Skim.
Oil State Refining Co	Enid	1,800	Skim.
Francis Oil & Refining Co	Francis	1,000	....
Frederick Oil & Refining Co	Frederick	600	Skim.
Garber Refinery, Inc	Garber	800	Skim.
Grandfield Oil & Refining Co	Grandfield	2,000	Skim.
Oklahoma-Texas Refining Co	Grandfield	1,200	Skim.
Union Oil & Refining Co	Grandfield	2,000	....
Rock Island Petroleum Co	Guthrie	1,500	Skim.
Bay State Refining Co	Healdton	1,000	Lube.
Cogswell Refining Co	Henryetta	2,000	....
Southern Refining Co	Haskell	1,000	Skim.
Meridian Petroleum Corporation	Hominy	800	Skim.
Great American Refining Co	Jennings	4,000	Skim.
Republic Refining Co	Jennings	1,000	Skim.
Damascus Refining & Manufacturing Co	Lawton	1,000	Skim.
Lawton Refining Co	Lawton	1,000	Skim.
Oklahoma Prod. & Refining Corp. of A	Muskogee	2,000	Wax
Sinclair Refining Co	Muskogee	600	S. & L.
Nyanza Refining Co	New Wilson	3,500	Skim.
Choctaw Oil & Refining Co	Oil City	50	Skim.
Cherokee Refining Co	Oilton	......	....
Cushing Petroleum Corporation	Oilton	1,000	Skim.
Pirtle-Pitman Oil Co	Oilkirk	2,000	Skim.
Atwood Refining Co	Oklahoma City	1,000	S. & L.
Choate Oil Corporation	Oklahoma City	2,000	S. & L.
Empire Refineries, Inc	Oklahoma City	2,000	Skim.
Home Petroleum Co	Oklahoma City	2,500	Skim.
Allied Refining Co	Okmulgee	1,000	S. & L.
Empire Refineries, Inc	Okmulgee	2,500	Wax
Indiahoma Refining Co	Okmulgee	10,000	Skim.
Meridian Petroleum Co	Okmulgee	3,000	Skim.
Phillips Higgrade Refining Co	Okmulgee	2,000	Skim.
Oneta Refining Co	Oneta	1,500	S. & L.
Empire Refineries, Inc	Ponca City	2,500	Wax
Marland Refining Co	Ponca City	5,000	Wax
Meridian Petroleum Co	Ponca City	2,000	S. & L.
Osage Mutual Oil & Refining Co	Pawhuska	1,000	Skim.
North American Oil & Refining Co	Pemeta	1,500	Skim.
Bison Refinery Co	Quay	1,000	Skim.
Mid-Continent Refining Co	Ringling	1,000	Skim.
Chestnut & Smith Corporation	Sand Springs	5,000	Skim.
Pierce Oil Corporation	Sand Springs	9,000	Wax
Big Six Prod. & Refining Co	Sapulpa	800	Skim.
Polar Prod. & Gasoline Co	Sapulpa	1,500	Skim.
Sapulpa Refining Co	Sapulpa	7,500	S. & L.
Constantin Refining Co	Tulsa	4,000	Skim.
Consumers Oil & Refining Co	Tulsa	2,000	Skim.
Cosden & Co	Tulsa	25,000	Wax
Mid-Co Gasoline	Tulsa	4,000	S. & L.
Pan American Refining Co	Tulsa	5,000	Skim.
The Texas Co	Tulsa	8,000	S. & L.
Tidal Gasoline Co	Tulsa	1,200	Skim.
Sinclair Refining Co	Vinita	10,000	S. & L.
Blue Ribbon Oil & Refining Co	Walters	......	....
Livingston Refiners Corporation	Walters	3,000	Skim.
Southern Oil Corporation	Walters	1,500	....
Canfield Refining Co	Yale	500	Skim.
Home Oil Refining Co. of Texas	Yale	2,000	Skim.

PETROLEUM REFINERIES IN THE UNITED STATES.
(Continued)

COMPANY	LOCATION	Daily Capacity	Type of Plant
	OKLAHOMA		
Ok-In Prod. & Refining Co	Yale	2,000	....
Pawnee Bill Oil & Refining Co	Yale	1,000	Skim.
Southern Oil Corporation	Yale	6,000	Skim.
The Sun)il Co	Yale	5,000	Skim.
Victor Refining Co	Yale	1,000	Skim.
Worth Oil & Refining Co	Yale	100	Lube
Yale Oil Corporation	Yale	1,200	Skim.
	PENNSYLVANIA		
Emery Manufacturing Co	Bradford	1,200	Wax
Kendall Refining Co	Bradford	650	Wax
Chippewa Oil Co	Bridgewater	200	S. & L.
Butler County Oil Refining Co	Bruin	1,000	Wax
Valvoline Oil Works, Ltd	Butler	1,000	Wax
Interior Oil & Gas Corporation	Clarendon	300	S. & L.
Levi Smith Refining Co	Clarendon	1,050	S. & L.
Tiona Refining Co	Clarendon	1,000	Wax
White Oil Corporation	Clarendon	1,000	S. & L.
The Canfield Oil Co	Coraopolis	400	S. & L.
Glenshaw Development Co	Coraopolis	600	Skim.
Pittsburgh Oil Refining Corporation	Coraopolis	1,000	Wax
Vulcan Oil Refining Co	Coraopolis	850	Wax
Pennsylvania Oil Products Refining Co	Eldred	1,000	Wax
Emlenton Refining Co	Emlenton	600	Wax
Atlantic Refining Co	Franklin	6,500	Comp.
Foco Oil Co	Franklin	600	S. & L.
Franklin Quality Refining Co	Franklin	700	S. & L.
Freedom Oil Works Co	Freedom	1,500	Wax
Pann. Refining Co	Karns City	100	Skim.
Starlight Refining Co	Karns City	100	Skim.
Conewango Refining Co	Langdale and Warren	1,400	S. & L.
Pure Oil Co	Marcus Hook	3,000	Comp.
Sun Company	Marcus Hook	10,000	S. L. & A.
The Texas Co	Marcus Hook	5,000	Asphalt
Island Petroleum Co	Neville Island	1,000	Was
Atlantic Refining Co	Oak Grove	200	Skim.
Continental Refining Co	Oil City	750	Wax
Independent Refining Co	Oil City	1,000	Wax
Penn-American Refining Co	Oil City	3,000	Wax
W. H. Daugherty & Son Refinjng Co	Petrolia	200	Skim.
Petrolia Refining Co	Petrolia	30	Skim.
Atlantic Refining Co	Philadelphia	50,000	Domp.
Atlantic Refining Co	Pittsburgh	4,000	Wax
A. D. Miller Sons Co	Pittsburgh	1,000	S. & L.
Waverly Oil Works Co	Pittsburgh	800	Lube.
Empire Oil Works	Reno	600	Wax
Crystal Oil Works	Rouseville	1,000	Wax
Penn. American Refining Co	Rouseville	3,000	Wax
Eastern Oil Refining Co	Russell	400	S. & L.
Amber Oil & Realty Co	Stoneham	75	Skim.
Tidioute Refining Co	Tidioute	600	S. & L.
American Oil Works	Titusville	800	S. & L.
Crew Levick Co	Titusville	2,000	Wax
Oil Creek Refining Co	Titusville	1,000	S. & L.
Titusville Oil Works	Tutusville	1,000	S. & L.
Crew Levick Co	Warren	935	Wax
Mutual Refining Co	Warren	500	S. & L.
Seneca Oil Works	Warren	560	Wax
Pure Oil Co	Warren	1,500	Wax
Superior Oil Works	Warren	400	Wax
United Refining Co	Warren	800	Wax
Warren Refining Co	Warren	1,700	Wax
Warr-Penn Refining Co	Warren	400	S. & L.
Wilburine Oil Works, Ltd	Warren	600	Wax

PETROLEUM REFINERIES IN THE UNITED STATES.
(Continued)

COMPANY	LOCATION	Daily Capacity	Type of Plant
	RHODE ISLAND		
Standard Oil Co. of N. Y	East Providence	10,000	Skim.
The Texas Co	Providence	5,000	Asphalt
	SOUTH CAROLINA		
Standard Oil Co. (N. J.)	Charleston	10,000	Skim
	TENNESSEE		
Victor Refining & Distributing Co	Nashville	500	Skim.
	TEXAS		
General Oil & Refining Co	Abilene	3,000	Skim.
Allen Reese S. Refining Co	Amarillo	2,000	Skim.
Humble Oil & Refining Co	Baytown	10,000	S. & L.
Magnolia Petroleum Co	Beaumont	25,000	Comp.
World Refining Co	Bridgeport	500	....
Baney Refining Corporation	Brownwood	500	Skim.
Brownwood Refining Co	Brownwood	200	Skim.
Carson Refining Co	Brownwood	400	Skim.
Freeport Gas Co	Bryanmound	5,000	Skim.
Bear Refining Co	Burkburnett	1,000	Skim.
Burk-Tex. Refining & Pipe Lin Co	Burkburnett	4,000	....
Crystal Petroleum & Refining Co	Burkburnett	600	Skim.
Invader Oil & Refining Co. of Texas	Burkburnett	1,500	Skim.
Manhattan Oil Refining Co	Burkburnett	3,500	Skim.
Chas. F. Noble Oil & Gas Co	Burkburnett	5,000	Skim.
Nortex Refining Co	Burkburnett	1,200	Skim.
Taxoil Refining Co	Burkburnett	300	Skim.
Tidal-Western Oil Corporation	Burkburnett	1,500	Skim.
Uniform Gasoline & Petroleum Co	Burkburnett	4,000	Top.
Victor Refining Co	Burkburnett	1,500	Skim.
Liberty Refining Co	Cisco	4,000	Skim.
Keen & Woolf Oil Co	Clinton	750	Top.
Magnolia Petroleum Co	Corsicana	2,000	Skim.
Aetna Petroleum Corporation	Dallas	2,500	Skim.
Hercules Petroleum Co	Dallas	3,500	S. ; L.
Sun Rise Refining Co	DeLeon	700	....
Dublin Oil & Refining Co	Dublin	2,500	Skim.
Keystone Refining Co	Dublin	1,000	Skim.
Keystone Refining Co	Dublin	5,000	....
Rex Refining Co	DeLeon	1,500	....
General Oil & Refining Co	Eastland	2,000	Skim.
Beavers-Electra Refining Co	Electra	2,000	Skim.
Waggoner Refining Co	Electra	1,500	Skim.
Rio Grande Oil Co	El Paso	2,000	Skim.
Gulf Refining Co	Fort Worth	5,000	Skim.
Home Oil Refining Co. of Texas	Fort Worth	5,000	Skim.
Magnolia Petroleum Co	Fort Worth	10,000	Skim.
Montrose Oil Refining Co., Inc	Fort Worth	4,000	Skim.
Ok-In Prod. & Refining Co	Fort Worth	5,000	....
Pierce Oil Corporation	Fort Worth	8,000	S. & L.
Souther Oil & Refining Co	Fort Worth	1,000	....
Star Refining & Prod. Co	Fort Worth	1,000	Skim.
Texas-Arizona Petroleum Co	Fort Worth	4,000	....
Texas Eagle Oil & Ref. Co., Inc	Fort Worth	5,000	....
Transcontinental Oil Co	Fort Worth	5,000	S. & L.
White Eagle Oil & Refining Co	Fort Worth	5,000	S. & L.
Empires Refineries, Inc	Gainesville	10,000	Skim.
The Texas Co	Gater	15,000	Skim.
Gorman Home Refinery	Gorman	2,000	Skim.
State Refining Association	Grand Prairie	1,200	Skim.
North Texas Oil & Refining Co	Greenville	......	....
Beacon Refining Co	Henrietta	2,500	Skim.
Galena Signal Oil Co. of Texas	Houston	3,000	S. & L.
Transatlantic Petroleum Co	Houston	1,000	Jube.
Deepwater Oil Refineries	Houston	1,000	Lube.
Burk Pipe Line & Refining Co	Iowa Park	2,500	Skim.

PETROLEUM REFINERIES IN THE UNITED STATES.
(Continued)

COMPANY	LOCATION	Daily Capacity	Type of Plant
	TEXAS		
Walker Consolidated Petroleum Co	Iowa Park	3,000	Skim.
K. M. A. Refining Co	K. M. A. Field	1,250	Skim.
Golden Star Refining Co	Mexia	1,000	Skim.
Texas-Mexia Refining Co	Mexia	1,000	Skim.
La Porte Oil Refining Co	Morgan's Point	1,000	Lube.
Pa-Tex Petroleum Co	Morgan's Point	350	....
Carolina Oil Co	Nacogodoches	400	Skim.
Mogul Prod. & Refining Co	Orange	3,000	....
Oriental Oil Co	Oriental	2,400	Wax
Panther City Oil & Refining Co	Panther	2,000	....
Port Houston Oil & Refining Co	Pasadena	200	....
White Oil Corporation	Pasadena	3,000	Lube.
Gulf Refining Co	Port Arthur	65,00	Comp.
The Texas Co	Port Arthur	40,000	Comp.
Turnbow Oil Corporation	Port Houston	......	....
The Texas Co	Port Neches	15,000	Asphalt
Consolidated Prod. & Refining Co	Ranger	3,000	....
Ranger Refining & Pipe Line Co	Ranger	2,000	Skim.
Great Eastern Oil & Refining Co	Riverside	2,000	....
Great Texas Oil & Refining Co	Saginaw	3,000	....
Southern Refining Co	San Antonio	500	Skim......
Grayburg Oil Co	San Antonio	1,800	Skim.
Humble Oil & Refining Co	San Antonio	2,000	Skim.
Elliott Jones & Co., Inc	San Antonio	4,000	Skim.
Mogul Prod. & Refining Co	San Jacinto	600	....
Buffalo Oil & Refining Co	Sherman	500	Skim.
Rex Oil & Refining Co	Sweetwater	1,000	Skim.
Sinclair Refining Co	Sinco (Houston)	5,000	S. & L.
Farmers Oil & Refining Co	Texarkana	2,000	....
Four States Refining Co	Texarkana	400	Skim.
Pierce Oil Corporation	Texas City	3,000	Wax
Thrall Oil Refining Co	Thrall	300	Skim.
Ranger Refining & Pipe Line Co	Tiffin	1,500	Skim.
Toyah Oil & Refinery Co	Toyah	50	....
Waco Refining Co	Waco	2,500	Skim.
Texas Oil Products Co	Waxahachie	......	....
Weatherford Refining Co	Weatherford	500	Skim.
American Refining Co	Wichita Falls	5,000	Skim.
Bankers Petroleum & Refining Co	Wichita Falls	1,000	Skim.
Mears Gasoline Co	Wichita Falls	2,000	Skim.
Lone Star Refining Co.	Wichita Falls	3,500	Skim.
Miller Petroleum Co	Wichita Falls	2,500	Skim.
New Tex Refining Co	Wichita Falls	1,500	....
Panhandle Refining Co	Wichita Falls	5,500	Skim.
Power Oil Refining Co	Wichita Falls	1,500	Skim.
Ranger-Wichita Oil & Refining Co	Wichita Falls	3,000	Skim.
Southwestern Prod. & Refining Co	Wichita Falls	1,000	Skim.
Sunshine State Oil & Refining Co	Wichita Falls	2,500	Skim.
Texhoma Oil & Refining Co	Wichita Falls	2,500	Skim.
	UTAH		
Utah Oil Refining Co	North Salt Lake	4,000	Wax
Dixie Oil Co	Virgin	50	....
	VIRGINIA		
The Texas Co	Norfolk	5,000	Asphalt
	WEST VIRGINIA		
The Pure Oil	Cabin Creek Junction	3,000	Wax
Warner-Quinlan Co	Cairo	500	Skim.
Elk Refining Co.	Falling Rock	1,000	S. & L.
Standard Oil Co. (N. J.)	Parkersburg	2,200	Wax
Ohio Valley Refining Co	St. Mary's	1,000	Wax

PETROLEUM REFINERIES IN THE UNITED STATES.
(Concluded)

COMPANY	LOCATION	Daily Capacity	Type of Plant
	WYOMING		
Midwest Refining Co	Casper	35,000	Wax
Standard Oil Co. (Ind.)	Casper	8,100	S. & C.
Northwestern Oil Refining Co	Cowley	1,000	Skim.
Wyatt Oil & Refining Co	Fetterman	500	Skim.
Mutual Refining & Prod. Co	Glenrock	2,500	Skim.
Midwest Refining Co	Greybull	10,000	Skim.
Wind River Refining Co	Lander	900	Skim.
Standard Oil Co. (Ind.)	Laramie	1,700	S. & C.
Midwest Refining Co	Laramie	5,000	Skim.
Lovell Refinery	Lovell	500	Skim.
McWhorter Oil & Refining Co	Lusk	250	Skim.
McWhorter Oil & Refining Co	Osage	250	Skim.
Alliance Oil & Refining Co	Thermopolis	1,000	Top.

PETROLEUM REFINERIES IN CANADA.

COMPANY	LOCATION	Daily Capacity
Imperial Oil Co. (L)	Dartsmouth, N. S	3,000
Imperial Oil Co. (L)	Ioco, B. C	3,500
Imperial Oil Co. (L)	Montreal, Que	2,500
Calgary Petroleum Products, Ltd	Okotoks, Alt	30
Canada Southern Oil & Refining Co	Okotoks, Alt	25
Southern Alberta Ref., Ltd	Okotoks, Alt	30
Canadian Oil Companies, Ltd. (L)	Petrolia, Ont	800
Canadian Oil Prod. & Ref. Co. (L)	Petrolia, Ont	150
British Columbia Refining Co	Moody, B. C	500
Continental Oil Co	Regina, Sask	......
Imperial Oil Co. (L)	Regina, Sask	2,500
Imperial Oil Co. (L)	Sarnia, Ontario	20,000
British-American Oil Co. (L)	Toronto	800
Great Lakes Oil & Ref. Co	Wallaceburg	250
North Star Oil & Ref. Co	Winnipeg	1000

PETROLEUM REFINERIES IN MEXICO.

COMPANY	LOCATION	Daily Capacity
Atlantic Refining Co	Port Lobos	10,000
(Cia. Refinadores y Productori de Petroleo La Atlantica).		
Texas Company	Port Lobos	......
Mexican Eagle Co., Ltd	Puerto Minatitlan	15,000
	(Isthmus of Tehauntepec.)	
La Corona Petroleum Co	Tampico	6,000
Mexican Eagle Oil Co., Ltd	Tampico	12,500
Pierce Oil Corporation	Tampico	10,000
Huasteca Petroleum Co	Tampico	60,000
Standard Oil Co. (N. J.)	Tampico	6,000
Texas Company	Tampico	6,000
Mexican Eagle Oil Co., Ltd	Tuxpan	5,000
Pierce Oil Corporation	Vera Cruz	2,500

The producing, distributing and marketing organizations owned and controlled by the Royal Dutch-Shell oil combine: (Oil, Paint, Drug Reporter)

1. Acetylene Gas and Benzine Maat.
2. Alliance Co. (Mexico).
   Operates 16,000 acres held in dispute by Mexican Eagle and Mexican Petroleum (Doheny) companies.
3. Anglo-Mexican Petroleum Co., Ltd. (London).
   Marketers for Mexican Eagle and Eagle Transport Co.; hence now closely related to Shell-Dutch. Markets in Central and South American and British Isles.
4. Anglo-Egyptian Oilfields, Ltd. (Egypt).
   July 6, 1911. $6,561,000. Managed by Anglo-Saxon.
5. Anglo-Persian Oil Co. (Persia).
   Marketing agreement until 1922 with Dutch-Shell.
6. Anglo-Saxon Petroleum Co., Ltd. (London).
   June 29, 1907. $38,880,000.
7. Asiatic Petroleum Co., Ltd. (Ceylon).
   Refiners, distributors, June 29, 1903. $9.720,000.
8. Asiatic Petroleum Co., Ltd. (Ceylon).
   Refiners, distributors, carriers. Nov. 13, 1917. $972,000.
9. Asiatic Petroleum Co., Ltd. (Egypt).
   Property acquired from Anglo-Saxon. March 25, 1911. $972,000.
10. Asiatic Petroleum Co., Ltd. (Federated Malay States).
    Feb. 29, 1911. $243,000. Property acquired from Anglo-Saxon.
11. Asiatic Petroleum Co., Ltd. (North China).
    Aug. 11, 1913. From Anglo-Saxon. $2,430,000.
12. Asiatic Petroleum Co., Ltd. (India).
    Property acquired from Anglo-Saxon. $2,673,000.
13. Asiatic Petroleum Co., Ltd. (Philippine Islands).
    Registered Jan. 30, 1914. $72,900.
14. Asiatic Petroleum Co., Ltd. (Siam).
    Aug. 11, 1913. From Anglo-Saxon. $364,500.
15. Asiatic Petroleum Co. (South China).
    Property acquired from Anglo-Saxon. Aug. 11, 1913. $1,701,000.
16. Asiatic Petroleum Co., Ltd. (Straits Settlements).
    Feb. 28, 1911. From Anglo-Saxon. $1,215,000.
17. Astra Romana Societe Anonyme (Rumania).
    Geconsolidceerde Hollandsche Maat. is heavily interested. $13.027,500.
18. Astra Refining Co. (Rumania)). $960,000.
19. Atjan Mining Co. (Sumatra).
20. Bataafche Petroleum Maatschappij (Holland).
    Jan. 1, 1907. Anglo-Saxon, managers. $56,000,000.
21. Belgian Benzine Co. $100,000.
22. Benzine Lagerungs Geselschaft (Blexien). $121,500.
23. Benzine Lagerungs Geselschaft (Breslau). $12,150.
24. Benzine Lagerungs Geselschaft (Hamburg). $7,000.
25. Benzine Lagerungs Geselschaft (Madgeburg). $85,050.
26. Benzinwerke Regensburg Geselschaft. $170,000.
27. Benzinwerke Rhenania (Dusseldorf). $204,120.
28. Bermudez Co., Ltd. (Venezuela). Sub. of General Asphalt Co.
29. *Bolivar Concessions (1917), Ltd. (Venezuela).
    Interested in Venezuelan Oil Concessions, Ltd., only. A source of supply but not a part of the Dutch-Shell group.
30. British-American Oil Co. (Toronto).
31. British-Borneo Petroleum Syndicate. $583,200.
32. British Imperial Oil Co., Ltd. (London).
    Property acquired from Anglo-Saxon, Aug. 7, 1912. $97,200.
34. British Imperial Oil Co., Ltd. (South Africa).
    Aug. 12, 1912. From Anglo-Saxon, $48,600.
35. British Western Isles Syndicate, Ltd. (London).
    June 4, 1912. $486,000.
36. California Oilfields, Ltd. (Liquidated). (Shell Company of California.)
    $1,914,000.
37. Caribbean Petroleum Syndicate, Ltd. (Venezuela).
    Owned jointly by General Asphalt and Dutch-Shell.

38. Ceram Oil Syndicate, Ltd. (Island of Ceram). (Dutch-Shell.) $972,000.
39. Ceram Petroleum Co. (Dutch East Indies). (Dutch-Shell.)
40. Chijoles Oil, Ltd. (Mexico). (See Tampico Panuco Oilfields, Ltd.) $972,000. Tampico Panuco Petroleum Maat.
41. Cleophane Oil & Gas Company (Oklahoma). (Liquidated.)
42. *Colon Development Co., Ltd. (Venezuela). Friendly to, but probably not as yet a part of the group. $486,000.
43. Commercial & Mining Company (London). $48,600.
44. Curacoa Petroleum Co. $1,600,000.
45. Curacoasche Scheepvaart Maatschappij (Island of Curacoa). Sept., 1916. Subsidiary of Bat. Peet. Maat. $800,000.
46. Danske Engelske Benzin Petroleum Akt. (Denmark). $135,000.
47. Danske Tyske Petroleum Company, Ltd. (Denmark). $240,000.
48. Dordtsche Petroleum Maatschappij. Dutch-Shell selling and refining agency in Dutch East Indies. $12,000,000.
49. Eagle Oil Transport Company, Ltd. (Tank steamers for Mexican crude and fuel. Now related to Dutch-Shell through Mexican-Eagle purchase.)
50. East Borneo Maat. (Borneo). $883,600.
51. Ernste Bayerische Petroleum Geselschaft. $346,500.
52. Finnische Petroleum Import, Geselschaft (Finland).
53. Geconsolideerde Hollandsche Petroleum Co. (Holland). Interested in Astra Romana, and Dutch-Shell companies are largely interested in it. Jan., 1907. $9,600,000.
54. General Asphalt Company, U. S. A. (Trinidad and Venezuela). $31,000,000. (The Dutch-Shell controls the petroleum production of all of this company's Trinidad and Venezuela holdings, but is apparently not interested in its asphalt business).
55. Gravenhag Association (London). (Liquidated.)
56. Grozny-Sundja Oil Fields, Ltd. (Russia). Managed by Anglo-Saxon. $1,458,000. March 31, 1913.
57. Helouan Petroleum Co. (Liquidted.) $243,000.
58. Java Petroleum Co. (Liquidated.) $280,000.
59. Kasbee Syndicate, Ltd. (Russia). $6.240,000.
60. Koetei Exploratie Maat. $520,000.
61. Koninkliijke Nederlandsche Maatschappij tot Exploitatie van Petroleum in Nederlandsche Indie. Incorporated, Holland, June 16, 1890, and amalgamated with Shell Transport & Trading Co., Ltd., as from Jan. 1, 1907. $60,700,000. (Royal Dutch.)
62. King Oil Company (Oklahoma). (Liquidated.)
63. La Corona Petroleum Maatschappiji (Holland). To consolidate Dutch-Shell interests in Mexico. $10,000,000. Steamships.
64. La Corona Petroleum Company (Mexico).
65. Lubricating & Fuel Oils, Ltd. (London). $486,000.
66. Mexican Eagle Oil Co., Ltd. (Mexico). $30,000,000.
67. Mineralöl & Benzine Werke (Rhenia). $240,000.
68. Mineralölwerke (Rhena nia).
69. Moeara Enim (Sumatra). $4,000,000.
70. Moesillir (Sumatra). $3,840,000.
71. Nederlandsche-Indische Eploration Syndicate.
72. Nederland-Indische Industrie and Handel. Maat. Anglo-Saxon, manager. $8,000,000. Blaik Papes, Koete.
73. Nederlandsche-Indische Petroleum Maat. $144,000.
74. Nederlandsche-Indische Tank Stoom-boot Company. Anglo-Saxon and B. P. M., managers. $1,200,000.
75. New Orleans Refining Co., Roxana Petroleum Corporation. $400,000.
76. New Schibaieff Petroleum Co., Ltd. (South Russia). $5,637,000. Anglo-Saxon is manager.
77. Norske Engelske Mineral Oil Akt. (Norway). $147,420.
78. North Caucasian Oil Fields, Ltd. (Grosny, South Russia). Jan. 29, 1901. Anglo-Saxon, manager. $3,645,000.
79. Nouvelie Societe du Standard Russe de Grosny. (Dutch-Shell.) $6,240,000
80. Oilfields of Mexico Company. Marketing and shipping obligations with Mexican Eagle. $8,500,000.
81. Panama Canal Storage Company.

82. Petroleum Development Co., Ltd. (Trinidad). Subsidiary of General Asphalt Co.

83. Puova Oil Company (Oklahoma). (Roxana Corporation.)

84. Periak Petroleum Maatschappij (North Sumatra). Dutch-Shell. 4,000,000.

85. Quintuple Oil Company (Oklahoma). Roxana Corporation. (Liquidated.)

86. Regatul-Roman. $4,632,000.

87. Rising Sun Petroleum Company (Japan). $2,000,000.

88. Red Sea Oilfields, Ltd. (Liquidated.) $2,187,000.

89. Roxana Petroleum Corporation (New Jersey). Holding company for Mid-Continent and Wyoming properties. $60,000,000. Mar. 8, 1917.

90. Roxana Petroleum Company of Oklahoma. Roxana Petroleum Corporation. $8,000,000. 1914.

91. Sarawak Brunei (Borneo).

92. Sebatik Petroleum Maat. $800.000.

93. Shanghai Langkat Maat. (Sumatra). $1,095,000.

94. Shell Company of Canada. $243,000.

95. Shell Company of California. To consolidate Dutch-Shell interests in California. $45,000.000. July, 1915.

96. "Shell" Marketing Company, Ltd. (London). Marketing in United Kingdom. $7,290,000.

97. Shell Transport & Trading Company, Ltd. (London). Registered Oct. 18, 1897, as a transporter and marketer of oil. Amalgamated with the Royal Dutch as from Jan. 1, 1907. $111,880,000.

98. Signal Oil Company (Oklahoma). (Roxana Corporation.) (Liquidated.)

99. Simplex Refining Company (California).

100. Societe Commerciale et Industrielle de Eaphte Caspienne et de la Mer Noire (Russia). (Rothschilds.) Feb., 1912. $5,200,000. Dutch-Shell.

101. Societa Anonima Italiana. $291,000.

101-a. Societa Nafta (Genoa).

102. Societe de Mazout (Russia). Dutch-Shell. (Rothschilds.) Feb., 1912. $12,000,000.

103. Sumatra Palembang (Sumatra). $2,800,000.

104. Sumatra Petroleum Company. (Liquidated.) $1,458,000.

105. Svensk Engelske Mineral Oil Akt. (Sweden). $540,000.

106. Tampico-Panuco Oil Fields, Ltd. (Mexico). Held by the Tampico-Panuco Petroleum Maat., which in turn is held the Bat. Pet. Maat. $1,550,000. Dec., 1916.

107. Tampico-Panuco Petroleum Maatschappij (Holland). Holds the Tampico-Panuco Oilfields, Ltd., the Chijol Oil, Ltd., and the Tampico-Panuco Valley Railway Co. $2,880,000.

108. Tampico-Panuco Valley Railway Company (Mexico). (See above.)

109. Tatakan Petroleum Company (?). $1,560.000.

110. Trinidad Lake Petroleum Company, Ltd. A subsidiary of the General Asphalt Company. All oil production controlled by Dutch-Shell.

111. Trinidad Oilfields, Ltd. Assets taken over by United Britain Oilfields of Trinidad, Ltd. Aug., 1913. $1,940,000.

112. Turner Oil Company (California). Bought out by Shell of California. $500,000.

113. United British Oilfields of Trinidad, Ltd. Managed by the United British West Indies Petroleum Syndicate, Ltd. $3,152,000. July 1, 1913.

114. United British Producing Company, Ltd. (Trinidad). Managed by the United British West Indies Petroleum Syndicate, Ltd. $1,458,000.

115. United British Refineries, Ltd. (Trinidad). Managed by United British West Indies Petroleum Syndicate, Ltd. $486,000.

116. United British West Indies Petroleum Syndicate, Ltd. (West Indies, British Guiana or elsewhere). Anglo-Saxon Company heavily interested along with the Burmah and Anglo-Persian crowd. July 18, 1912. $972,000.

117. Ural Caspian Oil Corporation, Ltd. 10,000 square miles on northeastern seaboard of Caspian Sea. April 15, 1910. $4,860,000. Looks like Dutch-Shell.

118. Valley Pipeline Company (California). (Dutch-Shell of California.) $10,000,000.

119. Venezuelan Oil Concession, Ltd. Dutch-Shell financially interested, and to be managers for at least 15 years from 1915. $2,430,000.

120. Vereignte Benzinfabriken Ces. $21,870.

121. W. K. Oil Company (California). Liquidated and owned by Shell of California. $500,000.

122. Yarhola Pipeline Company. (Roxana Petroleum Corporation.) $10,000,000.

123. Zuid Perlak Maat. (Sumatra). $600,000.

*Not a part of the combine—associated by marketing or other agreements.

STANDARD OIL GROUP.

Refiners and Marketers.

Company	Capitalization	Market Price	Market Value
Anglo-American	$15,000,000	25	$ 75,000,000
Atlantic Refining	5,000,000	1350	67,000,000
Borne-Scrymser	200,000	500	1,000,000
Chesebrough Mfg.	1,500,000	310	4,650,000
Continental Can	3,000,000	655	19,650,000
Galena Signal, 2d pfd	6,000,000	107	6,420,000
Galena Signal Oil, 1st pfd	2,000,000	125	2,500,000
'alena Signal, common	16,000,000	138	22,080,000
.nternational Pet.	6,265,000	31	38,844,000
Solar Refining	2,000,000	370	7,400,000
S. O. of California	99,373,310	282	280,282,706
S. O. of Indiana	30,000,000	800	240,000,000
S. O. of Kansas	2,000,000	600	12,000,000
S. O. of Kentucky	6,000,000	400	24,000,000
S. O. of Nebraska	1,000,000	550	5,500,000
S. O. of New Jersey	98,338,300	710	698,201,930
S. O. of New York	75,000,000	382	286,500,000
S. O. of Ohio	7,000,000	525	36,750,000
Swan & Finch	1,450,000	100	1,450,000
Vacuum Oil	15,000,000	440	66,000,000
Midwest Refining Co. (Wyoming)	....	...	....

Producing Companies.

Ohio Oil Company	$15,000,000	386	$231,000,000
Prairie Oil & Gas Company	18,000,000	750	135,000,000
South West Penn	20,000,000	313	62,600,000
Washington Oil	100,000	40	400,000
Carter Oil Co.	25,000,000	...	....

Pipe Lines and Carriers.

Buckeye Pipe Line	$10,000,000	100	$ 20,000,000
Crescent Pipe Line	3,000,000	36	2,160,000
Cumberland Pipe Line	1,488,851	200	2,977,600
Eureka Pipe Line	5,000,000	167	8,320,000
Illinois Pipe Line	20,000,000	184	36,800,000
Indiana Pipe Line	5,000,000	105	10,500,000
National Transit	6,362,500	22	11,198,000
New York Transit Company	5,000,000	185	9,250,000
Northern Pipe Line	4,000,000	112	4,480,000
Prairie Pipe Line	27,000,000	300	81,000,000
Southern Pipe Line	10,000,000	165	16,500,000
South West Penn	3,500,000	100	3,500,000
Union Tank Line	12,000,000	130	15,600,000

Total market values all companies	$2,486,214,236
Market value refining and marketing companies	1,834,928,636
Market value producing companies	429,000,000
Market value pipe line and carrying companies	222,282,600

DIRECTORY OF OIL ASSOCIATIONS.

Western Petroleum Refiners' Association—President, W. D. Richardson, Meridian Petroleum Corp., 324 Rialto Bldg., Kansas City, Mo.; Secretary, H. G. James, 800 Republic Bldg., Kansas City, Mo.

American Petroleum Institute—President, Thos. A. O'Donnell, 15 West 44th St., New York, N. Y.; Secretary, R. L. Welch, 15 West 44th St., New York, N. Y.

National Petroleum Association—President, Col. U. G. Lyons, Warrens, Pa.; General Counsel, Judge C. D. Chamberlin, Guardian Bldg., Cleveland, Ohio.

Kansas Oil Men's Association—President, John S. Longshore, care Sunflower Oil & Supply Co., Topeka, Kas.; Secretary, H. F. Bagby, Wichita, Kas.

American Independent Petroleum Association—President, L. V. Nicholas, Nicholas Bldg., Omaha, Nebr.; Secretary, H. F. Reynolds, 14 East Jackson Blvd., Chicago, Ill.

Oklahoma Oil Jobbers' Association—President, D. L. Gilland, 118 West 6th St., Tulsa, Okla.; Secretary, John E. Hutchens, Box 811, Enid, Okla.

Independent Oil Men's Association—President, T. J. Gay, Gay Oil Co., Little Rock, Ark.; Secretary, E. E. Grant, 110 South Dearborn St., Chicago, Ill.

Texas Oil Jobbers' Association—President, D. E. Little, Fort Worth, Tex.; Secretary, Albert W. Wolters, Taylor, Texas.

Minnesota Petroleum Club—Secretary, W. B. Cline, care Manhattan Oil Products Co., St. Paul, Minn.

Nebraska Independent Oil Men's Association—President, T. Wilbur Thornhill, Charleston Oil Co., Charleston, S. C.

Southern Petroleum Dealers' Association—President, L. V. Nicholas, Howard and 17th St., Omaha, Nebr.; Secretary, D. C. Patterson, Camden, S. C.

South Dakota Oil Jobbers' Association—President, H. L. Freeman, Lake Park Corp., Sioux Falls, S. D.

New Mexico Petroleum Association—Address, Allison Bldg., Roswell, N. M.

Independent Oil Marketers' Association—President, W. L. Moore, Dixie Oil & Grease Co., Atlanta, Ga.

Louisiana Petroleum Refiners' Association—President, I. G. Abney, Louisana Oil Refining Corporation, Shreveport, La.; Secretary, E. F. Buchanan, Crichton Refining Co., Crichton, La.

Wisconsin Independent Oil Men's Association—President, S. G. Hastings, Jr., Barkhousen Oil Co., Green Bay, Wis.

Indiana Oil Jobbers' Association—President, Paul Moorehead, Moorehead Oil Co., Hammond, Ind.; Vice-President, F. C. Enz, Evansville; Secretary, Russell Galloway, Hammond.

Arkansas-Tennessee Oil Jobbers' Association—President, T. G. Gay, Gay Oil Co., Little Rock, Ark.

Central West Oil Men's Association—Bowling Green, Ky.—President, Edward R. List; Secretary, F. L. Reeves.

Kentucky Oil Men's Association—Lexington, Ky.—President, Albert R. Marshall; Secretary, E. E. Loomis.

Central New York Oil Jobbers' Association—Syracuse, N. Y.—President, Alfred M. Cady, Syracuse, N. Y.; Secretary, W. D. Metzger, Syracuse, N. Y.

Mid-Continent Oil & Gas Association—213-14 Kennedy Bldg., Tulsa, Okla.—President, W. N. Davis; Secretary-Counsel, Harry H. Smith.

Gulf Coast and Louisiana Oil & Gas Association—14 Rossonian Bldg., Houston, Texas—President, W. S. Farish; Vice-President, I. R. Bordages; Secretary, Niels Esperson.

Mid-Continent Oil & Gas Association—Texas-Louisiana Division, Apartment 14, Rossonian Bldg., Houston, Texas—President, W. D. Cline; Secretary, Howard Bennette.

Gulf Coast Oil Producers' Association—Beaumont, Texas—President, J. C. Wilson; Secretary-Treasurer, R. J. Braud.

National Oil Exchange—Harris Trust Bldg., Chicago, Ill.—President W. D. Simmons, Viscosity Oil Co., Chicago; Secretary, T. J. Gay, Gay Oil Co., Little Rock, Ark.

Independent Oil and Gas Producers' Association of Louisiana—Shreveport, La.—President, C. D. Keen; Secretary, Thos. O. Harris.

New York State Oil Producers' Association—Bolivar, N. Y.—President, John P. Herrick, Olean, N. Y.; Secretary-Treasurer, W. Frank Richart, Wellsville, N. Y.

Independent Oil Producers' Agency—Union Oil Bldg., Los Angeles, Calif.—President, L. P. St. Clair; Secretary-Treasurer, W. B. Robb.

Ohio Gas and Oil Men's Association—Columbus, Ohio—President, F. O. Levering; Secretary-Treasurer, Wm. H. Thompson.

DIRECTORY OF OIL ASSOCIATIONS—Continued.

Independent Petroleum Marketers' Association—930-31 Marsh-Strong Bldg., Los Angeles, Calif.—President, H. S. Botsford; Secretary-Manager, H. H. Maxson.

Northwestern Oil Producers' Association—Bradford, Pa.—President, F. D. Wood; Secetary-Treasurer, Earl Weber.

Oil and Gas Producers' Association—Okmulgee, Okla.—President, John R. Rebold; Secretary, W. R. Alexander.

Oil Producers' Association—608 Main St., Bradford, Pa.—President, Wm. J. Healey; Secretary, Earl S. Weber.

Oil Traders Association of New York—35 South William St., New York—President, F. J. Snyder; Secretary, Jos. C. Smith.

Oil Trade Association of Philadelphia, Inc.—Philadelphia, Pa.—President, T. G. Cooper, T. G. Cooper & Co.; Secretary, James Stevenson, Stevenson Bros. & Co.

West Texas Oil Men's Association—Mineral Wells, Texas—President, J. Edgar Pew; Secretary, W. E. O'Neal.

AMERICAN GAS SYNDICATES.

CALIFORNIA

Southern California Gas Co	Garland Bldg	Los Angeles
Southern Counties Gas Co	724 S. Spring St	Los Angeles
Coast Valleys Gas & Electric Co	58 Sutter St	San Francisco
W. F. Boardman Co	718 Mission St	San Francisco
Coast Counties Gas & Electric Co	454 California St	San Francisco
Northern California Power Co	995 Market St	San Francisco
Pacific Gas & Electric Co	445 Sutter St	San Francisco

COLORADO

Western Light & Power Co		Boulder

FLORIDA

Southern Utilities Co		Palatka

ILLINOIS

Copley Gas & Electric Syndicate		Aurora
Illinois Traction System		Champaign
American Coke & Chemical Co	208 S. LaSalle St	Chicago
H. M. Byllesby & Co	Cont. & Coml. Natl. Bank	Chicago
Gas & Electric Improvement Co	33 S. LaSalle St	Chicago
Metropolitan Gas & Electric Co	Harris Trust Bldg	Chicago
L. E. Myers Co	Monadnock Block	Chicago
Peoples Gas Co	108 S. LaSalle St	Chicago
Middle West Utilities Co	72 W. Adams St	Chicago
North American Light & Power Co	2013 Peoples Gas Bldg	Chicago
Public Service Co. of Northern Illinois	72 W. Adams St	Chicago
Union Utilities Co	39 S. LaSalle St	Chicago
Wisconsin Power, Light & Heat Co	72 W. Adams St	Chicago
United Light & Railways Co	836 Edison Bldg	Chicago
E. A. Potter	Rector Bldg	Chicago
Southern Illinois Light & Power Co		Hillsboro

INDIANA

Northern Indiana Gas & Electric Co		Hammond
Interstate Public Service Co	510 Board of Trade Bldg	Indianapolis
W. A. Martin Gas Syndicate		LaPorte
Consolidated Gas & Oil Co		Ridgeville

IOWA

Iowa Railway & Light Co		Cedar Rapids
Runner Gas Co		Charles City
American Gas Construction Co		Newton
Iowa Gas & Electric Co		Washington

LOUISIANA

American Cities Co	201 Barone St	New Orleans

MARYLAND

General Utilities & Operating Co	Munsey Bldg	Baltimore
Southern Gas & Electric Corporation	213 Courtland St	Baltimore

MASSACHUSETTS

Commonwealth Gas & Electric Co	78 Devonshire St	Boston
Massachusetts Gas Co.	111 Devonshire St	Boston
Massachusetts Lighting Co.	77 Franklin St	Boston
Stone & Webster	147 Milk St	Boston
Charles H. Tenny & Co.	201 Devonshire St	Boston
Twin State Gas & Electric Co.		

MICHIGAN

Appleby & Wagner		Alma
W. E. Moss & Co	710 Union Trust Bldg	Detroit
American Public Utilities Co		Grand Rapids
United Light & Railways Co		Grand Rapids
Michigan Light Co.		Jackson
Utilities Operating Co	310 Peck Bldg	Kalamazoo

AMERICAN GAS SYNDICATES (Continued)

MINNESOTA

Public Improvement Co	348 Security Bldg	Minneapolis

MISSOURI

Union Public Service Co	1116 Commerce Bldg	Kansas City
Central Power & Light Co	1420 Chemical Bldg	St. Louis
Southern Illinois Light & Power Co		St. Louis
Light & Development Co. of St. Louis	750 Railway Exchange Bldg	St. Louis

NEBRASKA

Gas Construction Co	48th and Leavenworth Sts	Omaha
Union Power & Light Co	424 First Natl. Bank Bldg	Omaha

NEVADA

Sierra-Pacific Electric Co		Reno

NEW JERSEY

Cumberland County Gas Co		Millville
Public Service Gas Co	80 Park Place	Newark
Florida Utilities Co	715 Broad St	Trenton

NEW YORK

Brooklyn Union Gas Co	176 Remsen St	Brooklyn
Eastern Oil Co		Buffalo
South Shore National Gas & Fuel Co	Marine Trust Co. Bldg	Buffalo
Republic Light, Heat & Power Co	Marine Trust Co. Bldg	Buffalo
Empire Coke Co	103 Castle St	Geneva
New York State Gas & Electric Co		Ithaca
Associated Gas & Electric Co	43 Exchange Place	New York City
American Light & Traction Co	120 Broadway	New York City
American Power & Light Co	71 Broadway	New York City
Consolidated Gas Co	124-130 E. 15th St	New York City
Henry L. Doherty & Co	60 Wall St	New York City
Electric Bond & Share Co	71 Broadway	New York City
Federal Light & Traction Co	60 Broadway	New York City
General Gas & Electric Co	50 Pine St	New York City
Commonwealth Power, Railway & Light Co	14 Wall St	New York City
General Engr. & Management Corporation	141 Broadway	New York City
General Engr. & Management Corporation	141 Broadway	New York City
Lehigh Power Securities Corporation	71 Broadway	New York City
Nassau & Suffolk Light Co	149 Broadway	New York City
National Fuel Gas Co	26 Broadway	New York City
National Utilities Co	61 Broadway	New York City
North American Co	30 Broad St	New York City
Pearson Engineering Corporation	115 Broadway	New York City
United Gas & Electric Engineering Corp	61 Broadway	New York City
H. D. Wallbridge & Co	14 Wall St	New York City
J. G. White Management Corporation	43 Exchange Place	New York City
Peck-Shannahan-Cherry, Inc	Savings Bank Bldg	Syracuse
Utica Gas & Electric Co		Utica

NORTH CAROLINA

North Carolina Public Service Co		Greensboro
Carolina Power & Light Co		Raleigh

OHIO

Consolidated Gas, Electric & Water Co	1123 Illum Bldg	Cleveland
Continental Gas & Electric Corporation	Cuyahoga Bldg	Cleveland
Ohio Cities Gas Co		Columbus
Ohio Fuel Supply Co		Columbus
Ohio Gas Light & Coke Co		Napoleon

OKLAHOMA

Empire Gas & Fuel Co		Bartlesvlle

OREGON

Pacific Power & Light Co	Gasco Bldg	Portland

AMERICAN GAS SYNDICATES (Concluded)

PENNSYLVANIA

American Gas Co	West Washington Square	Philadelphia
Eastern Light & Fuel Co	Real Estate Trust Bldg	Philadelphia
Day & Zimmermann		Philadelphia
C. H. Geist Co	Land Trust Bldg	Philadelphia
Girardville Gas Co	4014 Chestnut St	Philadelphia
Gribbel Syndicate Co	1513 Race St	Philadelphia
United Chemical & Industrial Co	Widener Bldg	Philadelphia
National Gas, Elec. St. & Power Co	Witherspoon Bldg	Philadelphia
Public Service Co	1142 Real Estate Trust Bldg	Philadelphia
Philadelphia Suburban Gas & Elec. Co	S. W. Cor. 7th and Locust	Philadelphia
J. C. Reed & Co	Finance Bldg	Philadelphia
Union Railway Supply Co	Real Estate Trust Bldg	Philadelphia
United Gas Improvement Co	Broad and Arch Sts	Philadelphia
Arkansas Natural Gas Co	223 Fourth Ave	Pittsburgh
Manufacturers Light & Heat Co	248 Fourth Ave	Pittsburgh
Ohio Fuel Supply Co		Pittsburgh
Philadelphia Co	435 Sixth Ave	Pittsburgh
Union Natural Gas Corporation	Union Bank Bldg	Pittsburgh
Wabash Gas Co	Benedum-Trees Bldg	Pittsburgh
United Service Co	700 Scranton Life Bldg	Scranton

RHODE ISLAND

Blackstone Valley Gas & Electric Co		Pawtucket

TEXAS

North Texas Gas Co		Dallas
Texas Power & Light Co	Interurban Bldg	Dallas

VIRGINIA

Southern Gas & Electric Corporation		Richmond
Virginia Railway & Power Co		Richmond

WASHINGTON

North Pacific Public Service Co	Tacoma Bldg	Tacoma

WEST VIRGINIA

Boyd E. Horner Syndicate		Clarksburg
Columbia Gas & Electric Co		Huntington

WISCONSIN

Wisconsin Power, Light & Heat Co	900 Gay Bldg	Madison
Wisconsin Securities Co	1408 First Natl. Bank Bldg	Milwaukee

CANADA

Dominion Gas Co		Hamilton, Ont.
Quebec Railway, Light, Heat & Power Co		Quebec

PRINCIPAL PIPELINES.

Pipeline	Mileage	Capacity, Barrels
Alluwe Pipeline Co. (Kas. Oil Ref. Co.), Alluwe Dist., Okla., to Coffeyville, Kas.	40	2,500
Amalgamated Petroleum Co., Salt Lake Dist., Cal., to Los Angeles, Cal.	70	9,000
American Petroleum Co., Humble to E. Houston, Tex.	20	....
Associated Oil Co., Coalinga Dist., Cal., to Monterey, Cal.	105	15,000
Associated Oil Co., Santa Barbara Co., Cal., to Gaviota, Cal.	60	23,000
Arkansas City Pipeline Co., Blackwell to Arkansas City, Kas.	..	....
Associated Pipeline Co., Kern River Dist., Cal., to Port Costa, Cal.	281	13,000
Associated Pipeline Co., Kern River Dist., Cal., to Port Costa, Cal.	278	26,000
Bessemer Pipeline, Titusville, Pa., to W. Pa.	..	....
Buckeye Pipeline Co., Lima Division, Ohio-Ind. state boundary to Ohio-Penn. state boundary	700	75,000
Buckeye Pipeline Co., Macksburg Division, Eastern Ohio to Ohio-Penn. and Ohio-W. Va. boundary	350	10,000
Colive Oil Co., Healdton to Ardmore	..	....
Cosden & Co., adjacent wells to Bigheart, Okla.	..	500
Cosden Pipeline Co., various Okla. oil Dist. to West Tulsa, Okla.	..	30,000
Crescent Pipeline Co., Greggs, Pa., to Marcus Hook, Pa.	315	5,600
Crown Pipeline Co., Okmulgee, Okla., to Muskogee, Okla.	58	....
Cumberland Pipeline Co., Southeastern Kentucky to Kentucky-W. Va. boundary	475	10,000
Emery Pipeline Co., adjacent oil Dist. to Bradford, Pa.	480	1,000
Empire Pipeline Co., Eldorado and Augusta, Kas., to Ponca City, Okla.	85	....
Empire Pipeline Co., Ponca City, Okla., to Norfolk, Okla.	67	....
Empire Pipeline Co., northern Oklahoma to Independence, Kas.	70	....
Empire Pipeline Co., Healdton, Okla., to Gainesville, Tex. (Total)	55	35,000
Empire Pipeline Co., Gainesville, Tex., to Red River, Tex.	17	8 inch
Eureka Pipeline Co., Kentucky-W. Va. boundary and Ohio-W. Va. boundary to W. Va.-Pa. boundary	4,300	65,000
Franklin Pipe Co., adjacent fields to Franklin, Pa.	..	150
General Pipeline Co., Midway Dist., Cal., to Los Angeles and San Pedro.	156	25,000
General Pipeline Co., Liebere, Cal., to Mojave, Cal.	52	5,000
Gulf Pipeline Co., Tex.-Okla. State Line to Port Arthur, Tex.	458	28,000
Gulf Pipeline Co., Batson, Tex., to Sour Lake and Houston	76	14,000
Gulf Pipeline Co., La.-Tex. State Line to Lufkin Station, Tex.	117	9,600
Gulf Pipeline Co., Saltillo Station, Tex., to Fort Worth, Tex.	124	7,000
Gulf Pipeline Co. of Okla., Bartlesville, Okla., to Okla.-Tex. boundary.	275	25,000
Gulf Refining Co., of La., Mansfield, La., to La.-Tex. boundary	21	10,000
Gulf Pipeline Co., Olean, Tex., to Red River, Tex.	305	8 inch
Gulf Pipeline Co., Fort Worth, Tex., to Saltillo, Tex.	124	6 inch
Gulf Pipeline Co., Caddo, Tex., to Lufkin, Tex.	98	6 inch
Gulf Pipeline Co., Ranger, Tex., to Fort Worth, Tex.	86	8 inch
Gulf Pipeline Co., Houston to Sour Lake, Tex.	63	6 inch
Hale Petroleum Co., Eldorado, Kas., to Wichita, Kas.	20	7,500
Illinois Pipeline Co., Alton, Ill., to Centerbridge, Pa.	1,300	60,000
Illinois Pipeline Co., Grass Creek, Wyo., to Chatham, Wyo.	25	....
Illinois Pipeline Co., Elk Basin, Wyo., to Frannie, Wyo.	20	....
Illinois Pipeline Co., Big Muddy, Wyo., to Casper, Wyo.	20	20,000
Imperial Pipeline Co., Ltd., Sarnia, Ont., to Cygnet, O.	155	8 inch
Indiana Pipeline Co., Griffith, Ind., to Indiana-Ohio boundary	800	110,000
Magnolia Petroleum Co., Electra, Tex., to Sabine, Tex.	569	60,000
Magnolia Petroleum Co., Healdton, Okla., to Fort Worth, Tex.	137	60,000
Magnolia Petroleum Co., Cushing Dist., Okla., to Addington, Okla.	150	50,000

PRINCIPAL PIPELINES—(Continued).

Pipeline	Mileage	Capacity, Barrels
Magnolia Petroleum Co. (Double Line) Red River, Tex., to Beaumont, Tex.	800	8 inch
Magnolia Petroleum Co., Electra, Tex., to Bowie, Tex.	76	8 inch
Maryland Pipeline Co., Kay County, Okla., to Ponca City, Okla.	..	....
Midwest Refining Co., Salt Creek Dist., Wyo., to Casper, Wyo.	90	13,000
National Pipeline Co., Oil Fields in Wood Co., Ohio, to Findlay, O.	60	1,000
National Pipeline Co., Oil Fields in Southeastern Ohio to Marietta, Ohio	110	560
National Transit Co., Nedska, Pa., to New York-Pa. boundary	205	....
National Transit Co., Colegrave, Pa., to Milway, Pa	175	....
National Transit Co., Milway, Pa., to Fawn Grove, Pa	35	75,000
National Transit Co., Milway, Pa., to Point Breeze, Pa	70	....
National Transit Co., Milway, Pa., to Centerbridge, Pa	70	....
Natrona Pipeline Co, Salt Creek, Wyo., to Casper, Wyo	90	6 inch
New York Transit Co., Pa.-New York boundary to Buffalo, N. Y.	130	55,000
New York Transit Co., Olean, N. Y., to Bayonne, N. J., and Long Island, N. Y.	1,100	....
Northern Pipe Co., Pa.-Ohio boundary to Pa.-N. Y. boundary	525	60,000
Oklahoma Pipeline Co., Creek County, Okla., to McCurtain, Okla.	229	35,000
Paragon Refining Co., Sandusky County, Ohio, to Toledo, Ohio	237	4,000
Pierce Pipeline Co., Healdton, Okla., to Fort Worth, Tex	135	....
Prairie Pipeline Co., Drumright, Okla., to Ranger, Tex	..	8 inch
Prairie Pipeline Co. (Double Line), Ranger, Tex., to Red River, Tex.	260	8 inch
Prairie Pipeline Co., Cushing Dist., Okla., to Humboldt, Kan.	701	100,000
Prairie Pipeline Co., From Humboldt, Kan., to Sugar Creek, Mo., and Wood River, Ill	1,820	94,000
Prairie Pipeline Co., McCurtain, Okla., to Ida, La	90	31,000
Prairie Pipeline Co., Eldorado-Augusta, Kan., to Neodesha, Kan.	85	....
Pierce Pipeline Co., Healdton, Okla., to Fort Worth, Tex	135	....
ville, Pa.	210	9,000
Producers' Transportation Co., Coalinga Dist., Cal., to Junction, Cal.	41	15,000
Producers' Transportation Co., Sunset Dist., Cal., to Junction, Cal.	50	20,000
Producers' Transportation Co., Kern River Dist., Cal., to McKittrick, Cal	39	....
Producers' Transportation Co.,Lost Hills Dist., Cal., to Trunk Line, Cal	13	....
Producers' Transportation Co., Lost Hills Dist., Cal., to Trunk Line, Cal	3	....
Producers' Transportation Co., Junction, Cal., to Port San Luis, Cal.	74	30,000
Pure Oil Pipeline Co., Morgantown, W. Va., to Marcus Hook, Pa.	250	10,000
Rio Brava Oil Co., Saratoga, Tex., to Sour Lake, Tex	13	1,500
Pierce Pipeline Co., Fort Worth, Tex., to Red River, Tex	76	8 inch
Sinclair-Cudahy Pipeline Co., Cushing Dist., Okla., to Kansas City and Chicago	750	...
Sinclair-Cudahy Pipeline Co., Cushing Dist., Okla., to Coffeyville, Kan.	70	....
Sinclair-Cudahy Pipeline Co., branches and lateral in Okla. and Kansas	340	50,000
Sinclair-Cudahy Pipeline Co., Cushing field, Okla., to Whiting, Ind.	..	8 inch
Sinclair-Cudahy Pipeline Co., Cushing field to Healdton, Okla.	..	8 inch
Southern Pipeline Co., Pa.-W. Va. boundary to Philadelphia, Pa.	1,130	51,000
Southwestern Penn. Pipelines, exclusively in southwestern Pa.	1,650	45,000
Standard Oil Co., Cal., Kern River Dist., Cal., to Richmond, Cal.	281	65,000

PRINCIPAL PIPELINES (Concluded).

Pipeline	Mileage	Capacity, Barrels
Standard Oil Co., Cal., Midway Dist., Cal., to Bakersfield, Cal..	32	65,000
Standard Oil Co., Cal., Coalinga Dist., Cal., to Mendota, Cal.....	29	28,000
Standard Oil Co., Cal., Lost Hills Dist., Cal., to Pond, Cal......	21	20,000
Standard Oil Co., Cal., Northan Dist., Cal., to El Segundo, Cal..	24	27,000
Standard Oil Co., Cal., Newhall Dist., Cal., to Ventura, Cal.....	45	1,400
Standard Oil Co., Cal., Santa Mina Dist., Cal., to Port Hartford, Cal.	32	20,000
Standard Oil Co. of La., Ida, La., to Baton Rouge, La..........	522	35,000
Sun Co., Seneca and Wood Co., O., to Toledo, O................	250	1,000
Sun Pipeline Co., Humble, Tex. (also Yale, Okla.) to Sabine Pass, Tex.	100	21,000
Sun Pipeline Co., Humble, Tex., to Sour Lake, Tex............	53	6 inch
Sun Pipeline Co., Sour Lake, Tex., to Spindle Top, Tex.........	23	8 inch
Sun Pipeline Co., Spindle Top, Tex., to Sabine Pass, Tex........	25	8 inch
Sun Pipeline Co., Batson, Tex., to Sour Lake, Tex..............	16	8 inch
Sun Pipeline Co., Spindletop, Tex., to Sun Station, Tex..........	4	6 inch
Texas Co. (main lines) Bartlesville, Okla., to Port Arthur, Tex..	742	20,000
Texas Co. (main lines) Electra, Tex., to West Dallas, Tex.......	160	17,000
Texas Co. (main lines) Vivian, La., to Port Arthur, Tex.......	253	20,000
Texas Co. (main lines) Evangaline, Tex., to Garrison, Tex.......	96	9,600
Texas Co. (main lines) Healdton, Okla., to Sherman, Tex.......	60	12,000
Texas Co. (laterals) in Oklahoma and Texas..................	222	....
Texas Co. Dennison, Tex., to Port Arthur	400	6 inch
Texas Co., Logansport, Tex., to Port Arthur, Tex.............	155	8 inch
Texas Co. Ranger, Tex., to Fort Worth, Tex..................	85	8 inch
Texas Co. (two lines) Dallas, Tex., to Fort Worth, Tex.........	60	8 inch
Texas Co., Dayton, Tex., to Goose Creek......................	25	8 inch
Texas Co., Electra, Tex., to Fort Worth, Tex..................	130	6 inch
Texas Co., Humble, Tex., to Houston, Tex....................	15	6 inch
Texas Co., Healdton, Okla., to Gates Station, Tex.............	..	8 inch
Tidewater Pipe Co. (main line) Stoy, Ill., to Bayonne, N. J.....	830	11,000
Tidewater Pipe Co. (laterals) in Pennsylvania, N. Y., Ill. and Ind.	1,929	....
Union Oil Co., Orcutt, Cal., to Port San Luis, Cal...............	65	....
Union Oil Co., local lines in Ventura County, Cal..............	43	....
Union Oil Co., local lines in Los Angeles, Orange County, Fields, Cal.	51	....
Valley Pipeline Co., Coalinga Dist., Cal., to San Francisco Bay...	170	25,000
War Pipeline Co., Cushing Field, Okla., to Humboldt, Kan......	..	8 inch
Wilburine Pipeline Co., Shannopin, Pa., to Warren, Pa...........	125	5,000
Yarhola Pipeline Co., Healdton, Okla., to Cushing, Okla........	135	9,000
Yarhola Pipeline Co., Cushing, Okla., to St. Louis, Mo., and Wood River, Ill.	400	36,000

PIPE LINE TRANSPORTATION.

The oil pipe line was first introduced about 56 years ago and since that time has so demonstrated its superiority as a means of carrying crude oil from the well to the refinery, that this method of transportation has largely superseded all others. This has made possible the building of refineries in or near the large consuming centers, rather than at the wells, which are usually remote from the centers of population.

The pipes for conveying the oil are laid on the surface of the ground or at a depth varying from 18 inches to 3 feet beneath the surface and the main lines are generally eight inches in diameter. The oil is forced through the pipes by means of pumps operated either by steam or by internal combustion engines. The pump stations are located from 1½ to 90 miles apart, varying with the condition of the country through which the pipe lines extend, and the viscosity of the oil to be handled.

Some of the large pipe line systems are hundreds of miles in length. It is estimated by the U. S. Geological Survey that the total mileage of oil trunk lines in the United States today is approximately 34,000 and that the gathering systems, which are a fundamental part of the trunk systems, aggregate about 11,500 miles in length, making a total of 45,500 miles.

At the time most of the lines were constructed, the average cost per mile based on eight inch pipe was about $6,500. The cost of the average pump station at that time varied from $130,000 to $250,000. The fixed investment in pipe lines is estimated to be approximately $500,000,000.

The difference between the published pipe line tariff rates and the railroad rates for shipping crude oil have always been so large that refiners and producers even though they have no pipe line systems of their own, cannot afford to ship by rail except for comparatively short distances. The pipe line rates, although greatly increased in recent years, are still much lower than those charged by the railroads for tank car shipments.

In the construction of oil trunk lines, a reconnaissance survey is first made of the route for the line. In making the choice, attention is given to avoiding as much as possible excessively rough country, swamps, rivers, etc., and selecting a route which will admit of pumping stations being located near suitable supplies of water. Where possible, the lines are routed along or near the lines of railroads. In some instances they have been placed in the railroad right of way, the construction and maintenance of the pipe lines being greatly facilitated thereby. As soon as the route is definitely decided upon, careful surveys are made and maps prepared showing the exact locations, grades and contours. Rights of way for one or more lines of pipes and for telegraph and telephone lines are purchased outright; in others, they amount to a perpetual easement for the use of the land upon which the pipe lines and telegraph lines are constructed, giving the owners of the lines ingress and egress to and from the property for the purpose of laying new lines and operating and maintaining the ones in use. In some states pipe line companies have been granted powers of acquiring rights of way by condemnation proceedings.

The specifications for the pipe require that it be of a uniform quality of steel, that the threads be carefully made so as to make as perfect a union between the joints as possible, and that it be capable of safely withstanding an internal pressure of 2,000 pounds per square inch.

The actual construction work is commenced by the "right-of-way gang" who prepare the difficult places of the route selected. They remove the trees where these will interfere with the construction work, dig ditches and place casings at railroad crossings, build bridges across rivers and where necessary, build roads to facilitate the hauling and handling of the pipe.

Behind the "right-of-way gang" come the "stringing gang" who distribute the pipe.

The "stringing gang" is followed by the "pipe-laying gang." Where the work is done by hand, that is, using ordinary pipe tongs, this gang consists of about forty men. In its group are stabbers, tongsmen, rope men, bar men, jack men, etc., each of whom has his special work to perform in joining one length of pipe to another. In some instances the pipes have been joined by pipe machine. This is a more modern method enabling a very much smaller laying gang to be used and doing much more rapid work. Cases are on record where one pipe machine operated by a gang of 28 men has laid as much as 8,700 feet of eight-inch pipe in one day of nine hours, whereas the usual accomplishment of an ordinary gang of 40 men is from 2,500 to 4,000 feet per day.

Following the pipe gang comes the "ditching gang" whose duty is to dig the ditch and bury the pipe. Where the route is through comparatively level country free from rock in place, ditching machines can be used to good advantage. Where the country is hilly, plowing the ditch with teams and shoveling the dirt out by hand, is often advisable, but where rocky country is encountered, it is often necessary to dig the ditch entirely by hand, blasting much of the material to be removed. In some instances, the ditch has been dug first and the pipe joints, resting on skids or sleepers, were screwed into place over the open ditch. Where rivers or large bodies of water are to be crossed, it is customary to join the pipe on a flat boat or raft, which is moved along as the work proceeds. In places where the cost of digging ditches would be excessive, or where the pipe lines if buried would pass through strongly alkaline soil, it is usual to paint the pipe with asphalt, then before the asphalt has had opportunity to dry, to cover the painted pipe with a good grade of roofing paper, applying on the outside of the paper a second coat of asphalt.

The viscosity of the oil to be transported and the topography of the country through which the pipe lines pass, are the governing factors determining the distance between pumping stations. The average distance between pumping stations in the midwestern and eastern States is about 35 miles, while the average distance between stations in California, where a relatively thick, viscous oil is handled, is about 12 miles, although stations are sometimes not more than a mile and a half apart, and in extreme cases are placed as much as 90 miles apart.

The operating equipment of a pumping station consists of a pump house, boiler house, tool house, garage or barn, office, probably two oil tanks, ranging in size from 10,000 to 55,000 barrels capacity, water tower, fuel oil tanks and feed water tanks.

Equipment is usually provided in excess of ordinary demands so that there is always in reserve extra pump power to meet unusual demands, thereby avoiding shut-downs where repairs are needed to pumps and boilers. The usual forms of power are steam pumps and internal combustion engines. The pumps are designed to deliver through an eight inch pipe line approximately 30,000 barrels of oil in 24 hours, working under a line pressure of 700 to 900 pounds per square inch.

Practically all the pipe line companies engaged in the transportation of petroleum have, in addition to their trunk lines, extensive systems of gathering lines. These are provided for the purpose of collecting the oil from the producers' tanks and running it to a tank farm or to some point where it can conveniently enter the main trunk lines. In some cases, however, these gathering systems are owned by the producing companies, and not by the same companies that operate the trunk lines. The pipe used in such systems is usually smaller than that in the trunk line, most of it being from four to six inches in diameter.

As in the case of railroad operations, it is necessary to provide means for instant communication between different parts of a pipe line system. For this reason it is usual for the pipe line companies to own and operate their own telegraph and telephone systems. The telephone lines usually parallel the pipe lines, and are constructed along the same right of way, so that the line walker who patrols the pipe lines can also look after the condition of the telephone and telegraph system.

A pipe line system such as described is administered from a general office, and from branch offices located at convenient points in the territory served. The system is divided into divisions, each division being under the supervision of a superintendent, who looks after the operations of the line within his territory. The division is in turn sometimes subdivided into districts, each district being in charge of a foreman. Foremen report directly to the superintendents of their districts, and the superintendents to the general manager who has his office at the headquarters of the company.

The office is divided into several departments, such as an oil transportation department, an engineering department, a legal department, a tax department, an accounting department and a treasury deparment. (The above matter was furnished by C. P. Bowie in report of Bureau of Mines No. 2164.)

In general it may be said that the cost of transportation of petroleum is 4c to 10c per 100 barrels per mile. This widely varies because of the different ground contours, temperatures and oil viscosities.

Typical costs per mile of pipe line are as follows: (Sulentic in "Petroleum")

	Including Booster Stations	Without Booster Stations	Typical Oil capacity per day @ 800 lbs.
4 inch line	$9,000	$6,500	6,000
6 inch line	12,500	8,500	18,000
8 inch line	16.000	11,000	30,000
10 inch line	19,000	13,500	60,000

In order to make a very crude estimate of the cost of transporting oil by pipeline when using equipment of the highest economy, assume a single line operating under the following conditions at a load factor of 80 per cent for 300 days per year:

Size of line, 8 inches.

Length of line, 33 miles.

Pressure in line, 700 pounds per square inch.

Rate of discharge, 900 barrels per hour.

At this rate, the discharge would be 21 600 barrels per day or 6.480,000 barrels per year of 300 days. Assuming 6.5 barrels per ton, the yearly discharge would approximate 1,000,000 tons. The work equivalent of this discharge would be 33,000,000 ton-miles, calling for the continuous expenditure of 257 hp. Assuming the mechanical efficiency of the engine to be 75 per cent, the actual horsepower necessary to install would be 342.

The assumed costs would be as follows:

Line: 33 miles at $1 65 per foot	$287,500
Right of way at $0 25 per rod	2,640
Freight: 79 cars at $250	19,750
Haulage: 900 tons at $14 50	13,050
Laying pipe at $0.075 per foot	13,060
Burying pipe at $0.20 per foot	34,850
Engines, pumps, installed accessories	68,500
Pump stations, buildings and foundations	30,000
Tanks—	
Two 55,000 barrel at $18,500 each	37,000
Two 500 barrel at $500 each	1,000
Telegraph line: 33 miles at $550	18,150
Superintendence and incidentals	8,500
Total assumed costs	$534,000

The operating expense, including fixed charges based on the total assumed costs would be as follows:

Interest at 6 per cent	$32,040
Depreciation at 5 per cent	26,700
Administration	10,000
Attendance at pump stations and lines	11,500
Repairs to equipment, lines, etc	4,000
Fuel for pumping—3,000 barrels at $2.65	7,950
Total operating expense	$92,190

From which the cost of operation per ton-mile under the assumed conditions would be

$$\frac{92,190}{33,000,000} = \$0.0028$$

The relation between the cost of pipe line transportation and rail transportation is in the ratio of 1 to 10.

It should be noted that most of the pipeline costs are fixed and are mainly independent of the amount of oil pumped. As a result the transportation cost per ton-mile will vary almost inversely with the load factor of the line. If this hypothetical pipe line should be operated only one-tenth of the time assumed, the unit transportation cost would equal the rail cost. Furthermore, these figures are based on a life of 20 years (5 per cent amortization). A railroad would probably be used for various classes of freight as long as it existed, but a pipe line is of service only as long as oil is present for transportation. If the pipe line in question were to become obsolete in 10 years through the exhaustion of the oil fields or other causes, the ton-mile cost would be greatly increased.

The following examples show the relations existing between pressure, capacity, diameter, length of line and power required.

Disregarding viscosity, the general hydraulic formula for friction head in a pipe discharging a uniform volume is

$$F = k\frac{v^2L}{2gD} \qquad (1)$$

in which

F = friction head in feet of water = lb. per sq. in. ÷ 0.433
k = friction coefficient for 38 gravity oil = 0.024
v = velocity of flow, ft. per sec.
g = acceleration of gravity = 32 2 ft. per sec.
L = length of line, ft.
D = diameter of line, ft.

The formula for pressure in the line may be stated as

$$P = 0.433\,k\frac{v^2L}{2gD} \qquad (2)$$

in which P = pressure in line in pounds per sq. in.

The discharge Q of the line, cu. ft. per sec. can be easily derived and stated as

$$Q = \frac{3.1416\,D^2v}{4} \qquad (3)$$

in which Q varies directly as v. Since P varies directly as v^2 in Formula (2) and Q varies directly as v in Formula (3) it follows that P varies directly as Q^2.

The net horsepower required for a pipe line may be most readily calculated by noting that the pressure per square foot is equal to the number of foot-pounds required to displace 1 cu. ft. of oil or

$$Hp. = \frac{144\,P\,Q}{550} \qquad (4)$$

The following data in regard to the 36-mile, 8-inch Alton pipe line operating between Carlton and Wood River, is given by S. A. Sulentic, in "Petroleum." This line, constructed in 1913, has four stations, in each of which are installed four units each consisting of a 100 horsepower type of engine direct-connected to a 6 inch by 18 inch herringbone-geared power pump with 8 inch suction and 6 inch discharge. The performance of one station equipment (three units) is as follows:

Oil pumped during 10 days, barrels	140,000
Oil pumped per day, average, barrels	14,000
Pressure maintained in line, pounds per sq. in.	700
Brake horsepower, average	196
Pump efficiency, estimated, per cent	85
Fuel consumed by engines during 10 days, barrels	65.8
Fuel consumed by engines per day, pounds	2,020
Brake-horsepower-hours per day = 196 × 24	4,704
Fuel consumption per b.hp..-hr. pounds	0.43
Ft.-lb. of work per day developed by the engine 196 × 33,000 × 24 × 60	9,320,000,000
Ft.-lb. of work per day in oil pumped = 9,320,000,-000 × 0.85 (85% efficiency)	7,900,000,000
B.T.U. in fuel consumed per day = 2,000 × 18,000	36 000,000
Ft.-lb. of work per 1,000,000 B.T.U.	217,000,000
Daily operating cost:	
Fuel oil: 6.58 barrels at $1 50	9.87
Lubricating oil: 2 gallons at $0.22	0.44
Cylinder oil: 1.6 gallons at $0.21	0.34
Attendance: Total salaries of 2 engineers, 2 assistant engineers, 1 chief engineer and 2 telegraph operators	41.50
	$52.15
Cost per b.hp.-hr. ($52.15 ÷ 4,704)	0.011
Cost per barrel of oil pumped ($52.15 ÷ 14 000)	0.0037
Bbl. of oil pumped per barrel of fuel consumed (14,000 ÷ 6.58)	2,130

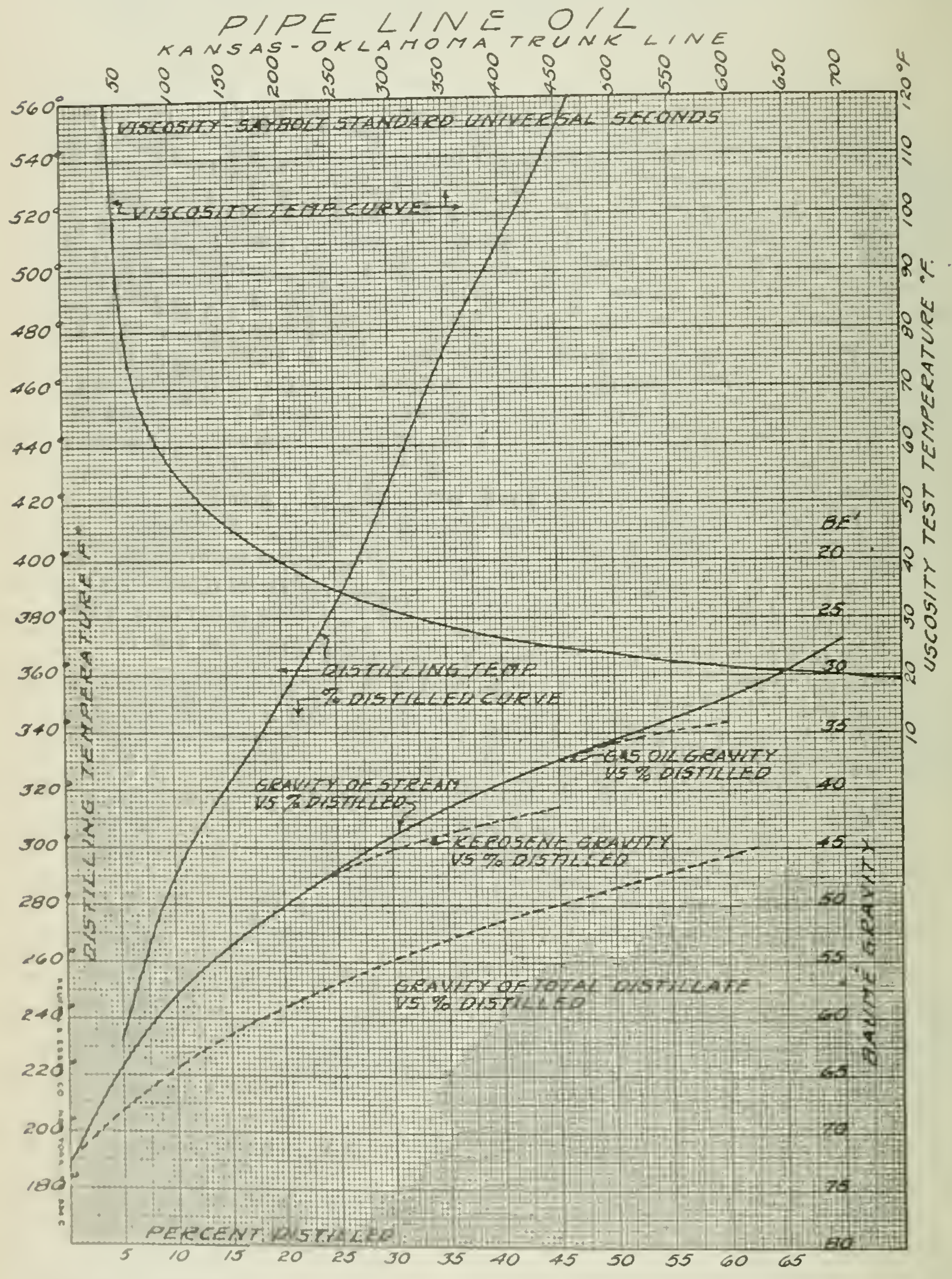


Fig. 20—Viscosity and Physical Properties of Typical Pipe Line Oil.

FRICTION PRESSURE LOSS AND CAPACITY OF OIL PIPE LINES AS AFFECTED BY VISCOSITY OF THE OIL.

$$P = \frac{c\,g\,q^2}{d^5} \quad \text{or} \quad q = \sqrt{\frac{Pd^5}{c\,g}}$$

P=friction pressure loss in pounds per square inch per 1000 ft. of pipe.
g=density of the oil at temperature of pumping.
q=gallons of oil per minute.
d=internal diameter of the pipe in inches.
c=coefficient from following table.

$M = \frac{g\,q}{d\,v}$ (from the value found for M look up the value of c in the table below. Use this value in the formulae given above.)

$$V = \text{absolute viscosity} = g\left(.00220\,S - \frac{1.8}{S}\right)$$

S=Saybolt viscosity in seconds (for viscosity conversion factors see section on method of testing for viscosity). (See fig. 21).

M	C	M	C	M	C
10,000	0.190	750	0.355	85	0.600
9,000	0.195	700	0.360	80	0.550
8,000	0.200	650	0.370	75	0.500
7,000	0.210	600	0.380	70	0.460
6,000	0.220	550	0.390	65	0.425
5,000	0.230	500	0.395	60	0.450
4,000	0.240	450	0.400	55	0.500
3,000	0.250	400	0.415	50	0.550
2,500	0.260	350	0.430	45	0.600
2,000	0.270	300	0.440	40	0.675
1,800	0.285	250	0.460	35	0.775
1,600	0.300	200	0.480	30	0.900
1,400	0.310	180	0.500	25	1.100
1,200	0.320	160	0.515	20	1.350
1,000	0.330	140	0.520	18	1.500
950	0.335	120	0.550	16	1.700
900	0.340	100	0.555	14	1.950
850	0.345	95	0.570	12	2.200
800	0.350	90	0.585	..	.....

DIAMETER FUNCTIONS OF STANDARD IRON AND STEEL PIPE.

Nominal Diameter, Inches	Actual Diameter, Inches (d)	d^4	d^5
½	.622	.14968	.09310
¾	.824	.46101	.37987
1	1.049	1.2109	1.2702
1½	1.510	6.7190	10.818
2	2.067	18.254	37.731
2½	2.496	37.161	91.750
3	3.068	88.597	271.82
4	4.026	262.72	1057.7
6	6.065	1353.1	8206.4
8	8.071	4243.3	34248.0
8	7.981	4057.2	32381.
10	10.192	10790.	109980.
10	10.136	10555.	106990.
10	10.020	10080.	101000.
12	12.000	20736.	248830.
14	14.250	41234.	587590.
15	15.250	54085.	824800.

PIPE LINE FORMULA.

Compiled by the National Transit Co.

P=Gauge pressure in pounds per square inch.
M=Number of miles.
B=Discharge in barrels (42 gal) per hour.
C=Constant for pipe sizes.

$$B = \sqrt{\frac{C \times P}{M}}$$

C for 2-inch pipe=36
C for 3-inch pipe=289
C for 4-inch pipe=1225
C for 5-inch pipe=3600
C for 6-inch pipe=9025
C for 8-inch pipe=38416
C for 10-inch pipe=116964
C for 12-inch pipe=289444

For every 3 degrees above 35 degrees Be' add 1% to B.

For every 3 degrees below 38 degrees Be' deduct 1% from B.

Net H. P.=BxPx.00041.

EQUIVALENT LENGTHS OF STANDARD PIPE TO ALLOW FOR VARIOUS SCREW FITTINGS IN CONDUITS CARRYING NON-VISCOUS LIQUIDS.

Nominal Pipe Size, Inches	Actual Inside Diameter, Inches	Gate Valve	Long-Sweep Elbow or on Run of Standard Tee	Medium-Sweep Elbow or on Run of Tee Reduced in Size ¼	Standard Elbow or on Run of Tee Reduced in Size ½	Angle Valve	Close Return Bend	Tee Through Side Outlet	Globe Valve
Factor of Resistance......		0.25	0.23	0.42	0.67	0.90	1.00	1.00	2.00
½.........	0.662	0.335	0.442	0.56	0.89	1.20	1.34	1.79	2.68
¾.........	0.824	0.475	0.627	0.79	1.27	1.71	1.90	2.52	3.80
1	1.049	0.640	0.844	1.07	1.72	2.30	2.56	3.40	5.12
1¼.........	1.38	0.902	1.19	1.51	2.42	3.24	3.61	4.80	7.22
1½.........	1.61	1.09	1.43	1.83	2.92	3.92	4.36	5.79	8.72
2	2.06	1.49	1.96	2.50	3.99	5.36	5.96	7.92	11.92
2½.........	2.46	1.86	2.46	3.13	5.00	6.72	7.47	9.93	14.94
3	3.06	2.46	3.25	4.11	6.66	8.87	9.86	13.11	19.72
3½.........	3.54	2.92	3.80	4.91	7.84	10.53	11.70	15.56	23.40
4	4.026	3.44	4.53	5.77	9.22	12.37	13.70	18.28	27.50
4½.........	4.506	3.95	5.20	6.63	1.60	14.22	15.80	21.01	31.60
5	5.047	4.57	6.00	7.68	12.20	16.47	18.30	24.33	36.60
6	6.065	5.72	7.55	9.61	15.30	20.61	22.90	30.45	45.00
7	7.024	6.90	9.10	11.59	18.50	24.84	27.60	36.70	55.20
8	7.981	8.10	10.69	13.60	21.71	29.16	32.40	43.09	64.80
10	10.020	10.70	14.10	17.97	28.70	38.52	42.80	56.92	85.60
12	12.090	12.50	17.80	22.68	36.28	48.60	54.00	71.82	108.00

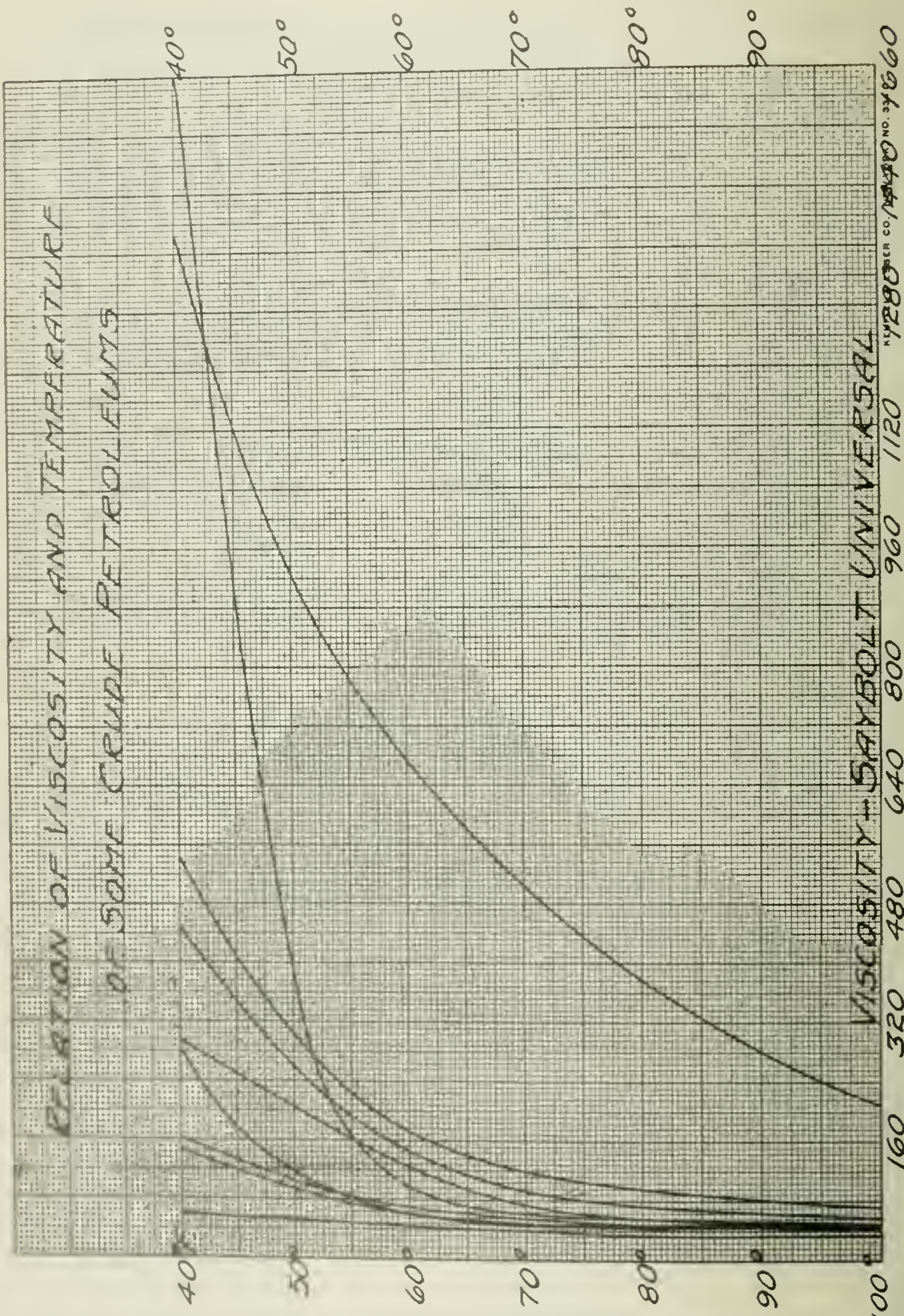


Fig. 21.—Relation of Viscosity to Temperature of Typical Crude Petroleums.

STORAGE OF PETROLEUM.

Petroleum is usually stored above ground in cylindrical steel or iron tanks of convenient proportions for requirements. A roof is provided to prevent admission of rain water and contamination. In the case of light oils evaporation losses are diminished by the use of an air tight roof but in the latter case, a special equilibrium valve is needed to allow the escape of the gas if the pressure exceeds a predetermined safe degree and to admit air when oil is abstracted. The main features characterizing an oil tank are:

1. Large draw-off valve at lowest point to remove water and sediment.

2. One or two manholes near base for entry.

3. Inlet pipe leading above top of tank and either discharging on base or flowing into second large pipe that conducts new oil to the base of tank and prevents undue splashing and consequently liberation of light products.

4. Garge glass or succession of gauge glasses to read off oil level.

5. Sometimes a float and outside measuring board and indicator to show level of liquid.

6. Floating or adjustable suction pipe to draw oil from top of liquid when discharging.

7. Sometimes for light oils in hot climates a water spray for roof or a dished roof for holding water.

8. The construction of an earthen embankment round the tank enclosing a space from one and a half to twice the volume of the tank so that in the event of a fire, the burning oil may be prevented from spreading.

9. All oil tanks should be painted outside: the finishing coat should be white or nearly so in a hot climate to prevent undue absorption of heat.

10. Oil tanks, especially when intended for light gravity oil, should be very closely riveted, and great care should be taken to close the seams before the rivets are inserted and driven.

11. One or more dipping pipes, sometimes combined with the escape valves are usually fitted for sampling.

The cost of steel tankage varies with the price of metal and labor, but for standard sized tanks the price varies from about $1.00 per barrel of capacity for 1,000 barrel tanks to $0.30 per barrel for 55,000 barrel tanks (1921).

LOSSES IN THE STORAGE OF CRUDE PETROLEUM.

The principal losses in the storage of crude petroleum are due to evaporation, to fire and to seepage.

Oils having the greatest loss are the crude oils containing the most gasoline, since they are the most volatile, most readily form explosive and inflammable mixtures and due to their low viscosity most readily flow through walls of loose texture.

The loss from evaporation is greater the larger the amount of gasoline. The loss also depends upon the temperatures of storage and upon the amount of surface exposed to atmospheric circulation. If the tank or container is perfectly tight, then there will be no loss by evaporation.

There are three general types of storage now in use in the Mid-Continent fields;—the earthen reservoir, the steel tank with wooden roof and the steel tank with a steel, gas-tight roof.

The 55,000 and 35,000 barrel steel tanks are the usual sizes. Altogether there are more than 3500 of these large steel tanks in use in the Mid-Continent field.

The earthen storage is extremely wasteful from both seepage and evaporation. Petroleum standing in this type of reservoir has been known to shrink 40% in volume in two or three weeks. The shrinkage in value is of course much greater as the portion lost by evaporation is the best of the gasoline.

The following losses by evaporation took place in steel tanks with no seepage, with wooden roof covered with paper and tarred and apparently tight. The oil was of 40° Be′ gravity and the tanks were of a diameter of 114½ feet.

Capacity	Loss in Gauge	Actual Loss	Period	Per Cent Loss
55,000 bbls.	1 ft. 1¾ in.	2101 bbls.	5 mos.	4.2
55,000 bbls.	1 ft. 2⅝ in.	2235 bbls.	4½ mos.	4.6
55,000 bbls.	11⅛ in.	1700 bbls.	3½ mos.	3.4
55,000 bbls.	1 ft. ½ in.	1910 bbls.	3¼ mos.	3.8

The above figures indicate that there might be a loss of 1% per month of storage in wood roof steel tanks and this might amount to as much as 6,000 barrels per year per tank.

It has been claimed that oil stored in white tanks is subjected to 1 to 1½% less evaporation than in red tanks and 2½% less evaporation than in black tanks.

Various types of insulation have been used with success.

A typical storage temperature for the Mid-Continent field for oil stored above ground would be 80° F. A typical temperature of the ground for a submerged tank would be 60° F. which would more nearly approach the storage temperature of the air for the whole year.

If tanks could be successfully and cheaply built in the ground, they would have the advantage of almost perfect insulation from outside heat, and the oil would be stored at practically the temperature at which it comes from the ground. For this submerged type of tank, concrete construction would be proper if capable of perfect construction. It should be monolithic, well reinforced and lined with a coating impervious to water and gasoline.

APPORTIONMENT OF THE LOSS SUSTAINED BY CRUDE ON ITS JOURNEY FROM THE WELL TO THE REFINERY.

Per Cent Volume Evaporated.

Location of Loss—	Summer	Autumn Spring	Winter	Ave.
Flow tank	1.2	1.0	0.8	1.0
Filling lease tank	1.2	1.0	0.8	1.0
Lease storage	1.8	1.4	1.2	1.5
Gathering	1.3	0.9	0.8	1.0
Transportation	1.2	0.9	0.8	1.0
Tank farm	0.9	0.7	0.6	0.7
Total	7.6	5.9	5.0	6.2

Next in quantity after the evaporation losses in the storage of crude oil is the loss due to fire. Petroleum fires destroyed 12,850,000 barrels of oil in the United States in 1918. From January 1, 1908, to January 1, 1918, approximately 12,850,000 barrels of oil and 5,024,506,000 cubic feet of gas were destroyed by fire in the United States entailing a total estimated property loss of $25,254,000. During this period 503 fires were reported. Of these fires 310 were caused by lightning and 193 by other causes. The losses from the fires caused by lightning were estimated to be $11,148 000 and from those due to other causes, $14,106,200. Directly and indirectly the fires resulted in the deaths of nearly 150 persons and were responsible for almost as many more being permanently disabled.

Loss from fire in the oil field storage in the year 1916 amounted to about $4,000,000.

The causes of fires are electrical discharges or open flames in the presence of an inflammable or explosive mixture of gasoline and air. The amount of gasoline vapor in air necessary for an explosive mixture is within the limits of 1½ per cent and 5 per cent by weight. Less than the lower limit or more than the upper limit will not ignite. In an open tank if the amount at the surface of the oil exceeds 1½ per cent there is at some point an explosive mixture and an igniting temperature of 900 degrees F. or over will cause it to take fire. In a perfectly tight tank with gasoline vapor in excess of the upper limit for an explosive mixture, there will be no fire unless the roof of the tank is open at some point.

The ingress of a flame through an opening may be prevented in the same way that the flame in the Davy miner's lamp is prevented from passing outward. This operates by having some metal screen or other material cool the flame and prevent it being propagated into the tank. This will not prevent ignition from an electrostatic discharge in the vapor space of the tank.

Methods for prevention of fires of oil in storage are as follows:

1. Means of preventing the passage of the spark in a portion of the unfilled space of the tank.

2. The maintenance of a mixture in the unfilled portion of the tank which is not an explosive mixture.

LOSS IN THE MID-CONTINENT FIELD FROM 5 DAYS STORAGE ON THE LEASE

SEASON	Mid-Continent Production, Barrels	Average Volume Lost, Per Cent	ACTUAL VOLUME LOST			VALUE LOST	
			Barrels	Gallons	Cu. Ft.	As Crude Value	As Gasoline Value
Jan., Feb. and Dec	45,000,000	1.14	513,000	21,540,000	2,880,000	$1,539,000	$ 4,740,000
Mar., Apr., May, Oct. and Nov	78,400,000	1.40	1,098,000	46,120,000	6,170,000	3,294,000	10,150,000
June, July, Aug. and Sept	72,200,000	1.80	1,298,000	54,520,000	7,290,000	3,894,000	11,990,000
Whole year, 1919	195,600,000	......	2,909,000	122,100,000	16,340,000	8,727,000	26,880,000

Showing per cent, and Actual Volume Lost, and Value Lost as Crude Through Storage on the Lease (Composite Results for Various Types of Lease Storage. From U. S. Bureau of Mines).

SEASON	TANK, Kind and Size	Percentage of Total Tankage	PER CENT VOLUME LOST				
			1st Day	3rd Day	5th Day	10th Day	40th Day
Summer (June, July, August and Sept.)	Steel, 250 bbls.	31.8	0.80	1.93	2.8	4.55	10.90
	Steel, 500 bbls.	33.4	0.52	1.27	1.97	3.11	7.74
	Wood, 1,600 bbls.	34.8	0.20	0.50	0.70	1.18	3.67
Average, 750 bbls.	....	....	0.50	1.21	1.79	2.90	7.33
Fall and Spring (Mar., April, May, Oct. and November)	Steel, 250 bbls.	31.8	0.58	1.42	1.96	3.55	8.06
	Steel, 500 bbls.	33.4	0.41	1.03	1.60	2.68	6.20
	Wood, 1,600 bbls.	34.8	0.16	0.43	0.63	1.07	3.21
Average, 750 bbls.	....	....	0.38	0.95	1.38	2.39	5.75
Winter (December, January and February)	Steel, 250 bbls.	31.8	0.42	1.09	1.65	3.00	6.1
	Steel, 500 bbls.	33.4	0.30	0.82	1.30	2.32	5.22
	Wood, 1,600 bbls.	34.8	0.12	0.40	0.57	0.99	2.93
Average, 750 bbls.	....	....	0.28	0.76	1.16	2.07	4.70
Whole Year	Steel, 250 bbls.	....	0.61	1.51	2.15	3.75	8.52
Whole Year	Steel, 500 bbls.	....	0.42	1.06	1.65	2.73	6.46
Whole Year	Wood, 1,600 bbls.	....	0.16	0.45	0.64	1.00	3.28
Average Whole Year, 750 bbls. average	....	....	0.39	0.45	1.46	1.48	6.01

3. A tank so placed and constructed that the cooling effect of the walls will tend to smother the flames and the ingress of air will be so arranged that the fire is not readily fed.

4. A means for quickly eradicating the fire after it is ignited.

Several more or less successful methods for extinction of oil tank fires have been in use. The best involves the use of mixtures of sodium bicarbonate and sulphuric acid which produce sufficient carbon dioxide to smother the flame. If some sort of saponifying agent is used the carbon dioxide will make a froth which will float on the surface of the oil and is very effective in extinguishing the flame.

The application of steam is very effective but in the storage of a very large amount of oil the steam is not always available when needed and at the point where needed.

For small oil fires dust or other finely divided mineral matter is effective in extinguishing the fire.

STANDARD SPECIFICATIONS FOR BRICK OR TILE ENCLOSED TANKS.

A concrete foundation must be built around base of tank and upon this must be built a 12 inch brick or interlocking tile wall, leaving an air space between wall and tank of not less than 6 inches. At the base of the air space a concrete gutter must be formed having a grade from the quarter points each way to a sewer opening: sewer to be carried underneath the wall to a running trap just outside and at least 2 feet underground.

The roof of the structure is to consist of a steel supporting frame upon which is to be placed successively No. 24 gauge dove-tailed plate reinforcement, concrete, metallic lath and a finish coat of cement mortar. The metallic lath to be carried over the cornice and fastened to the top of the wall and beneath the reinforced concrete ring which forms the wall plate: by this the whole concrete surface will have a protection of metallic lath. Walls of structure to be plastered on the outside with cement mortar.

The structure must have a 24 inch concrete or other incombustible ventilator resting on a steel ring, lower side of ring to be covered with No. 4 mesh wire screen: upper side of ring to be sealed with two flap (butterfly) doors, normally held open by chain with fusible link which, in case of the presence of heat, will allow the doors to close and, in case of gas pressure inside of structure, will force the flap doors open, and when pressure is relieved will allow them to close.

There should be placed about one foot above top of foundation a cast iron ventilating shutter on the end of a standard 8 inch nipple pipe, with flap door normally held open by wire rope with two fusible links, one near top of tank and one near flap door. Flap door to be provided with brass pin to insure easy operation. The face of the casting should have such bevel that when the flap door is closed it will be held closed by gravity. Tanks 20 feet or less in diameter to be provided with four, over 20 feet and under 50 feet in diameter to be provided with six, and 50 feet or over in diameter to be provided with eight such ventilators: to be equally spaced around tank in each case.

An opening must be left in the roof of the structure to allow of entrance to the top manhole of the tank, same to be covered with a door built of tile in steel frame, sealed lightly on asbestos gaskets and to be kept closed and locked at all times, except when in use for repairs.

Opposite the bottom manhole of the tank a door opening must be left in the wall, same to be covered with a door built of tile in steel frame, sealed lightly with asbestos gaskets, and to be kept closed and locked at all times, except when in use for repairs.

At the apex of the tank there must be placed a ring spray capable of handling all water that may come to it through a 2 inch pipe under 75 pounds pressure: pipe to be carried up inside the structure and to be controlled by a valve accessibly located at a distance and to be made automatic by means of a fuse.

All pump connections are to be carried underground into the housing.

FUEL OIL STORAGE TANKS REGULATIONS—DRAFTED BY FIRE PROTECTION ASSOCIATION.

The Committee on Inflammable Liquids of the National Fire Protection Association has submitted the following tentative regulations covering the construction of concrete tanks for fuel oil storage.

Setting of Tanks.—(a) Tanks, if underground, shall be buried so that the top of the tank will be not less than three feet below the level of the surface of the ground and below the level of any piping to which the tanks may be connected.

(b) Tanks shall be set on a firm foundation.

(c) All tanks shall be provided with a concrete or other non-bustible roof.

Material and Construction of Tanks.—(a) Reinforcement.—Sufficient steel reinforcement shall be used to resist the oil pressure, and the horizontal and vertical reinforcement shall be proportioned properly and located to reduce the shrinkage cracks, so that they will be too minute to permit leakage. The fiber stress in the steel shall not exceed 10,000 pounds per square inch. (Note. A fiber stress of 10,000 pounds per sq. in. should prevent shrinkage cracks although a number of tanks have been designed with a fiber stress of 6,000 to 8,000 pounds.)

(b) Concrete.—The concrete for floor and walls should be at least 8 inches thick, mixed in the proportion of 1:2:3 or better 1:1½:3 and having the coarse aggregate of clean, dense, crushed rock or gravel ranging in size from one inch down. The concrete shall be thoroughly mixed, carefully placed and worked around the reinforcement. The forms should not be held together by wire as is frequently done in building construction because leakage is likely to take place along the wire. The concrete shall preferably be poured in a continuous operation so as to form a monolithic construction. (Note. Where this cannot be done the bottom shall be poured without joints and the walls as a second continuous operation. One method of making a tight joint between the bottom of the tank and the walls is by means of a strip of galvanized iron six inches wide with joints riveted and soldered, so as to form a continuous band. This strip should be vertically embedded three inches in the floor slab and on the center line of the wall. The floor slab under the walls should be thoroughly cleaned, and before pouring the walls a mixture of 1:1 mortar should be placed in the bottom of the forms and around the galvanized strip to make a tight joint.)

(c) Finish.—As soon as the wall and sides have been poured the floor shall be floated and troweled smooth. The wall forms shall be removed as soon as the concrete has hardened sufficiently to be self-sustaining and all projections and irregularities shall be removed from the surface and all cavities filled with a 1:1 mortar thoroughly rubbed in and troweled smooth. No plastering shall be applied.

(d) Aging.—The concrete shall be allowed to harden at least 30 days and longer if possible. (Note. To assist in the setting of the concrete before it becomes oil soaked it is advantageous to use several priming coats of a 1:4 solution of 40° Baume' sodium silicate, followed by a finish coat of a 1:2 solution. This forms a glazed surface on the concrete, which although it is not permanent, gives the concrete an opportunity to harden until the protection from the silicate of soda is no longer necessary.)

Location of Pipe Connections.—All pipe connections to the tank shall be made through the top.

Venting of Tanks.—(a) Tanks shall be provided with a permanently open vent, or with a combined fill and vent fitting so arranged that the fill pipe cannot be opened without opening the vent pipe.

(b) Vent openings shall be screened with (30x30) brass mesh or equivalent, and shall provide sufficient area for allowing proper flow of liquid during the filling operation. Permanently open vent pipes shall be provided with weather-proof hoods and terminate at a point at least twelve feet above the top of the fill pipe and never within less than three feet, measured horizontally and vertically, from any window or other building opening. Where a battery of tanks is installed vent pipes may be run into a main header. Individual vent pipes should, however, be screened between tank and header and connection to the header should be not less than one foot above the level of the top of the highest reservoir from which the tanks may be filled.

(c) Fill pipes shall be screened and when installed in the vicinity of a building, shall not be located within five feet of any door or other opening and shall terminate in a metal box or casting provided with means for locking.

PROPERTIES OF STANDARD STEEL ROOF STORAGE TANKS.

Capacity	Dimensions	Barrels per Inch	U.S. Gals. per 1 In.	Lbs. per Bbl.	Weight Pounds	Relative Cost per Bbl.	Relative Selling Price	Relative Cost per Pound
55,000	114.5x30	152.80	6420	7.47	411,000	$0.3673	$20,200	$0.04916
37,500	95 x30	105.20	4420	8.00	300,000	0.4134	15,500	.05168
30,000	85 x30	84.24	3538	7.83	235,000	0.4133	12,400	.05277
25,000	75 x30	65.57	2754	8.08	202,000	0.4340	10,850	.05370
20,000	70 x30	57.12	2399	8.80	176,000	0.4750	9,500	.05398
15,000	60 x30	41.98	1763	8.67	130,000	0.4833	7,250	.05577
10,000	50 x30	29.15	1224	9.67	96,700	0.5400	5,400	.05582
5,000	35 x30	14.28	600	10.46	52,300	0.5800	2,900	.05545
2,000	35 x12	14.28	600	16.00	32,000	0.9300	1,860	.05810
1,700	35 x10	14.28	600	17.06	29,000	1.0240	1,740	.06000
3,800	30 x30	10.50	441	11.84	45,000	0.662	2,515	.05590
3,200	30 x25	10.50	441	12.06	38,600	0.688	2,200	.0570
2,500	30 x20	10.50	441	13.60	34,000	0.784	1,960	.0577
1,250	30 x10	10.50	441	19.20	24,000	1.164	1,455	.0606
1,000	30 x 8	10.50	441	22.00	22,000	1.355	1,355	.0616
2,000	25 x25	7.29	306	15.50	31,000	0.8875	1,775	.0572
1,500	25 x17′ 6″	7.29	306	15.80	23,700	0.943	1,415	.059
875	25 x10	7.29	306	20.23	17,700	1.257	1,100	.0621
1,000	20 x20	4.66	196	20.60	20,600	1.190	1,190	.0578
500	20 x10	4.66	196	27.60	13,800	1.74	870	.0631
1,000	30 x 8	10.50	441	24.40	24,400	3.10	1,550	Bleacher
760	30 x 6	10.50	441	31.19	23,700	1.89	1,435	Bleacher

Miscellaneous tanks:

U. S. gallons per inch of vertical tank = $0.4897\ d^2$.

Barrels per inch of vertical tank = $0.01166\ d^2$.

d = diameter of tank in feet.

DESIGN OF OIL TANKS (Chicago Bridge and Iron Works).

Weights include stairway outside, fixed ladder inside, manhole in lower ring and in roof. Plate thicknesses are nominal only, plates being bought by weight. All plates are 72″ wide. ¼″ plates figured at 10.2 lbs. per sq. ft. All seams are lap type. Horizontal seams and seams in bottom are single riveted. Roof for smaller tanks supported by column at center and radical rafters. Larger tanks have series of columns with rafters. Tanks of 30,000 bbls. and larger have ¼″ sketch plates in bottom.

Capacity in Barrels (42 Gallons)	Weight with ⅛-inch Roof	Weight Without Steel Roof	Deduct for Stair Replaced by Ladder	Add (to Weight with ⅛-inch Roof) for 3/16-inch Roof	Diameter	Height	Plate 1			Plate 2			Plate 3			Plate 4			Plate 5			Bottom, Inches	Bottom Angle, Inches	Top Angle, Inches	No. of Plates Around	Approximate Plate Length
							Thickness, In.	No. of Rows	Rivet Diam., In.	t, Inches	Rows	Rivet Inches	t, Inches	Rows	Rivet Inches	t, Inches	Rows	Rivet Inches	t, Inches	Rows	Rivet Inches					
500	12,000	9,500	1,000	700	17′ 4″	11′ 9″	3/16	1	7/16	3/16	1	7/16	..	...	..	..	....	..	..	....	1	3/16	3 x3 x ½	3x2x¼	3	18′ 4″
1,000	18,000	14,800	1,500	900	20′ 0″	17′ 6″	3/16	1	7/16	3/16	1	7/16	3/16	1	7/16	..	....	..	..	....	..	3/16	3 x3 x ¼	3x2x¼	4	15′11″
2,000	28,200	23,300	2,000	1,400	25′ 0″	23′ 3″	3/16	1	7/16	3/16	1	7/16	3/16	1	7/16	3/16	1	7/16	..	....	..	3/16	3 x3 x ¼	3x2x¼	5	15′11″
2,500	32,100	26,100	2,000	1,700	27′ 9″	23′ 3″	3/16	2	7/16	3/16	1	7/16	3/16	1	7/16	3/16	1	7/16	..	....	..	3/16	3 x3 x ¼	3x3x¼	5	17′ 8″
3,000	36,700	29,000	2,000	2,100	30′ 6″	23′ 3″	3/16	2	7/16	3/16	1	7/16	3/16	1	7/16	3/16	1	7/16	..	....	..	3/16	3 x3 x ¼	3x3x¼	6	16′ 3″
4,000	43,800	35,600	2,500	2,200	31′ 6″	29′ 0″	3/16	2	7/16	3/16	2	7/16	3/16	1	7/16	3/16	1	7/16	3/16	1	7/16	3/16	3 x3 x ¼	3x3x¼	6	16′ 9″
5,000	50,600	40,400	2,500	2,800	35′ 3″	29′ 0″	3/16	2	7/16	3/16	2	7/16	3/16	1	7/16	3/16	1	7/16	3/16	1	7/16	3/16	3 x3 x ¼	3x3x¼	6	18′ 9″
7,500	68,100	52,900	2,500	4,200	43′ 0″	29′ 0″	¼	3	7/16	3/16	2	7/16	3/16	2	7/16	3/16	1	7/16	3/16	1	7/16	3/16	3 x3 x ¼	3x3x¼	8	17′ 3″
10,000	86,000	65,600	2,500	5,600	49′ 9″	29′ 0″	¼	3	7/16	¼	2	7/16	3/16	2	7/16	3/16	1	7/16	3/16	1	7/16	3/16	3 x3 x ¼	3x3x¼	9	17′ 9″
12,500	104,900	78,700	2,500	7,000	55′ 9″	29′ 0″	5/16	3	⅝	¼	3	7/16	3/16	2	7/16	3/16	2	7/16	3/16	1	7/16	3/16	3½x3½x 5/16	3x3x¼	10	18′ 0″
15,000	122,500	91,200	2,500	8,400	61′ 0″	29′ 0″	5/16	3	⅝	¼	3	7/16	¼	2	7/16	3/16	2	7/16	3/16	1	7/16	3/16	3½x3½x 5/16	3x3x¼	11	17′11″
20,000	158,700	116,700	2,500	11,200	70′ 2″	29′ 0″	⅜	3	¾	5/16	3	⅝	¼	2	7/16	3/16	2	7/16	3/16	1	7/16	3/16	3½x3½x 5/16	3x3x¼	12	19′ 0″
25,000	188,000	136,000	2,500	14,000	78′ 9″	29′ 0″	⅜	3	¾	5/16	3	⅝	¼	2	⅝	3/16	2	7/16	3/16	1	7/16	3/16	3½x3½x 5/16	3x3x 5/16	14	18′ 3″
30,000	219,200	157,000	2,500	16,800	86′ 0″	29′ 0″	13/32	3	¾	11/32	3	⅝	¼	3	7/16	3/16	2	7/16	3/16	1	7/16	3/16-¼ SK	3½x3½x ⅜	3x3x 5/16	16	17′ 5″
35,000	250,000	177,000	2,500	19,600	93′ 0″	29′ 0″	13/32	4	¾	11/32	3	⅝	¼	3	7/16	3/16	3	7/16	3/16	1	7/16	3/16-¼ SK	3½x3½x ⅜	3x3x 5/16	17	17′11″
37,500	273,000	195,000	2,500	21,100	96′ 6″	29′ 0″	7/16	3	¾	11/32	3	⅝	9/32	2	⅝	¼	2	7/16	3/16	1	7/16	3/16-¼ SK	3½x3½x ⅜	3x3x 5/16	18	17′ 7″
40,000	295,000	210,000	2,500	22,700	100′ 0″	29′ 0″	7/16	4	¾	⅜	3	¾	5/16	2	⅝	¼	2	7/16	3/16	1	7/16	3/16-¼ SK	4 x4 x 7/16	3x3x ⅜	18	18′ 2″
45,000	325,000	230,000	2,500	25,500	106′ 0″	29′ 0″	15/32	4	¾	⅜	3	¾	5/16	3	⅝	¼	2	7/16	3/16	1	7/16	3/16-¼ SK	4 x4 x 7/16	3x3x ⅜	19	18′ 4″
50,000	360,000	255,000	2,500	28,000	111′ 6″	29′ 0″	½	4	¾	13/32	3	¾	5/16	3	⅝	¼	2	7/16	3/16	2	7/16	3/16-¼ SK	4 x4 x 7/16	3x3x ⅜	20	18′ 3″
55,000	373,500	270,500	2,500	30,500	117′ 0″	29′ 0″	½	4	¾	7/16	3	¾	5/16	3	⅝	¼	2	7/16	3/16	2	7/16	3/16-¼ SK	4 x4 x 7/16	3x3x ⅜	20	19′ 2″
66,000	440,000	331,000	3,000	30,500	117′ 0″	34′ 9″	⅝	4	⅞	½	4	¾	7/16	3	¾	5/16	3	⅝	¼	2	7/16	3/16-¼ SK	4 x4 x ½	3x3x ⅜	20	19′ 3″

RULES FOR FREIGHT SHIPMENTS OF GASOLINE AND NAPHTHAS.

(See Pamphlet No. 9—Bureau of Explosives—30 Vesey St., New York)

INFLAMMABLE LIQUIDS—RED LABEL.

1824 (a) All inflammable liquids must be shipped in packages complying with specifications that apply, as follows:

(b) In tightly closed metal cans of not exceeding ten gallons capacity, packed in wooden boxes complying with Specification No. 11.

(c) In well-stoppered glass or earthenware vessels of not exceeding one gallon capacity, cushioned in wooden boxes complying with Specification No. 2, or cushioned in wooden barrels or kegs complying with Specification No. 11, or in a well-stoppered glass or earthenware vessel of not exceeding five gallons capacity, well cushioned in a wooden box and not more than one such vessel in the box. The completed package must comply with swing and drop tests prescribed for boxed carboys by Specification No. 1.

(d) In well-stoppered glass, earthenware, or metal vessels of not exceeding one pint capacity when flash point is 20°F or lower in wooden boxes complying with specification No. 2, or cushioned in fiber board or corrugated strawboard containers complying with Specification No. 24.

(e) In wooden kits of not exceeding ten gallons capacity, packed in wooden boxes complying with Specification No. 2, or cushioned in wooden barrels or kegs complying with Specification No. 11.

(f) In metal-jacketed cans of not exceeding ten gallons capacity, complying with Specification No. 23.

(g) In well-stoppered carboys of not exceeding thirteen gallons capacity, cushioned in wooden boxes complying with Specification No. 1.

(h) In wooden barrels or kegs complying with Specification No. 10 when the flash point of the liquid is not lower than 20°F, or in wooden barrels or kegs complying with Specification No. 9 when the flash point is lower than 20°F unless otherwise provided in the tariffs under which shipment moves.

(i) In metal barrels or drums complying with Specification No. 5.

(j) In tank cars complying with Master Car Builders' specifications provided the vapor tension of the inflammable liquid corresponding to a temperature of 100°F does not exceed ten pounds per square inch. A tank car must not be used for shipping inflammable liquids with flash point lower than 20°F unless it has been tested with cold water pressure of sixty pounds per square inch and stenciled as required by Master Car Builders' specifications and is equipped with safety valves set to operate at 25 pounds per square inch, and with mechanical arrangement for closing dome cover as specified in paragraph 1824 (k).

(k) Liquid condensates from natural gas or from casinghead gas of oil wells, made either by the compression or absorption process, alone or blended with other petroleum products, must be described as Liquefied Petroleum Gas when the vapor pressure at 100°F (90°F Nov. 1 to Mch. 1) exceeds ten pounds per square inch.

When the liquid condensate alone or blended with other petroleum products has a vapor pressure not exceeding ten pounds per square inch, it must be described and shipped as Gasoline or Casinghead Gasoline.

Liquefied petroleum gas of vapor pressure exceeding ten pounds per square inch and not exceeding 15 pounds per square inch from April 1 to October 1 and 20 pounds per square inch from October 1 to April 1, must be shipped in metal drums or barrels which comply with Shipping Container Specification No. 5, or in special insulated tank cars approved for this service by the Master Car Builders' Association.

Liquefied petroleum gas of vapor pressure exceeding 15 or 20 pounds per square inch as provided herein, and not exceeding 25 pounds per square inch must be shipped only in metal drums or barrels which comply with Shipping Container Specification No. 5.

Liquefied petroleum gas of vapor pressure exceeding 25 pounds per square inch must be shipped in cylinders as prescribed for compressed gases.

When the liquid condensate, alone or blended with other petroleum products has a vapor pressure not exceeding 10 pounds per square inch, it must be described as Gasoline or Casinghead Gasoline and must be shipped in metal drums or barrels complying with Specification No. 5, or in ordinary tank cars, 60 pounds test class equipped with mechanical arrangement for closing of dome covers as specified in Master Car Builders' specifications for tank cars.

Every tank car containing liquid condensates, either blended or unblended, including liquefied petroleum gas, as defined herein must have safety valves set to operate at 25 pounds per square inch with a tolerance of 3 pounds above or below, and the mechanical arrangements for closing the dome covers of such cars must either be such as to make it practically impossible to remove the dome cover while the interior of the car is subjected to pressure, or suitable vents that will be opened automatically by starting the operation of removing the dome cover must be provided.

The shipper must attach securely and conspicuously to the dome and dome cover three special white dome placards measuring 4x10 inches. bearing the following wording:

CAUTION Avoid Accidents DO NOT REMOVE THIS DOME COVER WHILE GAS PRESSURE EXISTS IN TANK. Keep Lighted Lanterns Away.

4 Inches

10 Inches

One placard must be attached to each side of the dome and one placard be attached to the dome cover. The presence of these special dome placards must be noted on the shipping order by the shipper and by the carrier on the billing accompanying the car. Placards must conform to samples furnished by the Chief Inspector of the Bureau of Explosives.

(1) Carbon bisulphide in interior packages of capacity greater than one-half gallon must be shipped in metal cans of not less than 28 gauge boxed, complying with Specification No. 2, or in metal barrels or drums complying with Specification No. 5, such barrels or drums not to exceed 55 gallons capacity. Carbon bisulphide may also be shipped in tank cars complying with paragraph 1824 (j).

1825. (a) Packages containing inflammable liquids must not be entirely filled. Sufficient interior space must be left vacant to prevent leakage or distortion of containers due to increase of temperature during transit. In all such packages this vacant space must not be less than 2% of the total capacity of the container. In tank cars the vacant space must not be less than 2% of the total capacity of the tank, i. e., the shell and dome capacity combined. If the dome of tank cars does not provide this 2%, sufficient vacant space must be left in the shell of the tank to make up the difference.

(b) In packages containing alcohol, cologne spirits, high wines or other distilled spirits of 150 proof or over, the vacant interior space or allowance for wantage or ullage must be the maximum permitted by the United States Internal Revenue Regulations.

1826. Interior packages containing one quart or more of an inflammable liquid must be packed with their filling holes up and the top of the outside package must be plainly marked "THIS SIDE UP."

1827. Wooden-jacketed cans and wooden kits must not be used for the shipment of inflammable liquids, except as inside containers as provided by Specifications No. 2 or 11.

RULES FOR THE SHIPMENT OF PETROLEUM BY EXPRESS.

All shipments of articles subject to these regulations offered for the transportation by express in interstate commerce must be properly described by the shipper, and the proper and definite name of the dangerous article must be plainly marked on the outside of the package, in addition to the labels required herein. (a) Articles for which detailed instructions for packing are not given herein must be securely packed in containers strong enough to stand without rupture or leakage of contents, a drop of four feet to solid brick or concrete.

(b) Whenever orders are placed in foreign countries for the importation of dangerous articles to be forwarded from port of entry by express, the importer must furnish with the order to the foreign shipper and also to the forwarding agent at the port of entry, full and complete information as to the necessary packing, marking and labeling required by these regulations. The forwarding agent must see that the packages are properly packed, marked and labeled.

35 (d) Interior packages containing 1 pint or more of an inflammable or corrosive liquid must be packed with their filling holes up and the outside package must be plainly marked "THIS SIDE UP."

Inflammable Liquids—Red Label.

(37) Except as herein prescribed, the maximum quantity of any inflammable liquid packed in one outside container must not exceed 1 gallon when the flash point is 20°F or below and must not exceed 5 gallons when the flash point is above 20°F and below 80°F.

(38a) Packages containing inflammable liquids must not be entirely filled. Sufficient interior space must be left vacant to prevent leakage or distortion of containers due to increase of temperature during transit. In all such packages this vacant space must not be less than 3% of the capacity of the container.

(39a) All inflammable liquids must be shipped in packages complying with specifications that apply, as follows:

(b) In tightly closed metal cans of not exceeding 5 gallons capacity packed in wooden boxes complying with Specification No. 2 or cushioned in wooden barrels or kegs complying with Specification No. 11.

(c) In well-stoppered glass or earthenware vessels of not exceeding 1 quart capacity cushioned in wooden boxes complying with Specification No. 2 or cushioned in wooden barrels or kegs complying with Specification No. 11.

(d) In well-stoppered glass, earthenware, or metal vessels of not exceeding one pint (ether 1 pound) capacity when flash point is 20°F or lower and 1 quart capacity when flash point is above 20°F, cushioned in fiberboard or corrugated strawboard containers complying with Specification No. 24 and not exceeding 8 quarts in one package.

(e) In metal-jacketed cans of not exceeding 5 gallons capacity, complying with Specification No. 23.

(f) In metal drums of capacity not exceeding 5 gallons, complying with Specification No. 5.

(h) Liquefied petroleum gas, blended or unblended, when its vapor tension corresponding to a temperature of 100°F exceeds 10 pounds per square inch, must not be shipped by express except in steel containers conforming to paragraphs 57, 58 and 59.

For complete directions see the Bureau of Explosive pamphlet No. 9, Interstate Commerce Commission Regulations, 30 Vesey St., New York City.

OWNERSHIP OF TANK CARS.

Tank Cars Owned By Railroads.

Name and Location.	Tank Cars
Colorado & Southern	14
Delaware River & Union R. R	211
Denver & Rio Grande	44
East Jersey R. R.	120
El Paso & Western	98
Kansas City Southern Ry. Co.	193
Los Angeles & Salt Lake R. R. Co.	214
Midland Valley R. R. Co.	97
Missouri, Kansas & Texas Ry.	677
Morenci Southern Ry. Co.	2
New Orleans, Texas & Mexico R. R.	75
Northern Pacific R. R. Co.	34
Oregon-Washington R. R. & Nav. Co.	44
Pacific Electric Ry Co.	29
Pennsylvania R. R. Co.	514
Philadelphia & Reading Ry. Co.	20
St. Louis & San Francisco R. R. Co.	629
St. Louis, Brownsville & Mexico Ry.	59
St. Louis, Southwestern Ry. Co.	81
San Antonio & Arkansas Pass Ry. Co.	81
Santa Fe Ry. Co.	3,178
Santa Fe & Arizona Ry.	4
Southern Pacific Ry.	2,963
Texas & New Orleans R. R. Co	459
Trinity & Brazos Valley R. R. Co.	25
	9,813

Tank Cars Owned By Oil Industries.

Name and Location.	Tank Cars
Acme Petroleum Co., Kansas City, Mo.	60
Aetna Refining Co., Louisville, Ky.	50
Ajax Gasoline Co., Kansas City, Mo.	33
Akin Gasoline Co. Tulsa, Okla.	34
Allied Refining Co., The, Tulsa, Okla.	80
American Oil Co., Baltimore, Md.	10
American Refining Co., Wichita Falls, Texas.	248
American Oil Works, Ltd., Titusville, Pa.	42
Anderson & Gustafson, Chicago, Ill.	105
Apex Refining & Drilling Co., Loomis, Col.	8
Ardmore Producing & Refining Co., Ardmore, Okla.	16
Arrow Refining Co., Waco, Texas.	72
Associated Oil Co., Los Angeles, Cal.	315
Atlanta Refining & Mfg. Co., Atlanta, Ga.	7
Atlantic Petroleum Co., The, Tulsa, Okla.	25
Atlas Petroleum Co., Kansas City, Mo.	10
Atwood Refining Co., Oklahoma City, Okla.	39
Aurelius Thomas Gasoline Co., Drumright, Okla.	15
Barber Co., W. H., Minneapolis, Minn.	15
Berry's Sons Co., J. B., Oil City, Pa.	148
Biery Oil Co., Franklin, Pa.	25
Big Heart Petroleum Co., Big Heart, Okla.	215
Ellis Oil & Refining Co., Augusta, Kansas.	34
Boynton Gasoline Co., Tulsa Okla.	15
Boynton Refining Co., Boynton, Okla.	60
Burkburnett Refining Co., Burkburnett, Texas.	36
Butler County Oil Refining Co., Bruin, Pa.	92
Caddo Oil & Refining Co., Shreveport, La.	324
California Petroleum Exchange, Los Angeles, Cal.	15
Cameron Refining Co., Ardmore, Okla.	50
Canfield Refining Co., Yale, Okla.	43
Carlo Oil Co., Guthrie, Okla.	25
Capitol Refining Co., Buffalo, N. Y.	70
Carnegie Refining Co., Carnegie, Pa.	17
Carson Petroleum Co., Chicago, Ill.	256
Central Refining Co., Lawrenceville, Ill.	335
Champlin Refining Co., H. H., Enid, Okla.	202
Chestnut & Smith Corp., Tulsa, Okla.	232
Chickasaw Refining Co., Ardmore, Okla.	144
Childers Gasoline Co., Nowata, Okla.	15

Tank Cars Owned By Oil Industry—Continued.

Name and Location.	Tank Cars
Choate Oil Corp., Oklahoma City, Okla	184
Clarendon Refining Co., Clarendon, Pa	72
Cleveland Petroleum Refining Co., Cleveland, Okla	21
Climax Refining Co., Corsicana, Texas	11
Commonwealth Oil & Refining Co., Moran, Kans	23
Conewango Refining Co., Warren, Pa	152
Constantin Refining Co., West Tulsa, Okla	1,150
Continental Oil Co., The, Denver, Col	11
Continental Refining Co., Ltd., Oil City, Pa	70
Continental Refining Co., Bristow, Okla.	76
Cosden & Co., Tulsa, Okla	2,030
Craig Oil Co., The, Toledo, Ohio	175
Crew Levick Co., Philadelphia, Pa.	250
Crystal Oil Works, Oil City, Pa	32
Cushing Refining Co., (Cars operated by Empire Refineries, Inc.) Ponca City, Okla.	150
Daugherty & Son Refining Co., W. H., Petrolia, Pa	8
Deepwater Oil Refineries, Houston, Texas	50
De Soto Gasoline Co., Beaumont, Texas	8
Diamond Gasoline Co., Kansas City, Mo	40
Doty Oil Co., Oklahoma City, Okla	5
Eagle Gasoline Co., Tulsa, Okla	34
Eagle Refining Co., Wichita Falls, Texas	60
El Dorado Refining Co., El Dorado, Kans	186
Elk Refining Co., Charleston, W. Va	72
Emery Mfg. Co., Bradford, Pa	90
Emlenton Refining Co., Emlenton, Pa	78
Empire Oil Works, Oil City, Pa	90
Empire Refineries, Inc., Tulsa, Okla	1,860
Ensign Oil Co., of Pa., Pittsburgh, Pa	7
Evans-Thwing Refining Co., Kansas City, Mo	100
Falling Rock Cannel Coal Co., Charleston, W. Va	26
Federal Oil & Refining Co., Cushing, Okla	30
Fidelity Petroleum Co., (Cars operated by Uncle Sam Oil Co.) Tulsa, Okla.	75
Foco Oil Co., Franklin, Pa	20
Franchot & Co., D. W., Tulsa, Okla	12
Franklin Quality Refining Co., Franklin, Pa	24
Freedom Oil Works Co., The, Freedom, Pa	195
Freeport & Mexican Fuel Oil Corp., Houston, Texas	348
Galena-Signal Oil Co., of Texas, Houston, Texas	80
Gasoline Corp., New York, N. Y	30
General Petroleum Corporation, Los Angeles, Cal	66
Golden Rule Refining Co., Wichita, Kans	48
Great American Refining Co., Tulsa, Okla	100
Great Western Oil Refining Co., Erie, Kans	100
Gulf Refining Co., Pittsburgh, Pa	2,150
Hawkeye Oil Co., Waterloo, Ia	10
Hercules Petroleum Co., Dallas, Texas	272
Higrade Petroleum & Gasoline Co., Tulsa, Okla	22
High Grade Petroleum Products Co., St. Marys, W. Va	50
Home Oil Refining Co., of Texas, Ft. Worth, Texas	135
Home Petroleum Co., Oklahoma City, Okla	50
Hope Gasoline Co., Tulsa, Okla	10
Humble Oil & Refining Co., Houston, Texas	188
Illinois Oil Co., of Rock Island, Rock Island, Ill	176
Imperial Refining Co., Ardmore, Okla	216
Independent Refining Co., Ltd., Oil City, Pa	120
Indiahoma Refining Co., St. Louis, Mo	765
Indian Refining Co., Lawrenceville, Ill	1,300
Inland Refining Co., Tulsa, Okla	100
Interior Oil & Gas Corp., Clarendon, Pa	10
International-Ardmore Ref. Div., Tulsa, Okla., (The Ohio Cities Gas Co.)	16
International Oil & Gas Corp., Shreveport, La	20
Interocean Refining Co., Chicago, Ill	90
Invader Oil & Refining Co., Muskogee, Okla	25
Invincible Oil Refining Corp., Ft. Worth, Texas	175
Island Refining Co., The Pittsburgh, Pa	75
Johnson Oil Refining Co., Chicago Heights, Ill	40
Kanotex Refining Co., The, Arkansas City, Kans	220
Kansas City Refining Co., Kansas City, Kans	180
Kansas Oil Refining Co., Coffeyville, Kans	170
Kendall Refining Co., Bradford, Pa	50
Lake Park Refining Co., Kansas City, Mo	270
LaPorte Oil & Refining Co., Houston, Texas	10

Tank Cars Owned By Oil Industry—Continued.

Name and Location.	Tank Cars
Leader Oil Co., Casey, Ill	25
Lesh Refining Co., Arkansas City, Kans	44
Liberty Oil Co., Ltd., New Orleans, La	50
Liberty Pipe Line & Refining Co., Wichita, Kans	5
Liquefied Petroleum Gas Co., Tulsa, Okla	42
Lisle Refining Division, Arkansas City, Kans	18
Livingston Refining Corp., Tulsa, Okla	105
Lone Star Refining Co., Wichita Falls, Texas	60
Louisiana Oil Refining Co., Shreveport, La	230
Lubrite Refining Co., East St. Louis, Ill	92
McCombs Producing & Refining Co., Louisville, Ky	30
Magnolia Petroleum Co., Dallas, Texas	900
Marland Refining Co., Ponca City, Okla	844
Mexican Petroleum Corporation, New York, N. Y	1,175
Midco Gasoline Co., Tulsa, Okla	300
Mid Continent Refining Co., Tulsa, Okla	75
Midland Refining Co., El Dorado, Kans	250
Midwest Refining Co., The, Denver, Col	22
Miller's Oil Refining Works, Allegheny, Pa	50
Miller Petroleum Refining Co., Chanute, Kans	50
Montrose Oil Refining Co., Ft. Worth, Texas	50
Mutual Oil Co., Kansas City, Mo	125
Mutual Refining & Producing Co., Kansas City, Mo	50
Mutual Refining Co., Warren, Pa	30
Mutual Sales Co., Warren, Pa	10
National Refining Co., Cleveland, Ohio	1,004
National Oil Co., New York, N. Y	25
Noble Oil & Gas Co., Chas. F., Tulsa, Okla	200
Nortex Refining Co., Burkburnett, Texas	68
Northern American Refining Co., Oklahoma City, Okla	475
Northern Petroleum Co., Pittsburgh, Pa	26
Northern Oil Co., Wilmar, Minn	10
Nyanza Refining Co., New Wilson, Okla	10
Oconee Oil Refining Co., Athens, Ga	10
Ohio Cities Gas Co., Columbus, Ohio	1,400
Ohio Valley Refining Co., St. Marys, W. Va	75
Oil Products Corp., New York, N. Y	7
Oil State Gasoline Co., Tulsa, Okla	12
Oil State Refining Co., Enid, Okla	50
Oklahoma Natural Gasoline Co., Sapulpa, Okla	5
Oklahoma Petroleum & Gasoline Co., Tulsa, Okla	280
Oklahoma Producing & Refining Corp., Muskogee, Okla	275
Okmulgee Producing & Refining Co., Okmulgee, Okla	115
O. K. Refining Co. (Cars operated by The Home Refining Co. of Texas) Ft. Worth, Texas	15
Olsan Petroleum Co., Tulsa, Okla	11
Omaha Refining Co., Omaha, Neb	25
Oneta Refining Co., Tulsa, Okla.	52
Osage Gasoline Co., Kansas City, Mo	25
Ozark Refining Co., Ft. Smith, Ark	17
Pan-American Refining Co., Tulsa, Okla	310
Panhandle Refining Co., Wichita Falls, Texas	200
Paragon Refining Co., Toledo, Ohio	600
Pawnee Bill Oil & Refining Co., Yale, Okla	25
Pelican Oil Refining Co., Inc., New Orleans, La	19
Penn American Refining Co., Oil City, Pa	250
Pennsylvania & Delaware Oil Co., New York, N. Y	20
Pennsylvania Gasoline Co., Bradford, Pa	13
Pennsylvania Oil Products Refining Co., Eldred, Pa	40
Pennsylvania Refining Co., Ltd., The, Karns City, Pa	7
Peterson Co., Geo. C., Chicago, Ill	5
Petroleum Products Co., The, Pittsburgh, Pa	12
Petroleum Refining Co., Latonia, Ky	47
Phoenix Refining Co., Tulsa, Okla	180
Phillips Petroleum Co., The, Bartlesville, Okla	10
Pierce Oil Corp., St. Louis, Mo	1,500
Pittsburgh Oil Refining Co., Pittsburgh, Pa	85
Pittsburgh-Texas Oil & Gas Co., Muskogee, Okla	12
Polar Producing & Gasoline Co., Okmulgee, Okla	10
Prime Petroleum Products Co., Chicago, Ill	92
Producers & Refiners Corp., Blackwell, Okla	185
Prudential Oil Corp., Baltimore, Md	300
Pure Oil Co., Minneapolis, Minn	92
Randolph Petroleum Co., Tulsa, Okla	10

Tank Cars Owned By Oil Industry—Concluded

Name and Location.	Tank Cars
Ranger Refining Co., Kansas City	80
Record Oil Refining Co., The, New Orleans, La	35
Red C Oil Co., Baltimore, Md	15
Red River Refining Co., Crichton, La	30
Red River Refining Co. of Texas, Wichita Falls, Texas	50
Richfield Oil Co., Los Angeles, Cal	8
Rio Grande Oil Co., El Paso, Texas	22
Riverside Eastern Oil Co., Pittsburgh, Pa.	45
Riverside Western Oil Co., Tulsa, Okla	100
Robinson Oil Refining Co., Robinson, Ill	9
Roth Gasoline Co., Independence, Kans	10
Roxana Petroleum Co., Tulsa, Okla	750
St. Louis Oil & Refining Co., Eldorado, Kans	25
Sapulpa Refining Co., Sapulpa, Okla	445
Seneca Oil Works, Warren, Pa	65
Service Petroleum Co., The, Tulsa, Okla	15
Schaffer Oil & Refining Co., Chicago, Ill	450
Shell Co., of California, San Francisco, Cal	100
Simms Oil Co., Houston, Texas	500
Sinclair Refining Co., Chicago, Ill	3,700
Skagway Gasoline Co., Tulsa, Okla	6
Skelly Oil Co., Tulsa, Okla	12
Sloan & Zook, Bradford, Pa	62
Smiley Petroleum Co., Kansas City, Mo	95
Smith Refining Co., Levi, Clarendon, Pa	20
Southern Oil Corp., Kansas City, Mo	460
Southland Gasoline Co., Tulsa, Okla	16
Southwestern Producing & Refining Co., Wichita Falls, Texas	40
Sterling Oil & Refining Co., Wichita, Kans	175
Sterling Refining Co., Oklahoma City, Okla	20
Stewart Petroleum Co., Tulsa, Okla	20
Stoll Oil Co., Inc., Louisville, Ky	35
Stroud Co., B. B Bradford, Pa	25
Sunland Oil Co., Tulsa, Okla	28
Sunshine State Oil & Refining Co., Wichita Falls, Texas	110
Superior Oil Works, Ltd., Warren, Pa	35
Texas Co., The, New York, N. Y	4,100
Texhoma Oil & Refining Co., Wichita Falls, Texas	80
Tidal Gasoline Co., Tulsa, Okla	70
Tiona Refining Co., Clarendon, Pa	50
Titusville Oil Works, Titusville, Pa	60
Totem Gasoline Co., Tulsa, Okla	10
Transcontinental Refining Co., Pittsburgh, Pa	815
Travis Oil Co., Tulsa, Okla	50
Tribes Gasoline Co., Tulsa, Okla	15
Turner Oil Co., Los Angeles, Cal	6
Twin Hills Gasoline Co., Okmulgee, Okla	7
Union Oil Co. of California, Los Angeles, Cal	325
Union Petroleum Co., Philadelphia, Pa	200
United Oil Co., The, Denver, Col	20
United Oil Refining Co., West Lake, La	15
United Refining Co., Warren, Pa	45
Union Tank Line (Standard)	25,000
Valvoline Oil Works, Ltd., East Butler, Pa	130
Ventura Refining Co., Los Angeles, Cal	15
Vickers Petroleum Co., Potwin, Kans	25
Vulcan Oil Refining Co., Cleveland, Ohio	48
Wabash Refining Co., Robinson, Ill	160
Wadhams Oil Co., Milwaukee, Wis	10
Waggoner Refining Co., Electra, Texas	80
Walker Oil & Refining Co., Houston, Texas	10
Warren Oil Co., Warren, Pa	415
Warren Refining Co., Warren, Pa	70
Waverly Oil Works Co., Pittsburgh, Pa	50
Webster Oil & Gasoline Co., Yale, Okla	5
Western Oil Corp., Tulsa, Okla	80
Western Petroleum Co., Chicago, Ill	10
White Eagle Petroleum Co., Augusta, Kans	450
White Oil Corp., Houston, Texas	335
Wichita Valley Refining Co., Iowa Park, Texas	125
Wilburne Oil Works, Ltd., Warren, Pa	75
Wilhoit Refining Co., Springfield, Mo	110
Wight Producing & Refining Corp., Tulsa, Okla	11
Tank Car Companies	10,000

RULES GOVERNING THE LOCATION OF NEW LOADING RACKS AND NEW UNLOADING POINTS FOR CASINGHEAD GASOLINE, REFINERY GASOLINE, NAPHTHA OR INFLAMMABLE LIQUID WITH FLASH POINT BELOW 30°F.

The location of new loading racks and unloading points for volatile inflammable liquids is considered of great importance, and there is at present lack of uniformity in the enforcement of proper safe-guards for the protection of life and property. The following rules for the location of new installations shall govern all carriers under Federal control. These rules are not applicable to present locations.

For the purpose of these rules casinghead gasoline is defined to be any mixture containing a condensate from casinghead gas or natural gas obtained by either the compression or the absorption process, and having a vapor tension in excess of 8 pounds per square inch.

Loading.

1. (a) New loading racks for refinery gasoline, naphtha, or any liquid (other than casinghead gasoline) with flash point below 30°F. Must not be located nearer than 50 feet to a track over which passenger trains are moved when physical conditions permit and in no case less than 25 feet.

(b) New loading racks for casinghead gasoline must be located not less than 100 feet distant from a track over which passenger trains are moved when physical conditions permit, and in no case less than 50 feet. When within 75 feet of such a track a retaining wall, dike or earthen embankment shall be placed between the installation and the track, so constructed as effectually to prevent liquids from flowing on to the track in case of accident.

(c) In loading casinghead gasoline, the tank car and the storage tank shall be so connected as effectually to permit the free flow of the gasoline vapors from the tank car to the storage tank and to positively prevent the escape of these vapors to the air, or the vapors must be carried by a vent line to a point not less than 100 feet distant from the nearest track over which passenger trains are moved.

Unloading.

2. (a) When new unloading points requiring railroad service for the unloading of tank cars of refinery gasoline, benzine, or any liquid (other than casinghead gasoline) with flash point below 30°F are required, the location shall be subject to negotiation between the carrier and the interested oil company.

(b) New locations for the unloading of casinghead gasoline shall be placed a minimum distance of 50 feet from a track over which passenger trains are moved where physical conditions do not permit a greater distance, and a maximum distance of 100 feet shall be required where physical conditions permit, where old or new installations are placed within 75 feet of a track over which passenger trains are moved a retaining wall, dike or earthen embankment shall be placed between the installation and the track, so constructed as effectually to prevent liquids from flowing on to the track in case of accident.

Storage.

3 (a) These regulations apply only to above-ground tanks for which railroad service is required. Under-ground tanks should be considered by interested railroads as occasion may arise. All storage tanks will be considered above ground unless they are buried so that the top of the tank is covered with at least three feet of earth.

(b) All tanks should be set upon a firm foundation and be electrically grounded.

(c) Each tank over 1,000 gallons in capacity shall have all manholes, hand holes, vent openings, and other openings which may contain inflammable vapor, provided with 20x20 mesh brass wire screen or its equivalent, so attached as to completely cover the openings and be protected against clogging, these screens may be made removable but should be kept, normally, firmly attached. Such a tank must also be properly vented or provided with a suitable safety valve set to operate at not more than 5 pounds per square inch for both interior pressure and vacuum, manhole covers kept closed by their weight only will be considered satisfactory.

(d) Tanks used with a pressure discharge system must have a safety valve set at not more than one-half of the pressure to which the tank was originally tested.

(e) Tanks containing over 500 gallons and not exceeding 18,000 gallons of gasoline, benzine, naphtha, casinghead gasoline, or any liquid with flash point below 30°F, must be located not less than 20 feet from a track over which passenger trains are moved.

(f) For capacities exceeding 18,000 gallons, the following distances shall govern:

Capacity of tanks (in gallons)	Minimum distance from a track over which passenger trains are moved.
18,001 to 30,000	40 feet
30,001 to 48,000	50 feet
48,001 to 100,000	60 feet
100,001 to 150,000	80 feet
150,001 to 250,000	100 feet
250,001 to 500,000	150 feet
Over 500,000	200 feet

(g) Where practicable, tanks should be located on ground sloping away from railroad property. If this is impracticable, then the tanks must be surrounded by dikes of earth, or concrete, or other suitable material, of sufficient capacity to hold all the contents of the tanks, or of such nature and location that in case of breakage of the tanks the liquid will be diverted to points such that railroad property and passing trains will not be endangered.

General.

4 (a) In measuring distance from any railroad track the nearest rail shall be considered as the starting point.

(b) During the time that the tank car is connected by loading or unloading connections, there must be signs placed on track or car so as to give necessary warning. Such signs must be at least 12x15 inches in size and bear the words "Stop—Tank Car Connected" or "Stop—Men at Work," the word "Stop" being in letters at least 4 inches high and the other words in letters at least 2 inches high. The letters must be white on a blue background. The party loading or unloading the tank car is responsible for furnishing, maintaining, and placing these signs.

(c) In laying pipe lines on railroad property for the loading or unloading of tank cars, they must be laid at a depth of at least three feet, and at points where such pipe lines pass under tracks they must be laid at least four feet below the bottom of the ties.

(d) All connections between tank cars and pipe lines must be in good condition and must not permit any leakage. They must be frequently examined and replaced when they have become worn in order to insure at all times absolutely tight connections. Tank cars must not be left connected to pipe lines except when loading or unloading is going on and while a competent man is present and in charge.

(e) The ends of the pipe lines for loading or unloading tank cars from their bottom opening, when on railroad property should be placed in shallow pits with brick or concrete walls not closer than 8 feet from center line of track. These pits should be ventilated and be protected by substantial one-piece covers, level with the surface of the ground, which must be kept locked in place when the pits are not in use. These pits should not be drained into a sewer or running stream.

(f) Except when closed electric lights are available, the loading or unloading of tank cars on railroad property shall not be permitted except during daylight when artificial light is not required. The presence of flame lanterns, nearby flame switch lights or other exposed flame lights or fires during the process of loading or unloading is prohibited.

B. W. DUNN,
Chief Inspector.

THE MEASUREMENT AND GAUGING OF PETROLEUM.

The unit of measurement of petroleum in the United States is the barrel of 42 U. S. gallons. The important units of measurement with factors for their conversion to one another are given below. Other units of measurement are to be found on pages 554-5-6. In measuring petroleum, it is necessary to strap the tanks in which it is contained and to prepare gauging tables for each tank. The tanks are usually identified by number. In the case of the vertical cylindrical tanks it is very simple to prepare gauging tables as the amount per inch is figured from formulae (1) on pages 135, 151, 182. Using an adding machine each inch is added and summed until the height of the tank is reached.

In making gauging tables for horizontal cylindrical tanks formula (4), page 151, may be used but this is rather tedious. With flat ends and with diameters up to 10 feet the tables on pages 159 to 173 are useful as it is only necessary to multiply the total capacity of the tank by the factor given for the depth desired. The result is in gallons. For horizontal tanks of any size, the tables given on pages 155-6 are most suitable. It is only necessary to first make a table showing the per cent of the total diameter represented by each inch in diameter and to multiply the corresponding per cent of capacity by the total capacity.

The capacity of tanks with standard bumped ends is derived from formula (3) on page 151. The contents of tanks with bumped ends may be found as described on pages 153-4. For irregular tanks and tanks with coils and pipe, tables are made by measuring out water from the tank. On a lease or at the refinery it is usual to gauge all tanks every morning. The measurement may be done with a steel tap plumb bob at the end for the total amount of fluid and with a "thief" which measures the water in the bottom of the tank. A gauging stick may be used which is chalked with special chalk or carries a strip of sensitive paper showing the demarcation between it and water may be used. A formula for impregnating paper indicator for this purpose is as follows:

Calcium chloride	10 grams
Gum Dextrin	15 grams
Glycerin	5 C. C.
Acetic Acid 99%	3 C. C.
Water	30 C. C.
Umber	10 grams

For the correction of the volume of oil to a temperature of 60°F use the table on page 152.

The following table is used in the calculation of capacities of reservoirs and tanks and in quickly converting different measures of petroleum and water into each other.

MEASUREMENT OF WATER AND PETROLEUM AT 60° F.

Multiply or divide, as required, the weight-measure values by the specific gravity of the petroleum. Specific gravity of average crude oil = 0.850; fuel oil = 0.900; gasoline = 0.750; kerosene = 0.820; gas oil = 0.850.

	Cubic Foot	Cubic Inch	U. S. Gallon	Imperial Gallon	Liter	Petroleum Barrel	Pound	Kilo-gram	Metric Ton
Cubic Foot	1.000	1728.	7.48	6.23	28.317	0.1781	62.37	28.29	.02829
Cubic Inch	.0005787	1.000	.004329	.003605	.016387	$1.306 . 10^{-4}$	.03609	.01637	$1.637 . 10^{-5}$
U. S. Gallon	.13367	231.	1.000	.8328	3.785	.02381	8.338	3.782	.003782
Imperial Gallon	.1605	277.4	1.201	1.000	4.545	.02859	10.01	4.541	.004541
Liter	.03532	61.03	.2642	.2200	1.000	.00629	2.203	.999034	.000999
Petroleum Barrel	5.615	9703.	42.00	34.98	159.3	1.000	350.2	158.85	.15885
Pound (Av.)	.01603	27.71	.1199	.0999	.4539	.002856	1.000	.45359	.0004536
Kilogram	.03535	61.08	.2644	.2202	1.001	.006296	2.205	1.000	.001
Metric Ton	35.35	61080.	264.4	220.2	1001.	6.296	2205.	1000.	1.000
Pood (Russian)	.5791	1000.	4.331	3.607	16.40	0.1031	36.12	16.38	.01638

1 Koku (Jap) = 4.756 gal. 1 Piculi (Jap) = 133½ lbs. 1 Yen = 0.498 cts.

HORIZONTAL CYLINDRICAL TANKS.

(1) Total capacity of horizontal cylindrical tank in gallons.

$C = .0034\ d^2L$

d = diameter in inches. L = length in inches.

c = capacity in U. S. gallons.

(2) Total capacity of horizontal cylindrical tanks in barrels without bumped ends.

$C = 0.14\ d^2l$

d = diameter in feet.

l = length in feet.

c = capacity in barrels.

(3) Total capacity of horizontal cylindrical tank in barrels with bumped ends (when radius of bumped end = d ft.)

$C = d^2\ (0.14\ l + .019\ d)$

Capacity of each bumped end = $.019\ d^3$ bbls. = $.4024\ d^3$ gallons ($.000233d^3$ if d = inches)

(4) Liquid contents of partially filled tanks.

C = Liquid contents in gallons.

L = Length of tank in inches.

d = Diameter of tank in inches.

x = Depth of liquid contents in inches.

$$C = \frac{L}{231}\left(0.004363\ d^2\ \text{Cos}^{-1}\ \frac{d-2x}{d} - \frac{d-2x}{2}\sqrt{x(d-x)}\right)$$

$\text{Cos}^{-1}\ \frac{d-2x}{d}$ means the value of the angular degrees whose cosine is $\frac{d-2x}{d}$

The cosine of an angle is the ratio in its right angled triangle, of the side adjacent the angle to the hypothenuse of the triangle.

When L = 300 inches
d = 100 inches
x = 30 inches

$$\frac{d-2x}{d} = .4$$

$\text{Cos}^{-1}\ .4 = 66.42°$ (From Trigonometric tables)

$$C = \frac{300}{231}\left[0.004363\ (10000)\ (66\ 42) - 20\sqrt{2100}\right]$$

$$= \frac{300}{231}\ (2897 - 882.)$$

= 2617 gallons.

CORRECTIONS OF GAUGED VOLUME OF OIL TO 60° F.

Multiply the volume in the tank or car at the observed temperature by the following factor to get the volume at 60° F. for each commodity.

Observed Temperature	Casinghead Gasoline	Gasoline and Naphtha	Kerosene	Gas Oil	Fuel Oil	Asphalt
30	1.0240	1.0178	1.0151	1.0135	1.0123	1.0111
32	1.0224	1.0166	1.0141	1.0126	1.0115	1.0103
34	1.0208	1.0154	1.0131	1.0117	1.0107	1.0095
36	1.0193	1.0142	1.0121	1.0108	1.0099	1.0088
38	1.0177	1.0130	1.0111	1.0099	1.0091	1.0080
40	1.0161	1.0118	1.0101	1.0090	1.0082	1.0073
42	1.0145	1.0106	1.0091	1.0081	1.0074	1.0066
44	1.0129	1.0095	1.0080	1.0072	1.0066	1.0059
46	1.0113	1.0083	1.0070	1.0063	1.0058	1.0051
48	1.0098	1.0071	1.0060	1.0054	1.0050	1.0044
50	1.0082	1.0059	1.0050	1.0045	1.0041	1.0037
52	1.0065	1.0048	1.0040	1.0036	1.0033	1.0029
54	1.0048	1.0036	1.0030	1.0027	1.0025	1.0021
56	1.0032	1.0024	1.0020	1.0018	1.0017	1.0014
58	1.0016	1.0012	1.0010	1.0009	1.0009	1.0007
60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
62	0.9984	0.9988	0.9990	0.9991	0.9992	0.9992
64	0.9968	0.9976	0.9980	0.9982	0.9984	0.9985
66	0.9952	0.9964	0.9970	0.9973	0.9976	0.9978
68	0.9936	0.9952	0.9960	0.9964	0.9967	0.9971
70	0.9919	0.9940	0.9950	0.9955	0.9959	0.9963
72	0.9903	0.9928	0.9940	0.9946	0.9951	0.9956
74	0.9887	0.9917	0.9930	0.9937	0.9943	0.9948
76	0.9871	0.9905	0.9920	0.9928	0.9935	0.9941
78	0.9855	0.9893	0.9909	0.9919	0.9927	0.9934
80	0.9839	0.9881	0.9899	0.9910	0.9918	0.9927
82	0.9823	0.9869	0.9889	0.9901	0.9910	0.9920
84	0.9807	0.9857	0.9879	0.9892	0.9902	0.9912
86	0.9790	0.9845	0.9868	0.9883	0.9893	0.9905
88	0.9774	0.9833	0.9856	0.9875	0.9885	0.9898
90	0.9758	0.9821	0.9848	0.9865	0.9877	0.9891
92	0.9741	0.9809	0.9838	0.9856	0.9869	0.9884
94	0.9725	0.9798	0.9828	0.9847	0.9860	0.9877
96	0.9708	0.9786	0.9818	0.9838	0.9852	0.9870
98	0.9692	0.9774	0.9808	0.9829	0.9844	0.9862
100	0.9676	0.9762	0.9797	0.9820	0.9836	0.9855
102	0.9660	0.9750	0.9787	0.9811	0.9828	0.9848
104	0.9643	0.9738	0.9777	0.9802	0.9820	0.9841
106	0.9626	0.9726	0.9767	0.9793	0.9812	0.9834
108	0.9610	0.9714	0.9757	0.9784	0.9804	0.9827
110	0.9594	0.9702	0.9747	0.9776	0.9796	0.9819
112	0.9578	0.9690	0.9736	0.9767	0.9788	0.9812
114	0.9562	0.9678	0.9726	0.9758	0.9880	0.9805
116	0.9545	0.9666	0.9716	0.9749	0.9772	0.9798
118	0.9529	0.9654	0.9706	0.9740	0.9764	0.9791
120	0.9513	0.9642	0.9696	0.9731	0.9756	0.9784

METHOD OF GAUGING A HORIZONTAL CYLINDRICAL TANK WITH BUMPED ENDS (RADIUS OF CURVATURE = d).

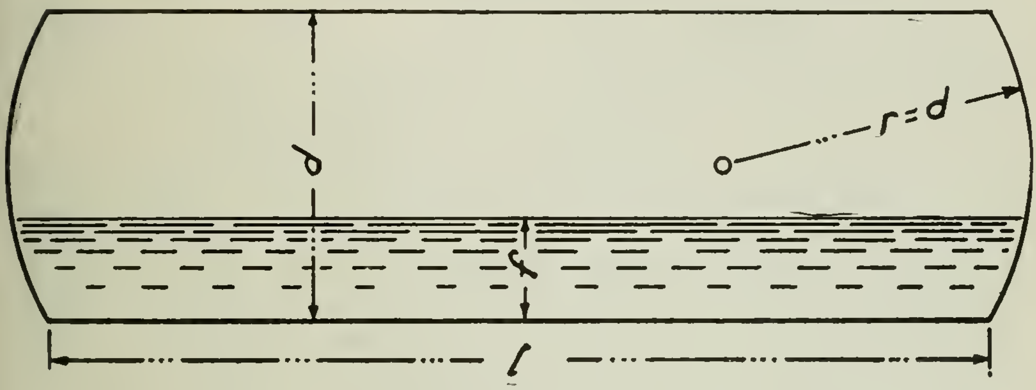


Fig. 22—Horizontal Cylindrical Tank Diagram.

d = diameter of tank in inches.
c = total capacity of cylindrical portion of tank in U. S. gallons.
f = liquid depth of the contents of the tank in inches.

$c = 0.0034\ d^2 l$
$b = 0.0004666\ d^3$ = capacity of both bumped ends in U. S. gallons.

$\frac{100f}{d}$ = % liquid depth of total diameter.

EXAMPLE: d = 87.0 inches
l = 378.2 inches
f = 21.1 inches

then c = 9733. gallons
and b = 307. gallons
10040. gallons = total capacity of tank

and $\frac{100f}{d} = 24.25\%$

From the tables of the following pages 155-158.
24.25% of d = 12.06% of b = 37. gallons
and = 18.78% of c = 1828. gallons
Therefore total contents = 1865. gallons

Take the temperature of the oil with a tank thermometer and in the preceding table giving the corrections for gauged volume of oil to 60°F, look up this temperature. Multiply the above calculated volume by the factor corresponding to this temperature and use the product as contents of the tank. This gives the volume at 60°F. In the case of the above tank containing 1865 gallons of gasoline at a temperature, for instance of 80°F the factor used would be 0.9881 and the net contents of the tank at 60°F would be 1843 gallons.

Method of Constructing a Gauging Table for Horizontal Cylindrical Tank With Standard Bumped Ends. (r = d) for Each .1 Inch.

Assume tank diameter = 87.0 inches.
length = 378.2 inches.

Total capacity of cylindrical portion = 9,733 gallons.
bumped ends = 307 gallons.
total capacity = 10,040 gallons.

To construct this table, a slide rule (Thacher) reading to the fifth place is very convenient. Set the rule with a divisor of 87.0 and with the one setting of the rule, read off the per cent of diameter for each 0.1 inch in depth to one-half of the diameter of the tank, that is 43.5 inches. Now look up in the tables on following pages, the corresponding values, interpolating if that accuracy is desired, for the capacity of the cylindrical portion and the bumped end portions of the tank and record these values as shown below. Now set the slide rule with the total capacity of the cylindrical portion in gallons as multipiier and read off and record the capacities corresponding to each 0.1 inch of diameter as already set out. Do the same with the bumped ends. Add the two values and the gauging table is complete up to half full. Now subtract the preceding value from each value of total gallons and with the adding machine sum each value. This completes the table. The following sets forth enough to illustrate the method:

Depth, in Inches	% of Diameter	% of Cylinder Capacity	% of Bumped Capacity	Actual Gallons Cylinder Part	Bumped Part	Total
0.1	0.12	.007	0.00	0.7	0.0	0.7
1.0	1.15	.21	0.01	20.4	0.0	20.4
1.1	1.26	.24	0.01	23.4	0.0	23.4
2.0	2.30	.59	0.03	57.4	0.1	57.5
2.1	2.41	.63	0.04	61.3	0.1	61.4
3.0	3.45	1.07	0.11	104.1	0.4	104.5
3.1	3.56	1.12	0.12	109.0	0.4	109.4
4.0	4.64	1.67	0.23	162.5	0.7	163.2
4.1	4.71	1.71	0.24	166.4	0.7	167.1
5.0	5.75	2.30	0.44	223.8	1.4	225.2
6.0	6.90	3.01	0.64	292.9	2.0	294.9
7.0	8.05	3.78	0.92	367.9	2.8	370.7
43.0	49.42	49.26	48.96	4794.5	150.3	4944.8
43.5	50.00	50.00	50.00	4866.5	153.5	5020.0
44.0						5095.2
80.0						9669.3

TABLE FOR GAUGING THE CONTENTS AT VARIOUS LIQUID DEPTHS OF HORIZONTAL CYLINDRICAL TANKS.

For Bumped Ends, See Next Table.

% d = percentage of total diameter of tank.

% c = percentage of total capacity of tank.

%d	%c	%d	%c	%d	%c	%d	%c	%d	%c
0.1	0.0053	5.1	1.9250	10.1	5.2805	15.1	9.497	20.1	14.341
0.2	0.0152	5.2	1.9814	10.2	5.3580	15.2	9.588	20.2	14.444
0.3	0.0279	5.3	2.0383	10.3	5.4350	15.3	9.679	20.3	14.547
0.4	0.0429	5.4	2.0956	10.4	5.5122	15.4	9.771	20.4	14.649
0.5	0.0600	5.5	2.1535	10.5	5.5902	15.5	9.863	20.5	14.751
0.6	0.0788	5.6	2.2116	10.6	5.6690	15.6	9.956	20.6	14.854
0.7	0.0992	5.7	2.2705	10.7	5.7472	15.7	10.048	20.7	14.957
0.8	0.1212	5.8	2.3297	10.8	5.8258	15.8	10.142	20.8	15.060
0.9	0.1445	5.9	2.3895	10.9	5.9050	15.9	10.234	20.9	15.163
1.0	0.1692	6.0	2.4497	11.0	5.9848	16.0	10.327	21.0	15.267
1.1	0.1952	6.1	2.5105	11.1	6.0645	16.1	10.422	21.1	15.371
1.2	0.2223	6.2	2.5715	11.2	6.1445	16.2	10.515	21.2	15.475
1.3	0.2508	6.3	2.6333	11.3	6.2255	16.3	10.609	21.3	15.579
1.4	0.2800	6.4	2.6952	11.4	6.3060	16.4	10.703	21.4	15.683
1.5	0.3104	6.5	2.7579	11.5	6.3870	16.5	10.797	21.5	15.787
1.6	0.3419	6.6	2.8211	11.6	6.4685	16.6	10.893	21.6	15.892
1.7	0.3744	6.7	2.8845	11.7	6.5500	16.7	10.986	21.7	15.998
1.8	0.4077	6.8	2.9483	11.8	6.6320	16.8	11.082	21.8	16.101
1.9	0.4421	6.9	3.0127	11.9	6.7145	16.9	11.178	21.9	16.206
2.0	0.4773	7.0	3.0771	12.0	6.7970	17.0	11.273	22.0	16.312
2.1	0.5134	7.1	3.1426	12.1	6.8795	17.1	11.369	22.1	16.418
2.2	0.5501	7.2	3.2082	12.2	6.9630	17.2	11.465	22.2	16.524
2.3	0.5881	7.3	3.2742	12.3	7.0460	17.3	11.561	22.3	16.630
2.4	0.6263	7.4	3.3408	12.4	7.1305	17.4	11.657	22.4	16.737
2.5	0.6660	7.5	3.4075	12.5	7.2145	17.5	11.754	22.5	16.842
2.6	0.7061	7.6	3.4749	12.6	7.2990	17.6	11.851	22.6	16.949
2.7	0.7470	7.7	3.5426	12.7	7.3830	17.7	11.949	22.7	17.055
2.8	0.7886	7.8	3.6106	12.8	7.4680	17.8	12.046	22.8	17.161
2.9	0.8310	7.9	3.6790	12.9	7.5540	17.9	12.143	22.9	17.269
3.0	0.8742	8.0	3.7480	13.0	7.6390	18.0	12.240	23.0	17.376
3.1	0.9179	8.1	3.8171	13.1	7.7245	18.1	12.338	23.1	17.483
3.2	0.9625	8.2	3.8869	13.2	7.8110	18.2	12.437	23.2	17.590
3.3	1.0075	8.3	3.9570	13.3	7.8970	18.3	12.535	23.3	17.698
3.4	1.0533	8.4	4.0276	13.4	7.9840	18.4	12.633	23.4	17.806
3.5	1.0998	8.5	4.0983	13.5	8.0710	18.5	12.732	23.5	17.913
3.6	1.1470	8.6	4.1696	13.6	8.1580	18.6	12.831	23.6	18.022
3.7	1.1947	8.7	4.2411	13.7	8.2450	18.7	12.930	23.7	18.130
3.8	1.2432	8.8	4.3131	13.8	8.3330	18.8	13.030	23.8	18.240
3.9	1.2921	8.9	4.3855	13.9	8.4210	18.9	13.130	23.9	18.348
4.0	1.3418	9.0	4.4582	14.0	8.5090	19.0	13.229	24.0	18.457
4.1	1.3920	9.1	4.5312	14.1	8.5975	19.1	13.329	24.1	18.566
4.2	1.4429	9.2	4.6045	14.2	8.6860	19.2	13.429	24.2	18.675
4.3	1.4941	9.3	4.6782	14.3	8.7755	19.3	13.529	24.3	18.784
4.4	1.5461	9.4	4.7525	14.4	8.8645	19.4	13.630	24.4	18.892
4.5	1.5986	9.5	4.8270	14.5	8.9545	19.5	13.731	24.5	19.010
4.6	1.6515	9.6	4.9015	14.6	9.0440	19.6	13.832	24.6	19.110
4.7	1.7052	9.7	4.9769	14.7	9.1345	19.7	13.934	24.7	19.220
4.8	1.7594	9.8	5.0523	14.8	9.2240	19.8	14.035	24.8	19.330
4.9	1.8142	9.9	5.1280	14.9	9.3150	19.9	14.146	24.9	19.440
5.0	1.8693	10.0	5.2040	15.0	9.406	20.0	14.238	25.0	19.551

TABLE FOR GAUGING HORIZONTAL CYLINDRICAL TANKS—Continued.

% d = percentage of total capacity of tank.
% c = percentage of total capacity of tank.

%d	%c	%d	%c	%d	%c	%d	%c	%d	%c
25.1	19.662	30.1	25.350	35.1	31.314	40.1	37.480	45.1	43.775
25.2	19.773	30.2	25.467	35.2	31.436	40.2	37.606	45.2	43.902
25.3	19.884	30.3	25.584	35.3	31.558	40.3	37.731	45.3	44.028
25.4	19.995	30.4	25.701	35.4	31.680	40.4	37.856	45.4	44.155
25.5	20.106	30.5	25.818	35.5	31.802	40.5	37.981	45.5	44.282
25.6	20.217	30.6	25.935	35.6	31.924	40.6	38.106	45.6	44.409
25.7	20.328	30.7	26.052	35.7	32.046	40.7	38.231	45.7	44.538
25.8	20.439	30.8	26.170	35.8	32.168	40.8	38.355	45.8	44.663
25.9	20.550	30.9	26.288	35.9	32.290	40.9	38.479	45.9	44.790
26.0	20.661	31.0	26.407	36.0	32.412	41.0	38.604	46.0	44.918
26.1	20.773	31.1	26.524	36.1	32.534	41.1	38.730	46.1	45.043
26.2	20.886	31.2	26.642	36.2	32.657	41.2	38.856	46.2	45.171
26.3	20.998	31.3	26.760	36.3	32.780	41.3	38.982	46.3	45.298
26.4	21.110	31.4	26.878	36.4	32.902	41.4	39.108	46.4	45.424
26.5	21.222	31.5	26.996	36.5	33.025	41.5	39.233	46.5	45.550
26.6	21.334	31.6	27.114	36.6	33.147	41.6	39.358	46.6	45.678
26.7	21.447	31.7	27.232	36.7	33.269	41.7	39.482	46.7	45.803
26.8	21.560	31.8	27.351	36.8	33.392	41.8	39.608	46.8	45.930
26.9	21.672	31.9	27.470	36.9	33.515	41.9	39.735	46.9	46.058
27.0	21.785	32.0	27.589	37.0	33.638	42.0	39.862	47.0	46.183
27.1	21.898	32.1	27.708	37.1	33.762	42.1	39.988	47.1	46.311
27.2	22.011	32.2	27.827	37.2	33.885	42.2	40.114	47.2	46.438
27.3	22.125	32.3	27.946	37.3	34.003	42.3	40.240	47.3	46.565
27.4	22.239	32.4	28.065	37.4	34.131	42.4	40.365	47.4	46.693
27.5	22.353	32.5	28.184	37.5	34.254	42.5	40.490	47.5	46.819
27.6	22.467	32.6	28.302	37.6	34.377	42.6	40.615	47.6	46.947
27.7	22.581	32.7	28.422	37.7	34.501	42.7	40.741	47.7	47.074
27.8	22.695	32.8	28.543	37.8	34.625	42.8	40.869	47.8	47.201
27.9	22.810	32.9	28.660	37.9	34.759	42.9	40.994	47.9	47.329
28.0	22.923	33.0	28.781	38.0	34.873	43.0	41.120	48.0	47.457
28.1	23.038	33.1	28.899	38.1	34.996	43.1	41.246	48.1	47.583
28.2	23.152	33.2	29.020	38.2	35.119	43.2	41.372	48.2	47.710
28.3	23.266	33.3	29.140	38.3	35.242	43.3	41.499	48.3	47.837
28.4	23.380	33.4	29.260	38.4	35.368	43.4	41.628	48.4	47.965
28.5	23.494	33.5	29.380	38.5	35.491	43.5	41.749	48.5	48.093
28.6	23.611	33.6	29.500	38.6	35.615	43.6	41.876	48.6	48.220
28.7	23.728	33.7	29.620	38.7	35.739	43.7	42.002	48.7	48.348
28.8	23.842	33.8	29.740	38.8	35.865	43.8	42.129	48.8	48.475
28.9	23.957	33.9	29.860	38.9	35.988	43.9	42.257	48.9	48.603
29.0	24.072	34.0	29.981	39.0	36.110	44.0	42.383	49.0	48.729
29.1	24.187	34.1	30.102	39.1	36.234	44.1	42.510	49.1	48.857
29.2	24.302	34.2	30.223	39.2	36.359	44.2	42.637	49.2	48.983
29.3	24.418	34.3	30.344	39.3	36.483	44.3	42.762	49.3	49.112
29.4	24.535	34.4	30.465	39.4	36.608	44.4	42.890	49.4	49.239
29.5	24.651	34.5	30.587	39.5	36.732	44.5	43.018	49.5	49.366
29.6	24.769	34.6	30.708	39.6	36.856	44.6	43.142	49.6	49.494
29.7	24.884	34.7	30.829	39.7	36.981	44.7	43.268	49.7	49.621
29.8	25.000	34.8	30.950	39.8	37.106	44.8	43.397	49.8	49.748
29.9	25.116	34.9	31.071	39.9	37.230	44.9	43.521	49.9	49.877
30.0	25.233	35.0	31.192	40.0	37.355	45.0	43.648	50.0	50.000

TABLE FOR GAUGING THE CONTENTS AT VARIOUS LIQUID DEPTHS OF BUMPED ENDS OF HORIZONTAL CYLINDRICAL TANKS.

% d = percentage of total diameter of tank.
% b = percentage of total contents of both bumped ends.

%d	%b	%d	%b	%d	%b	%d	%b	%d	%b
0.1	0.00	5.1	0.32	10.1	1.62	15.1	4.18	20.1	7.99
0.2	0.00	5.2	0.34	10.2	1.66	15.2	4.24	20.2	8.09
0.3	0.00	5.3	0.36	10.3	1.69	15.3	4.31	20.3	8.19
0.4	0.00	5.4	0.38	10.4	1.73	15.4	4.38	20.4	8.28
0.5	0.01	5 5	0.40	10.5	1.77	15.5	4.44	20.5	8.38
0.6	0.01	5.6	0.41	10.6	1.81	15.6	4.50	20.6	8.46
0.7	0.01	5.7	0.43	10.7	1.85	15.7	4.57	20.7	8.54
0.8	0.01	5.8	0.45	10.8	1.89	15.8	4.63	20.8	8.63
0.9	0.01	5.9	0.47	10.9	1.94	15.9	4.70	20.9	8.72
1.0	0.01	6.0	0.49	11.0	1.98	16.0	4.77	21.0	8.81
1.1	0.01	6.1	0.50	11.1	2.03	16.1	4.83	21.1	8.89
1.2	0.01	6.2	0.52	11.2	2.07	16.2	4.90	21.2	8.97
1.3	0.01	6.3	0.53	11.3	2.11	16.3	4.96	21.3	9.06
1.4	0.02	6.4	0.54	11.4	2.15	16.4	5.03	21.4	9.15
1.5	0.02	6.5	0.56	11.5	2.20	16.5	5.10	21.5	9.24
1.6	0.02	6.6	0.58	11.6	2.24	16.6	5.17	21.6	9.34
1.7	0.02	6.7	0.60	11.7	2.29	16.7	5.25	21.7	9.44
1.8	0.02	6.8	0.62	11.8	2.33	16.8	5.32	21.8	9.54
1.9	0.02	6.9	0.64	11.9	2.38	16.9	5.40	21.9	9.64
2.0	0.02	7.0	0.66	12.0	2.43	17.0	5.48	22.0	9.74
2.1	0.03	7.1	0.68	12.1	2.48	17.1	5.55	22.1	9.84
2.2	0.03	7.2	0.70	12.2	2.54	17.2	5.63	22.2	9.93
2.3	0.04	7.3	0.73	12.3	2.59	17.3	5.71	22.3	10.03
2.4	0.04	7.4	0.75	12.4	2.65	17.4	5.78	22.4	10.12
2.5	0.05	7.5	0.78	12.5	2.70	17.5	5.86	22.5	10.22
2.6	0.05	7.6	0.81	12.6	2.75	17.6	5.94	22.6	10.32
2.7	0.06	7.7	0.84	12.7	2.80	17.7	6.02	22.7	10.42
2.8	0.06	7.8	0.87	12.8	2.85	17.8	6.10	22.8	10.52
2.9	0.07	7.9	0.90	12.9	2.90	17.9	6.17	22.9	10.62
3.0	0.07	8.0	0.92	13.0	2.95	18.0	6.25	23.0	10.72
3.1	0.08	8.1	0.95	13.1	3.01	18.1	6.33	23.1	10.82
3.2	0.08	8.2	0.98	13.2	3.06	18.2	6.41	23.2	10.93
3.3	0.09	8.3	1.01	13.3	3.12	18.3	6.49	23.3	11.04
3.4	0.10	8.4	1.05	13.4	3.17	18.4	6.57	23.4	11.14
3.5	0.11	8.5	1.08	13.5	3.22	18.5	6.64	23.5	11.25
3.6	0.12	8.6	1.11	13.6	3.28	18.6	6.72	23.6	11.36
3.7	0.13	8.7	1.14	13.7	3.33	18.7	6.80	23.7	11.47
3.8	0.14	8.8	1.17	13.8	3.39	18.8	6.88	23.8	11.58
3.9	0.15	8.9	1.20	13.9	3.44	18.9	6.96	23.9	11.69
4.0	0.16	9.0	1.23	14.0	3.50	19.0	7.05	24.0	11.80
4.1	0.17	9.1	1.26	14.1	3.56	19.1	7.13	24.1	11.90
4.2	0.18	9.2	1.30	14.2	3.62	19.2	7.21	24.2	12.01
4.3	0.19	9.3	1.33	14.3	3.68	19.3	7.29	24.3	12.12
4.4	0.20	9.4	1.36	14.4	3.74	19.4	7.37	24.4	12.22
4.5	0.21	9.5	1.40	14.5	3.80	19.5	7.46	24.5	12.32
4.6	0.22	9.6	1.43	14.6	3.87	19.6	7.55	24.6	12.43
4.7	0.24	9.7	1.46	14.7	3.93	19.7	7.63	24.7	12.54
4.8	0.26	9.8	1.50	14.8	4.00	19.8	7.72	24.8	12.66
4.9	0.28	9.9	1.54	14.9	4.06	19.9	7.81	24.9	12.77
5.0	0.30	10.0	1.58	15.0	4.12	20.0	7.90	25.0	12.89

TABLE FOR GAUGING THE CONTENTS AT VARIOUS LIQUID DEPTHS OF BUMPED ENDS OF HORIZONTAL CYLINDRICAL TANKS (Concluded)

% d = percentage of total diameter of tank.
% b = percentage of total contents of both bumped ends.

%d	%b	%d	%b	%d	%b	%b	%b	%d	%b
25.1	12.95	30.1	19.06	35.1	26.05	40.1	33.74	45.1	41.77
25.2	13.06	30.2	19.19	35.2	26.20	40.2	33.90	45.2	41.94
25.3	13.17	30.3	19.32	35.3	26.35	40.3	34.05	45.3	42.11
25.4	13.29	30.4	19.43	35.4	26.50	40.4	34.20	45.4	42.28
25.5	13.40	30.5	19.55	35.5	26.65	40.5	34.35	45.5	42.45
25.6	13.51	30.6	19.68	35.6	26.80	40.6	34.50	45.6	42.61
25.7	13.63	30.7	19.81	35.7	26.95	40.7	34.65	45.7	42.77
25.8	13.75	30.8	19.94	35.8	27.10	40.8	34.80	45.8	42.93
25.9	13.87	30.9	20.07	35.9	27.25	40.9	34.95	45.9	43.09
26.0	13.98	31.0	20.22	36.0	27.40	41.0	35.10	46.0	43.25
26.1	14.10	31.1	20.37	36.1	27.55	41.1	35.26	46.1	43.41
26.2	14.22	31.2	20.52	36.2	27.70	41.2	35.42	46.2	43.57
26.3	14.34	31.3	20.67	36.3	27.84	41.3	35.58	46.3	43.73
26.4	14.46	31.4	20.82	36.4	27.99	41.4	35.75	46.4	43.89
26.5	14.58	31.5	20.97	36.5	28.13	41.5	35.92	46.5	44.05
26.6	14.70	31.6	21.11	36.6	28.28	41.6	36.08	46.6	44.22
26.7	14.82	31.7	21.25	36.7	28.43	41.7	36.24	46.7	44.38
26.8	14.94	31.8	21.39	36.8	28.59	41.8	36.39	46.8	44.54
26.9	15.16	31.9	21.52	36.9	28.75	41.9	36.55	46.9	44.71
27.0	15.19	32.0	21.65	37.0	28.90	42.0	36.70	47.0	44.88
27.1	15.31	32.1	21.79	37.1	29.05	42.1	36.86	47.1	45.05
27.2	15.43	32.2	21.93	37.2	29.20	42.2	37.02	47.2	45.23
27.3	15.56	32.3	22.07	37.3	29.35	42.3	37.18	47.3	45.31
27.4	15.68	32.4	22.20	37.4	29.50	42.4	37.34	47.4	45.59
27.5	15.80	32.5	22.34	37.5	29.65	42.5	37.50	47.5	45.77
27.6	15.92	32.6	22.47	37.6	29.80	42.6	37.67	47.6	45.95
27.7	16.04	32.7	22.60	37.7	29.95	42.7	37.83	47.7	46.12
27.8	16.16	32.8	22.74	37.8	30.10	42.8	37.99	47.8	46.29
27.9	16.28	32.9	22.87	37.9	30.26	42.9	38.16	47.9	46.46
28.0	16.40	33.0	23.00	38.0	30.42	43.0	38.32	48.0	46.63
28.1	16.53	33.1	23.14	38.1	30.58	43.1	38.49	48.1	46.80
28.2	16.65	33.2	23.28	38.2	30.74	43.2	38.65	48.2	46.96
28.3	16.77	33.3	23.41	38.3	30.91	43.3	38.81	48.3	47.13
28.4	16.90	33.4	23.55	38.4	31.08	43.4	38.97	48.4	47.30
28.5	17.02	33.5	23.69	38.5	31.25	43.5	39.13	48.5	47.46
28.6	17.14	33.6	23.84	38.6	31.40	43.6	39.30	48.6	47.62
28.7	17.27	33.7	23.99	38.7	31.56	43.7	39.46	48.7	47.77
28.8	17.39	33.8	24.15	38.8	31.72	43.8	39.62	48.8	47.93
28.9	17.51	33.9	24.31	38.9	31.87	43.9	39.78	48.9	48.09
29.0	17.63	34.0	24.45	39.0	32.02	44.0	39.95	49.0	48.25
29.1	17.76	34.1	24.59	39.1	32.16	44.1	40.12	49.1	48.42
29.2	17.89	34.2	24.74	39.2	32.31	44.2	40.29	49.2	48.59
29.3	18.02	34.3	24.89	39.3	32.46	44.3	40.46	49.3	48.76
29.4	18.15	34.4	25.05	39.4	32.60	44.4	40.62	49.4	48.93
29.5	18.27	34.5	25.20	39.5	32.75	44.5	40.79	49.5	49.10
29.6	18.40	34.6	25.36	39.6	32.91	44.6	40.95	49.6	49.28
29.7	18.53	34.7	25.52	39.7	33.06	44.7	41.11	49.7	49.46
29.8	18.66	34.8	25.68	39.8	33.32	44.8	41.27	49.8	49.64
29.9	18.80	34.9	25.84	39.9	33.45	44.9	41.44	49.9	49.82
30.0	18.93	35.0	25.90	40.0	33.58	45.0	41.60	50.0	50.00

CONTENTS OF HORIZONTAL TANKS (GALLONS).

Multiply Capacity in Tables by Length of Tanks in Inches.

36 Inches in Diameter	37 Inches in Diameter	38 Inches in Diameter	Depth Inches	39 Inches in Diameter	40 Inches in Diameter	41 Inches in Diameter
....	....	....	20½	....	....	2.858
....	....	....	20	....	2.720	2.769
....	....	....	19½	2.586	....	....
....	....	2.445	19	2.501	2.547	2.951
....	2.327	....	18½	....	....	....
2.203	2.247	2.290	18	2.332	2.374	2.415
2.047	2.087	2.126	17	2.165	2.202	2.239
1.893	1.923	1.963	16	1.998	2.032	2.065
1.739	1.770	1.801	15	1.832	1.863	1.894
1.585	1.613	1.643	14	1.669	1.697	1.724
1.434	1.459	1.484	13	1.509	1.533	1.557
1.286	1.308	1.330	12	1.351	1.372	1.393
1.140	1.159	1.179	11	1.198	1.216	1.233
.999	1.015	1.032	10	1.047	1.063	1.079
.861	.875	.889	9	.903	.916	.929
.729	.740	.752	8	.763	.774	.785
.603	.612	.621	7	.631	.639	.648
.483	.490	.497	6	.505	.512	.518
.371	.376	.382	5	.387	.392	.398
.268	.271	.275	4	.280	.283	.287
.175	.178	.180	3	.183	.185	.188
.096	.098	.099	2	.100	.102	.103
.034	.035	.035	1	.036	.036	.037

42 Inches in Diameter	43 Inches in Diameter	44 Inches in Diameter	Depth Inches	45 Inches in Diameter	46 Inches in Diameter	47 Inches in Diameter
....	....	....	23½	....	....	2.755
....	....	....	23	....	3.597	3.653
....	....	....	22½	3.442	....	....
....	....	3.291	22	3.344	3.397	3.450
....	3.143	....	21½	....	....	....
2.998	3.050	3.100	21	3.149	3.199	3.218
2.817	2.864	2.908	20	2.955	3.002	3.047
2.633	2.679	2.721	19	2.763	2.805	2.846
2.455	2.495	2.533	18	2.572	2.609	2.647
2.276	2.313	2.347	17	2.381	2.416	2.450
2.098	2.132	2.163	16	2.193	2.225	2.256
1.922	1.952	1.981	15	2.009	2.037	2.061
1.750	1.776	1.802	14	1.827	1.852	1.876
1.589	1.603	1.623	13	1.618	1.672	1.693
1.414	1.434	1.451	12	1.473	1.494	1.513
1.252	1.269	1.287	11	1.304	1.321	1.338
1.094	1.110	1.125	10	1.139	1.151	1.168
.942	.955	.968	9	.980	.993	1.005
.797	.807	.817	8	.827	.838	.848
.657	.666	.675	7	.682	.691	.699
.526	.532	.540	6	.546	.552	.558
.403	.408	.414	5	.418	.421	.428
.291	.294	.297	4	.301	.304	.308
.190	.193	.194	3	.197	.199	.200
.104	.106	.107	2	.108	.110	.111
.037	.038	.038	1	.038	.039	.039

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tanks in Inches.

48 Inches in Diameter	49 Inches in Diameter	50 Inches in Diameter	Depth Inches	51 Inches in Diameter	52 Inches in Diameter	53 Inches in Diameter
....	....	....	26½	....	....	4.776
....	....	....	26	....	4.597	4.660
....	....	....	25½	4 422	....	....
....	....	4.250	25	4 309	4 371	4.431
....	4 082	....	24½	....	....	....
3.917	3.975	4.033	24	4.085	4 146	4.203
3.707	3.765	3.817	23	3.865	3.922	3.976
3.498	3.555	3.602	22	3 647	3.700	3 749
2 289	3.345	3.388	21	3 431	3.479	3.523
3.084	3.136	3.175	20	3.216	3 259	3.300
2 881	2.928	2.964	19	3.002	3.044	3.078
2 679	2.722	2.755	18	2.790	2.825	2.859
2 478	2.517	2.548	17	2 580	2.613	2 644
2 281	2 316	2.344	16	2 374	2.405	2.243
2 087	2 118	1.145	15	2.170	2.199	2.222
1 900	1 924	1.948	14	1 971	1.996	2.016
1 716	1 734	1.756	13	1 777	1.797	1.815
1 533	1.550	1.509	12	1 585	1 605	1.622
1.353	1.370	1.386	11	1.402	1 417	1.433
1.180	1 195	1 210	10	1 223	1.235	1.251
1.017	1.027	1.040	9	1.052	1.063	1.077
.859	.866	.878	8	.888	.897	.907
708	.716	.723	7	.729	.737	.746
565	.575	.578	6	.583	.587	.595
432	.440	.442	5	.447	.451	.454
.310	.317	.319	4	.319	.326	.329
201	.205	.208	3	.211	.214	.214
133	.114	.114	2	.114	.117	.119
040	.041	.041	1	.041	.041	.042

54 Inches in Diameter	55 Inches in Diameter	56 Inches in Diameter	Depth Inches	57 Inches in Diameter	58 Inches in Diameter	59 Inches in Diameter
....	....	....	29½	....	....	5.918
....	....	....	29	....	5.719	5.790
....	....	....	28½	5 523	....	....
....	....	5.331	28	5 390	5.467	5.535
....	5 143	....	27½	....	....	....
4 957	5 023	5.089	27	5.153	5.217	5.280
4 723	4 785	4.847	23	4.907	4.967	5.026
4 490	4 547	4.605	25	4.662	4.717	4.773
4 258	4.311	4 365	24	4.417	4.469	4.521
4 490	4 547	4.005	25	4.662	4.717	4.773
4 258	4 311	4.365	24	4.417	4.469	4.521
4 026	4 076	4 125	23	4.175	4.223	4.271
3 794	3 842	3.886	22	3.934	3.987	4.023
3 566	3 611	3.651	21	3.694	3.736	3.777
3 310	3 381	3.418	20	3.456	3.495	3.534
3 116	3 152	3 188	19	3.222	3.256	3.293
2 893	2 926	2 950	18	2.992	3.020	3.057
2 674	2 701	2.734	17	2.766	2.788	2.823
2 459	2 486	2.513	16	2 543	2.563	2.594
2 218	2 271	2.296	15	2.321	2.344	2.369
2 011	2 061	2 084	14	2 104	2.128	2.149
[illegible]	1 857	1.878	13	1.805	1.916	1.934
1 640	1 657	1.675	12	1 692	1 710	1.726
1 449	1 464	1 478	11	1 496	1.509	1.524
1 265	1 279	1 290	10	1.304	1.316	1.329
1 086	1 099	1.108	9	1.120	1.130	1.141
915	926	.936	8	.943	.953	.961
755	759	.769	7	.776	.784	.791
602	607	.614	6	.620	.626	.631
461	466	.470	5	.473	.479	.483
331	335	.337	4	.340	.344	.347
217	219	.220	3	.223	.425	.227
119	120	.121	2	.122	.123	.124
042	042	043	1	.043	.044	.044

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tanks in Inches.

60 Inches in Diameter	61 Inches in Diameter	62 Inches in Diameter	Depth Inches	63 Inches in Diameter	64 Inches in Diameter	65 Inches in Diameter
....	....	....	32½	....	....	7.182
....	....	....	32	....	6.963	7.039
....	....	....	31½	6.747	....	....
....	....	6.535	31	6.610	6.686	6.755
....	6.326	....	30½	....	....	....
6.119	6.193	6.267	30	6.337	6.410	6.472
5.858	5.929	5.999	29	6.065	6.134	6.193
5.598	5.668	5.732	28	5.794	5.858	5.915
5.339	5.407	5.465	27	5.523	.5.584	5.639
5.082	5.146	5.199	26	5.254	5.310	5.363
4.826	4.885	4.935	25	4.986	5.038	5.089
4.572	4.625	4.672	24	4.722	4.709	4.817
4.318	4.366	4.412	23	4.458	4.503	4.547
4.066	4.111	4.153	22	4.196	4.239	4.281
3.818	3.859	3.898	21	3.937	3.976	4.016
3.572	3.609	3.645	20	3.683	3.718	3.756
3.328	3.363	3.397	19	3.490	3.464	3.496
3.088	3.120	3.151	18	3.181	3.213	3.242
2.582	2.881	2.910	17	2.937	2.964	2.992
2.621	2.646	2.672	16	2.608	2.723	2.748
2.392	2.417	2.440	15	2.463	2.486	2.508
2.171	2.192	2.213	14	2.232	2.254	2.274
1.954	1.972	1.991	13	2.008	2.027	2.045
1.743	1.759	1.776	12	1.791	1.898	1.823
1.538	1.552	1.567	11	1.581	1.505	1.608
1.341	1.352	1.366	10	1.378	1.390	1.401
1.152	1.161	1.173	9	1.183	1.192	1.203
.971	.980	.988	8	.906	1.005	1.013
.799	.806	.812	7	.819	.827	.833
.634	.642	.648	6	.653	.659	.664
.487	.491	.496	5	.500	.504	.506
.349	.354	.357	4	.359	.362	.365
.229	.230	.233	3	.235	.238	.238
.125	.126	.128	2	.128	.129	.131
.045	.045	.045	1	.046	.046	.047

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tank in Inches.

66 Inches in Diameter	67 Inches in Diameter	68 Inches in Diameter	Depth Inches	69 Inches in Diameter	70 Inches in Diameter	71 Inches in Diameter
....	....	....	35½	....	....	8.570
....	....	....	35	....	8.330	8.413
....	....	....	34½	8.094	....	....
....	....	7.861	34	7.944	8.026	8.107
....	7.631	....	33½	....	....	....
7.406	7.485	7.567	33	7.640	7.723	7.801
7.120	7.194	7.273	32	7.348	7.421	7.495
6.834	6.904	6.979	31	7.051	7.120	7.190
6.549	6.617	6.687	30	6.755	6.819	6.886
6.264	6.327	6.395	29	6.459	6.519	6.583
5.981	6.041	6.104	28	6.164	6.222	6.283
5.699	5.756	5.814	27	5.870	5.927	5.983
5.419	5.473	5.528	26	5.580	5.634	5.686
5.141	5.191	5.244	25	5.292	5.343	5.291
4.865	4.913	4.961	24	5.006	5.052	5.098
4.592	4.637	4.681	23	4.724	4.764	4.809
4.322	4.363	4.403	22	4.444	4.481	4.524
4.054	4.092	4.128	21	4.167	4.204	4.241
3.789	3.824	3.859	20	3.893	3.929	3.962
3.529	3.561	3.593	19	3.625	3.657	3.688
3.273	3.302	3.331	18	3.360	3.388	3.418
3.020	3.046	3.074	17	3.101	3.125	3.152
2.772	2.797	2.821	16	2.846	2.868	2.894
2.530	2.553	2.575	15	2.595	2.617	2.640
2.294	2.314	2.333	14	2.352	2.372	2.391
2.064	2.080	2.099	13	2.116	2.135	2.150
1.839	1.855	1.871	12	1.886	1.901	1.916
1.622	1.635	1.650	11	1.663	1.674	1.693
1.413	1.426	1.439	10	1.449	1.459	1.476
1.213	1.223	1.235	9	1.242	1.254	1.264
1.022	1.030	1.041	8	1.047	1.060	1.063
.841	.847	.855	7	.859	.871	.874
.670	.675	.680	6	.687	.689	.697
.512	.516	.529	5	.524	.528	.531
.368	.371	.374	4	.377	.378	.382
.240	.243	.244	3	.246	.249	.250
.131	.132	.133	2	.134	.135	.136
.047	.047	.047	1	.048	.048	.048

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tank in Inches.

72 Inches in Diameter	73 Inches in Diameter	74 Inches in Diameter	Depth Inches	75 Inches in Diameter	76 Inches in Diameter	77 Inches in Diameter
....	....	....	38½	....	....	10.079
....	....	....	38	....	9.819	9.912
....	....	....	37½	9.562	....	....
....	....	9.309	37	9.400	9.489	9.579
....	9.059	....	36½	....	....	....
8.813	8.899	8 989	36	9 076	9 160	9.246
8.500	8.582	8.669	35	8.752	8.832	8.914
8 188	8.267	8.349	34	8.428	8.505	8.583
7.887	7.953	8.030	33	8 104	8.178	8.253
7.887	7.953	8.030	33	8 104	8.178	8.253
7.567	7.639	7 712	32	7.782	7.782	7.924
7.259	7.326	7.395	31	7.461	7.528	7.596
6.952	7.015	7.080	30	7 142	7.205	7.268
6.645	6.706	6.766	29	6.824	6.885	6.944
6.341	6.397	6.454	28	6.509	6.567	6.622
6.038	6.091	6.145	27	6.195	6.250	6.302
5.736	5.786	5.839	26	5.885	5.938	5.988
5.439	5.485	5.535	25	5 578	5.628	5.675
5.144	5.188	5.232	24	5.274	5.320	5.364
4.852	4.892	4.934	23	4.975	5.014	5.056
4.563	4.599	4.639	22	4.677	4.715	4.753
4.278	4.311	4.374	21	4.383	4.418	4.453
3.997	4.025	4.062	20	4 094	4.127	4.161
3.719	3.748	3.781	19	3.809	3 839	3.871
3.446	3.474	3.501	18	3 529	3.556	3.585
3.179	3.204	3.229	17	3.255	3.280	3.305
2.917	2.938	2.962	16	2 985	3.008	3.032
2.658	2.681	2.702	15	2 723	2.744	2.764
2.408	2.429	2.447	14	2 467	2.485	2.503
2.167	1.184	2.200	13	2.216	2.234	2.250
1.932	1.946	1.960	12	1.978	1.990	2.003
1.703	1.716	1.727	11	1.742	1.753	1.767
1.483	1.494	1.505	10	1 515	1.527	1.538
1.272	1.281	1.291	9	1.300	1.309	1.318
1.071	1.079	1.086	8	1.095	1.102	1.110
.880	.887	.893	7	.899	.906	.912
.701	.707	.712	6	.717	.722	.727
.536	.540	.544	5	.518	.551	.555
.386	.388	.391	4	.393	.396	.399
.252	.253	.254	3	.256	.259	.260
.138	.138	.139	2	.140	.141	.142
.048	.049	.049	1	.050	.050	.050

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tanks in Inches.

78 Inches in Diameter	79 Inches in Diameter	80 Inches in Diameter	Depth Inches	81 Inches in Diameter	82 Inches in Diameter	83 Inches in Diameter
....	....	....	41½	....	....	11.711
....	....	....	41	....	11.431	11.531
....	....	....	40½	11.154	....	....
....	....	10.880	40	10.978	11.075	11.172
....	10.610	....	39½	....	....	....
10.343	10.439	10.533	39	10.627	10.720	10.814
10.000	10.097	10.187	38	10.277	10.365	10.456
9.666	9.756	9.841	37	9.927	10.012	10.098
9.329	9 416	9.496	36	9.578	9.659	9.741
8.994	9.076	9.151	35	9.231	9.307	9.385
8.659	8.737	8.809	34	8.884	8.958	9.032
8.325	8.398	8.468	33	8.538	8.608	8.679
7.992	8.060	8.128	32	8.194	8.260	8.328
7.660	7.724	7.789	31	7.854	7.916	7.980
7.330	7.391	7.454	30	7.514	7.575	7.633
7.001	7.059	7.120	29	7.176	7.234	7.286
6.676	6.734	6.788	28	6.842	6.893	6.947
6.354	6.407	6.458	27	6.508	6.557	6.610
6.035	6.085	6.132	26	6.181	6.228	6.274
5.719	5.764	5.809	25	5.583	5.899	5.943
5 406	5.449	5.490	24	5.532	5.574	5.615
5.096	5.138	5.175	23	5.212	5.252	5.291
4.791	4.829	4.864	22	4.900	4.933	4.970
4.487	4.523	4.557	21	4.592	4.624	4.657
4.189	4.224	4.254	20	4.286	4.316	4.436
3.897	3.928	3.956	19	3.987	4.013	4.043
3 610	3.637	3.665	18	3.691	3.717	3.742
3 329	3.355	3.377	17	3.403	3.426	3.450
3.053	3.076	3.098	16	3.120	3.141	3.164
2 784	2.804	2.825	15	2.846	2.863	2.883
2.522	2.540	2.558	14	2.576	2.592	2.612
2 267	2.282	2.299	13	2.315	2.329	2.345
2 019	2.033	2.047	12	2.062	2.074	2.089
1 779	1 791	1.804	11	1.816	1.827	1.840
1 548	1.560	1.570	10	1.582	1.501	1.606
1.328	1.336	1 345	9	1.355	1.365	1.372
1 118	1.126	1.132	8	1.141	1 148	1.156
.919	.925	.931	7	.937	.943	.950
.731	.736	.742	6	.746	.752	.757
.559	.563	.565	5	.569	.574	.576
.401	.404	.407	4	.409	.412	.415
.261	.264	.265	3	.267	.269	.269
.113	.143	.145	2	.146	.147	.148
.051	.051	.051	1	.052	.052	.053

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tank in Inches.

84 Inches in Diameter	85 Inches in Diameter	86 Inches in Diameter	Depth Inches	87 Inches in Diameter	88 Inches in Diameter	89 Inches in Diameter
....	....	....	44½	....	....	13.466
....	....	....	44	....	13.165	....
....	....	....	43½	12.867	....	....
....	....	12.573	43	12.679	12.783	12.887
....	12.283	....	42½	....	....	....
11.995	12.099	12.201	42	12.303	12.401	12.501
11.632	11.731	11.829	41	11.927	12.019	12.116
11.269	11.363	11.457	40	11.552	11.638	11.734
10.906	10.997	11.086	39	11.177	11.261	11.352
10.544	10.632	10.716	38	10.802	10.884	10.970
10.183	10.267	10.347	37	10.430	10.508	10.589
9.822	9.903	9.979	36	10.058	10.132	10.209
9.462	9.540	9.611	35	9.759	9.759	9.832
9.104	9.177	9.245	34	9.318	9.387	9.458
8.747	8.816	8.883	33	8.951	9.018	9.085
8.392	8.459	8.523	32	8.587	8.651	8 713
8.040	8.105	8 164	31	8.226	8.287	8.345
7.690	7.751	7.807	30	7.865	7.925	7.978
7.344	7.401	7.454	29	7.509	7.566	7.617
7.000	7.054	7.104	28	7.156	7.210	7.258
6.658	6.710	6.756	27	6.805	6.856	6.901
6.320	6.369	6.413	26	6.458	6.504	6.549
5.986	6.030	6.074	25	6.118	6.158	6.201
5.656	5.699	5.738	24	5.773	5.816	5.858
5.330	5.368	5.404	23	5.445	5.482	5.516
5.007	5.043	5.078	22	5.114	5.150	5.182
4.690	4.724	4.756	21	4.790	4.821	4.855
4.378	4.410	4.440	20	4.469	4.499	4.528
4.071	4.098	4.126	19	4.155	4.181	4.211
3.770	3.796	3.821	18	3.847	3.872	3.896
3.475	3.497	3.522	17	3.544	3.576	3.590
3.186	3.206	3.227	16	3.249	3.269	3.291
2.904	2.924	2.941	15	2.961	2.980	2.999
2.629	2.646	2.663	14	2.679	2.699	2.714
2.362	2.378	2.393	13	2.406	2.421	2.439
2.104	2.116	2.129	12	2.142	2.154	2.169
1.853	1.865	1.876	11	1.888	1.900	1.200
1.613	1.621	1.633	10	1.641	1.656	1.663
1.383	1.391	1.400	9	1.407	1.416	1.425
1.162	1.169	1.176	8	1 185	1.190	1.200
.954	.962	.967	7	.973	.979	.983
.760	.765	.770	6	.776	.778	.784
.580	.585	.587	5	.592	.595	.598
.417	.420	.422	4	.429	.429	.430
.272	.274	.275	3	.278	.279	.280
.148	.149	.151	2	.151	.153	.154
.053	.053	.053	1	.054	.055	.055

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tanks in Inches.

90 Inches in Diameter	91 Inches in Diameter	92 Inches in Diameter	Depth Inches	93 Inches in Diameter	94 Inches in Diameter	95 Inches in Diameter
....	....	....	47½	....	....	15.342
....	....	....	47	....	15.021	15.136
....	....	....	46½	14 703	....	....
....	....	14.388	46	14.501	14.612	14.726
....	14 078	....	45½	....	....	....
13.770	13.880	13.988	45	14 098	14 207	14.316
13.378	13 487	13.590	44	13 696	13.802	13.905
12.987	13.094	13 194	43	13 296	13.397	13.495
12.597	12.701	12 798	42	12 896	12.993	13.086
12.209	12.308	12.403	41	12.497	12.590	12.679
11.822	11.915	12 008	40	12.098	12.187	12 273
11.436	11.525	11.613	39	11.699	11.785	11.867
11.051	11.137	11 218	38	11.301	11.381	11 463
10.667	10.750	10.826	37	10.906	10.983	11.061
10.284	10.363	10.438	36	10.513	10 587	10.662
9 903	9 977	10.050	35	10 123	10.193	10.265
9 524	9.596	9.665	34	9.733	9.800	9.870
9.184	9.216	9.281	33	9.344	9.410	9.476
8 773	8.837	8.900	32	8 962	9.024	9.084
8 403	8.463	8.523	31	8.580	8.639	8.697
8 035	8.093	8.149	30	8 200	8.257	8.313
7 670	7.724	7.777	29	7.827	7.880	7.932
7.308	7.358	7.409	28	7.456	7.506	7.553
6 948	6.996	7.046	27	7.089	7.138	7.182
6 593	6 638	6 687	26	6.727	6.771	6.812
6 242	6 283	6.331	25	6.367	6.407	6.450
5 894	5 934	5 976	24	6.013	6.052	6 090
5 552	5.588	5.626	23	5.662	5.700	5.734
5 215	5 248	5 284	22	5.320	5.352	5.386
4 883	4 916	4.948	21	4.979	5.010	5.042
4 656	4.587	4.617	20	4 647	4.673	4.701
4 235	4 264	4 292	19	4.317	4.343	4.368
3 921	3 946	3 972	18	3.996	4.021	4.045
3 611	3 635	3 657	17	3.681	3.703	3.727
3 309	3 331	3.353	16	3.375	3.393	3.414
3 014	3.035	3.056	15	3 073	3.091	3.109
2 729	2 747	2.763	14	2.781	2.796	2.814
2 452	2 468	2.480	13	2.497	2 510	2.524
2 183	2 196	2 210	12	2.222	2.232	2.248
1 922	1 934	1.946	11	1.957	1.966	1.981
1 673	1 682	1 696	10	1.703	1 714	1.723
1 433	1.443	1 455	9	1.455	1.469	1.474
1 204	1 214	1 216	8	1.226	1.232	1.240
989	995	1 000	7	1.007	1.010	1.019
787	793	799	6	803	.807	.812
601	605	608	5	.613	.616	.618
432	435	440	4	.440	.445	.445
281	284	290	3	.290	.291	.292
151	155	156	2	.157	.158	.160
055	055	.056	1	.056	.056	.056

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tanks in Inches.

96 Inches in Diameter	Depth Inches	97 Inches in Diameter	96 Inches in Diameter	Depth Inches	97 Inches in Diameter
....	48½	15.995	6.128	24	6.163
15.668	48	15.785	5.770	23	5.803
15.248	47	15.365	5.416	22	5.450
14.828	46	14 945	5 066	21	5.101
14.410	45	14.525	4.726	20	4.757
13.992	44	14.108	4.394	19	4.421
13.574	43	13.692	4.068	18	4.092
13.158	42	13.276	3.752	17	3.770
12.744	41	12.860	3 444	16	3.455
12.336	40	12.446	3 139	15	3.145
11 930	39	12.033	2.838	14	2.844
11.524	38	11 622	2.546	13	2.554
11.119	37	11.214	2.260	12	2.273
10.716	36	10.807	1.990	11	2.001
10.315	35	10 400	1.728	10	1.742
9.915	34	9.997	1.480	9	1.492
9.518	33	9 599	1.240	8	1.254
9.124	32	9.204	1.016	7	1.032
8.736	31	8.810	.804	6	.821
8.352	30	8.420	.620	5	.625
7.974	29	8.035	.447	4	.448
7.600	28	7.654	.292	3	.293
7.230	27	7.274	.160	2	.160
6.862	26	6.897	.057	1	.057
6.494	25	6.526			

98 Inches in Diameter	Depth Inches	99 Inches in Diameter	98 Inches in Diameter	Depth Inches	99 Inches in Diameter
....	49½	166.662	6.569	25	6.607
16.327	49	16.446	6.203	24	6.239
15.898	48	16.016	5.841	23	5.874
15.473	47	15 587	5.484	22	5.514
15.049	46	15.159	5.131	21	5.160
14.626	45	14.732	4.786	20	4.814
14.205	44	14.305	4.449	19	4.472
13.784	43	13.880	4.116	18	4.138
13.363	42	13.458	3.792	17	3.811
12.944	41	13.036	3.472	16	3.941
12.527	40	12.615	3.160	15	3.181
12.111	39	12 197	2.856	14	2.878
11.698	38	11.780	2 565	13	2.583
11.287	37	11 365	2.282	12	2.298
10.877	36	10.952	2.016	11	2.025
10.468	35	10.539	1.754	10	1.759
10.063	34	10.128	1.501	9	1.508
9.661	33	9.723	1.260	8	1.266
9.263	32	9.322	1.035	7	1.040
8.867	31	8.921	.823	6	.828
8.473	30	8 526	.628	5	.633
8.085	29	8 136	.453	4	.453
7.700	28	7.747	.295	3	.297
7.318	27	7.362	.162	2	.162
6.940	26	6 982	.058	1	.058

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tank in Inches.

100 Inches in Diameter	Depth Inches	101 Inches in Diameter	100 Inches in Diameter	Depth Inches	101 Inches in Diameter
....	50½	17.342	6 647	25	6.685
17.000	50	17.122	6 274	24	6.311
16.565	49	16.683	5 908	23	5.942
16.132	48	16.247	5.546	22	5 579
15.699	47	15.812	5.190	21	5.221
15.267	46	15.377	4 841	20	4.808
14.837	45	14.942	4.498	19	4.523
14.407	44	14.507	4.162	18	4.185
13.987	43	14 073	3.833	17	3.855
13.551	42	13.642	3.511	16	3.531
13.125	41	13.213	3.198	15	3.215
12.700	40	12 784	2.893	14	2.908
12.277	39	12.356	2.597	13	2.612
11.855	38	11.931	2.311	12	2.324
11.436	37	11 508	2.035	11	2.041
11.020	36	11.000	1.769	10	1.779
10.605	35	10.672	1.516	9	1.524
10.194	34	10.257	1.274	8	1.282
9.785	33	9.846	1.040	7	1.053
9.379	32	9 437	.833	6	.838
8.977	31	9.032	.636	5	.640
8.578	30	8.630	.456	4	.458
8.184	29	8.233	.297	3	.298
7.793	28	7.840	.162	2	.162
7.407	27	7.450	.058	1	.158
7 024	26	7.065			

102 Inches in Diameter	Depth Inches	103 Inches in Diameter	102 Inches in Diameter	Depth Inches	103 Inches in Diameter
....	51½	18.033	7.108	26	7.148
17 687	51	17.811	6.722	25	6.764
17 246	50	17.364	6 340	24	6.387
16 805	49	16.918	5.972	23	6.010
16.364	48	16.473	5.608	22	5.644
15 924	47	16.030	5 251	21	5.281
15 485	46	15.587	4.895	20	4 924
15 047	45	15.144	4.549	19	4 576
14 609	44	14.701	4 208	18	4.230
14 172	43	14.259	3.877	17	3.896
13 738	42	13.819	3.554	16	3 508
13 304	41	13.384	3.235	15	3.250
12 871	40	12.950	2.916	14	2.938
12 440	39	12.516	2.622	13	2.639
12 011	38	12.083	2.333	12	2.348
11 587	37	11.655	2.056	11	2.069
11 163	36	11.229	1.787	10	1.798
10 743	35	10 805	1.531	9	1.542
10 325	34	10 386	2 178	8	1.295
9 911	33	9.968	2.057	7	1.064
9 498	32	9.556	.854	6	.844
9 087	31	9.147	.642	5	.646
8 680	30	8 738	.458	4	.462
8 282	29	8.331	.300	3	.301
7 884	28	7.930	.163	2	.164
7 497	27	7.537	.058	1	.059

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tank in Inches.

104 Inches in Diameter	Depth Inches	105 Inches in Diameter	104 Inches in Diameter	Depth Inches	105 Inches in Diameter
....	52½	18.742	7.190	26	7.229
18.387	52	18.513	6.804	25	6.841
17.936	51	18.057	6.423	24	6.457
17.485	50	17.603	6.046	23	6.075
17.035	49	17.150	5.671	22	5.704
16.587	48	16.697	5.308	21	5.336
16.140	47	16.245	4.950	20	4.978
15.693	46	15.794	4.599	19	4.626
15.247	45	15.343	4.255	18	4.277
14.802	44	14.893	3.920	17	3.938
14.357	43	14.447	3.588	16	3.608
13.912	42	14.002	3.267	15	3.285
13.470	41	13.558	2.955	14	2.971
13.032	40	13.116	2.653	13	2.667
12.597	39	12.675	2.361	12	2.373
12.164	38	12.237	2.080	11	2.090
11.732	37	11.802	1.809	10	1.814
11.297	36	11.371	1.548	9	1.556
10.872	35	10.940	1.300	8	1.308
10.450	34	10.511	1.068	7	1.074
10.029	33	10.088	.850	6	.853
9.610	32	9.666	.649	5	.652
9.198	31	9.249	.467	4	.469
8.789	30	8.837	.302	3	.304
8.382	29	8.430	.164	2	.165
7.978	28	8.025	.059	1	.059
7.582	27	7.623			

106 Inches in Diameter	Depth Inches	107 Inches in Diameter	106 Inches in Diameter	Depth Inches	107 Inches in Diameter
....	53½	19.463	7.668	27	7.710
19.101	53	19.230	7.272	26	7.312
18.639	52	18.766	6.877	25	6.919
18.180	51	18.303	6.491	24	6.526
17.723	50	17.841	6.111	23	6.14
17.266	49	17.381	5.733	22	5.767
16.810	48	16.922	5.366	21	5.395
16.354	47	16.463	5.005	20	5.029
15.898	46	16.004	4.648	19	4.673
15.444	45	15.545	4.300	18	4.323
14.991	44	15.087	3.960	17	3.980
14.539	43	14.629	3.626	16	3.643
14.089	42	14.176	3.302	15	3.320
13.642	41	13.724	2.988	14	3.001
13.196	40	13.275	2.680	13	2.696
12.752	39	12.828	2.384	12	2.398
12.310	38	12.384	2.101	11	2.110
11.869	37	11.943	1.824	10	1.834
11.434	36	11.503	1.564	9	1.571
11.005	35	11.069	1.314	8	1.320
10.576	34	10.635	1.077	7	1.084
10.150	33	10.205	.858	6	.862
9.725	32	9.779	.655	5	.658
9.303	31	9.354	.470	4	.473
8.888	30	8.937	.306	3	.306
8.474	29	8.523	.166	2	.167
8.069	28	8.116	.059	1	060

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tank in Inches.

108 Inches in Diameter	Depth Inches	109 Inches in Diameter	108 Inches in Diameter	Depth Inches	109 Inches in Diameter
....	54½	20.198	7.756	27	7.796
19.828	54	19.962	7.352	26	7.391
19.359	53	19.490	6.953	25	6.993
18.892	52	19.019	6.560	24	6.597
18.426	51	18.548	6.176	23	6.209
17.961	50	18.077	5.797	22	5.827
17.496	49	17.607	5.428	21	5.453
17.031	48	17.137	5.059	20	5.084
16.567	47	16.670	4.696	19	4.720
16.103	46	16.203	4.343	18	4.367
15.639	45	15.737	4.000	17	4.022
15.178	44	15.272	3.661	16	3.682
14.719	43	14.810	3.335	15	3.353
14.263	42	14.349	3.020	14	3.032
13.810	41	13.890	2.711	13	2.723
13.359	40	13.435	2.409	12	2.422
12.910	39	12.983	2.121	11	2.131
12.464	38	12.531	1.843	10	1.852
12.019	37	12.083	1.575	9	1.586
11.576	36	11.639	1.323	8	1.336
11.135	35	11.197	1.085	7	1.095
10.698	34	10.758	.868	6	.871
10.265	33	10.322	.662	5	.665
9.836	32	9.892	.476	4	.477
9.412	31	9.463	.309	3	.309
9.992	30	9.037	.169	2	.170
8.576	29	8.619	.060	1	.060
8.165	28	8.207			
110 Inches in Diameter	**Depth Inches**	**111 Inches in Diameter**	**110 Inches in Diameter**	**Depth Inches**	**111 Inches in Diameter**
......	55½	20.946	8.244	28	8.290
20.570	55	20.703	7.833	27	7.878
20.093	54	20.219	7.428	26	7.468
19.616	53	19.738	7.026	25	7.063
19.140	52	19.259	6.628	24	6.665
18.664	51	18.781	6.238	23	6.274
18.188	50	18.305	5.856	22	5.888
17.715	49	17.829	5.481	21	5.509
17.244	48	17.353	5.116	20	5.136
16.774	47	16.877	4.754	19	4.771
16.304	46	16.403	4.396	18	4.413
15.836	45	15.932	4.046	17	4.059
15.368	44	15.461	3.704	16	3.718
14.905	43	14.992	3.366	15	3.385
14.444	42	14.523	3.036	14	3.062
13.983	41	14.064	2.724	13	2.748
13.524	40	13.589	2.428	12	2.445
13.066	39	13.130	2.140	11	1.153
12.608	38	12.676	1.864	10	1.870
12.155	37	12.223	1.599	9	1.600
11.704	36	11.772	1.347	8	1.347
11.258	35	11.323	1.102	7	1.106
10.816	34	10.879	.876	6	.880
10.378	33	10.437	.671	5	.671
9.944	32	10.002	.479	4	.480
9.514	31	9.570	.310	3	.312
9.087	30	9.141	.170	2	.170
8.664	29	8.714	.060	1	.061

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tank in Inches.

112 Inches in Diameter	Depth Inches	113 Inches in Diameter	112 Inches in Diameter	Depth Inches	113 Inches in Diameter
....	56½	21 707	8.338	28	8.383
21.325	56	21.461	7.919	27	7.962
20.837	55	20 971	7.507	26	7.548
20.349	54	20.481	7.101	25	7.139
19.863	53	19 991	6 703	24	6.736
19.379	52	19 504	6.307	23	6.339
18.897	51	19.017	5.916	22	5 948
18.415	50	18 530	5.536	21	5.560
17 936	49	18 044	5 163	20	5.188
17.457	48	17.559	4.795	19	4 817
16.980	47	17.074	4.434	18	4.457
16.503	46	16.590	4.081	17	4.101
16.028	45	16.112	3.738	16	3.755
15.554	44	15.638	3.402	15	3.419
15.080	43	15.165	3.077	14	3.091
14.610	42	14.692	2.764	13	2.772
14.141	41	14.221	2.457	12	2.468
13.672	40	13.751	2.162	11	2.171
13.210	39	13.283	1.881	10	1.887
12.751	38	12.821	1.610	9	1.615
12.292	37	12.361	1.350	8	1.357
11.838	36	11.904	1.111	7	1.113
11.388	35	11.449	.885	6	.886
10.942	34	10.999	.674	5	.675
10.497	33	10.552	.482	4	.486
10.055	32	10.108	.314	3	.317
9.620	31	9.669	.171	2	.171
9.188	30	9 235	.061	1	.062
8 761	29	8 805			

114 Inches in Diameter	Depth Inches	115 Inches in Diameter	114 Inches in Diameter	Depth Inches	115 Inches in Diameter
....	57½	22.482	8.856	29	8.898
22.093	57	22.230	8.425	28	8.468
21.599	56	21.733	8.003	27	8.040
21.105	55	21.236	7.583	26	7.622
20.611	54	20.740	7.176	25	7.213
20.117	53	20.244	6.770	24	6 806
19.624	52	19.748	6.369	23	6.401
19.132	51	19 252	5.978	22	6.007
18 643	50	18 756	5 592	21	5.619
18.155	49	18.262	5 212	20	5 238
17.668	48	17 772	4.841	19	4 865
17.181	47	17.282	4.476	18	4.499
16.695	46	16.795	4 120	17	4 139
16.212	45	16.309	3.771	16	3 786
15.731	44	15.823	3.436	15	3.451
15.253	43	15.341	3.109	14	3 121
14.775	42	14.862	2.786	13	2.799
14.299	41	14.383	2.481	12	2.491
13.828	40	13.906	2 183	11	2.192
13 360	39	13 431	1.898	10	1.907
12.893	38	12 964	1 624	9	1 632
12.428	37	12.497	1.365	8	1.371
11.967	36	12.033	1.120	7	1.126
11.511	35	11 572	.890	6	.895
11.057	34	11.116	.681	5	.684
10.609	33	10.664	.488	4	.490
10.165	32	10.217	.317	3	.319
9.722	31	9.771	.172	2	.173
9.288	30	9.331	.062	1	.062

HORIZONTAL TANKS—(Continued).

Multiply Capacity in Tables by Length of Tank in Inches.

116 Inches in Diameter	Depth Inches	117 Inches in Diameter	116 Inches in Diameter	Depth Inches	117 Inches in Diameter
......	58½	23.271	8.944	29	8.988
22.875	58	23.016	8.513	28	8.555
22.371	57	22.506	8.086	27	8.125
21.868	56	21.998	7.663	26	7.701
21.366	55	21.493	7.247	25	7.232
20.865	54	20.989	6.838	24	6.870
20.365	53	20.485	6.434	23	6.460
19.866	52	19.992	6.036	22	6.065
19.368	51	19.479	5.645	21	5.675
18.870	50	18.977	5.262	20	5.292
18.373	49	18.476	4.888	19	4.913
17.877	48	17.975	4.519	18	4.541
17.382	47	17.478	4.160	17	4.179
16.888	46	16.984	3.813	16	3.826
16.398	45	16.491	3.468	15	3.483
15.911	44	15.999	3.136	14	3.149
15.427	43	15.510	2.813	13	2.828
14.944	42	15.024	2.502	12	2.516
14.462	41	14.540	2.201	11	2.215
13.981	40	14.056	1.914	10	1.925
13.501	39	13.578	1.639	9	1.645
13.023	38	13.102	1.376	8	1.385
12.549	37	12.632	1.131	7	1.136
12.079	36	12.162	.899	6	.903
11.613	35	11.698	.686	5	.689
11.152	34	11.238	.492	4	.496
10.697	33	10.778	.320	3	.321
10.250	32	10.323	.175	2	.175
9.812	31	9.872	.062	1	.063
9.377	30	9.428			

118 Inches in Diameter	Depth Inches	119 Inches in Diameter	118 Inches in Diameter	Depth Inches	119 Inches in Diameter
....	59½	24.074	9.476	30	9.524
23.671	59	23.816	9.031	29	9.082
23.160	58	23.301	8.595	28	8.643
22.649	57	22.787	8.165	27	8.207
22.138	56	22.273	7.739	26	7.779
21.627	55	21.760	7.319	25	7.357
21.117	54	21.247	6.905	24	6.940
20.609	53	20.734	6.496	23	6.529
20.102	52	20.221	6.094	22	6.127
19.597	51	19.710	5.702	21	5.730
19.092	50	19.203	5.317	20	5.342
18.587	49	18.697	4.937	19	4.959
18.083	48	18.191	4.562	18	4.587
17.582	47	17.685	4.197	17	4.220
17.082	46	17.182	3.845	16	3.867
16.584	45	16.681	3.501	15	3.520
16.088	44	16.180	3.163	14	3.180
15.595	43	15.682	2.841	13	2.853
15.105	42	15.188	2.526	12	2.535
14.620	41	14.697	2.223	11	2.232
14.137	40	14.209	1.932	10	1.938
13.651	39	13.725	1.655	9	1.659
13.171	38	13.245	1.390	8	1.396
12.698	37	12.767	1.141	7	1.146
12.225	36	12.291	.909	6	.910
11.758	35	11.818	.691	5	.696
11.[illegible]	34	11.350	.497	4	.498
10.[illegible]	33	10.888	.322	3	.325
10.377	32	10.429	.175	2	.178
9.921	31	9.975	.063	1	.063

HORIZONTAL TANKS—(Concluded).

Multiply Capacity in Tables by Length of Tank in Inches.

120 Inches in Diameter	Depth Inches	120 Inches in Diameter	Depth Inches	120 Inches in Diameter	Depth Inches
24.479	60	14.287	40	5.363	20
23.954	59	13.797	39	4.981	19
23.434	58	13.314	38	4.608	18
22.914	57	12.833	37	4.240	17
22.395	56	12.354	36	3.882	16
21.877	55	11.881	35	3.538	15
21.359	54	11.411	34	3.198	14
20.842	53	10.944	33	2.866	13
20.328	52	10.483	32	2.537	12
19.815	51	10.024	31	2.239	11
19.305	50	9.567	30	1.949	10
18.795	49	9.124	29	1.668	9
18.287	48	8.683	28	1.396	8
17.780	47	8.244	27	1.151	7
17.273	46	7.816	26	.915	6
16.767	45	7.393	25	.699	5
16.265	44	6.976	24	.501	4
15.768	43	6.561	23	.326	3
15.273	42	6.153	22	.178	2
14.779	41	5.751	21	.063	1

GAUGING TABLE FOR EACH ONE-QUARTER INCH IN DEPTH FOR TANK AS DETAILED ON PETROLEUM IRON WORKS COMPANY DRAWING No. 2050-A

8050-Gallon 78-Inch Diameter Tank With Steam Coils for Type "A" and "A-1" Cars

Steam Coils, Con.

Steam Coils 46 Gallons Deducted

DOME

Depth	Bottom	Feet	Gallons	Feet	Gallons	Feet	Gallons	Feet	Gallons	Feet	Gallons	Feet	Gallons	Feet	Gallons
0	....	1	731	2	2037	3	3565	4	5241	5	6583	6	7695	7	8085
¼	....	¼	754	¼	2067	¼	3598	¼	5174	¼	6611	¼	7713	¼	8088
½	....	½	777	½	2097	½	3631	½	5206	½	6638	½	7731	½	8091
¾	....	¾	801	¾	2128	¾	3664	¾	5238	¾	6665	¾	7749	¾	8094
1	20	1	825	1	2159	1	3697	1	5269	1	6692	1	7766	1	8097
¼	28	¼	849	¼	2189	¼	3730	¼	5301	¼	6719	¼	7783	¼	8100
½	37	½	875	½	2220	½	3765	½	5332	½	6746	½	7800	½	8103
¾	46	¾	898	¾	2251	¾	3796	¾	5364	¾	6772	¾	7816	¾	8106
2	55	2	823	2	2282	2	3830	2	5395	2	6798	2	7832	2	8109
¼	65	¼	948	¼	2313	¼	3863	¼	5427	¼	6824	¼	7847	¼	8112
½	76	½	973	½	2344	½	3896	½	5458	½	6850	½	7862	½	8115
¾	88	¾	998	¾	2375	¾	3929	¾	5489	¾	6876	¾	7877	¾	8118
3	100	3	1024	3	2406	3	3963	3	5520	3	6901	3	7891	3	8120
¼	113	¼	1050	¼	2437	¼	3997	¼	5551	¼	6927	¼	7905	¼	8123
½	126	½	1076	½	2468	½	4030	½	5582	½	6952	½	7918	½	8126
¾	139	¾	1102	¾	2499	¾	4063	¾	5613	¾	6977	¾	7931	¾	8129
4	153	4	1128	4	2531	4	4096	4	5644	4	7002	4	7943	4	8132
¼	167	¼	1154	¾	2562	½	4130	¼	5675	¼	7027	¼	7954	¼	8235
½	181	½	1180	½	2594	½	4163	½	5703	½	7052	½	7965	½	8138
¾	196	¾	1207	¾	2625	¾	4196	¾	5737	¾	7077	¾	7976	¾	8141
5	211	5	1234	5	2657	5	4229	5	5767	5	7101	5	7986	5	8144
¼	226	¼	1261	¼	2688	¼	4262	¼	5799	¼	7125	¼	7995	¼	8147
½	241	½	1288	½	2720	½	4295	½	5829	½	7149	½	8003	½	8150
¾	256	¾	1315	¾	2752	¾	4328	¾	5859	¾	7173	¾	8010	¾	8153
6	272	6	1343	6	2784	6	4361	6	5889	6	7197	6	8015	6	8155
¼	287	¼	1370	¼	2816	¼	4394	¼	5919	¼	7221	¼	8018	¼	.....
½	305	½	1398	½	2848	½	4427	½	5949	½	7244	½	8021	½	.....
¾	319	¾	1426	¾	2880	¾	4460	¾	5979	¾	7267	¾	8024	¾	.....
7	335	7	1454	7	2912	7	4493	7	6009	7	7290	7	8027	7	.....
¼	352	¼	1482	¼	2944	¼	4526	¼	6039	¼	7313	¼	8030	¼	.....
½	369	½	1510	½	2976	½	4559	½	6069	½	7335	½	8033	½	.....
¾	386	¾	1538	¾	3008	¾	4592	¾	6098	¾	7357	¾	8036	¾	.....
8	403	8	1567	8	3041	8	4624	8	6127	8	7379	8	8039	8	.....
¼	421	¼	1595	¼	3073	¼	4657	¼	6157	¼	7401	¼	8042	¾	.....
½	439	½	1624	½	3106	½	4690	½	6186	½	7422	½	8045	½	.....
¾	457	¾	1653	¾	3138	¾	4723	¾	6215	¾	7443	¾	8048	¾	.....
9	476	9	1682	9	3171	9	4755	9	6244	9	7484	9	8050	9	.....
¼	496	¼	1711	¼	3203	¼	4788	¼	6273	¼	7485	¼	8053	¼	.....
½	516	½	1740	½	3236	½	4820	½	6302	½	7506	½	8056	½	.....
¾	536	¾	1769	¾	3269	¾	4853	¾	6351	¾	7526	¾	8059	¾	.....
10	556	10	1799	10	3302	10	4885	10	6359	10	7546	10	8062	10	.....
¼	577	¼	1826	¼	3334	¼	4918	¼	6388	¼	7566	¼	8065	¼	.....
½	598	½	1857	½	3367	½	4950	½	6416	½	7585	½	8068	½	.....
¾	619	¾	1887	¾	3400	¾	4982	¾	6444	¾	7604	¾	8071	¾	.....
11	640	11	1917	11	3433	11	5014	11	6472	11	7623	11	8074	11	.....
¼	662	¼	1947	¼	3466	¼	5046	¼	6500	¼	7641	¼	8077	¼	.....
½	681	½	1977	½	3499	½	5078	½	6528	½	7659	½	8080	½	.....
¾	707	¾	2007	¾	3532	¾	5110	¾	6556	¾	7677	¾	8083	¾	.....

DOME 244 gallons = 11.60 gallons to one inch.

Furnished by Pennsylvania Tank Car Company, Sharon, Pa.

Outage Table for Standard 6,000 Gallons Capacity Tank Car.

Table for gauging tanks by the inch. Capacity in U. S. gallons of a 72½" diameter tank. Official dome capacity, including dish in head, 222 gallons. Length of tank, bend line to bend line, 27′ 8¼″.

Inches	Gallons	Inches	Gallons	Inches	Gallon
1	16.62	26	1964.88	50	4482.36
2	46.94	27	2067.94	51	4580.68
3	85.99	28	2171.75	52	4677.68
4	131.84	29	2276.29	53	4773.38
5	183.44	30	2381.39	54	4868.52
6	240.16	31	2487.05	55	4959.99
7	301.30	32	2593.30	56	5050.69
8	366.47	33	2699.71	57	5139.43
9	435.23	34	2806.40	58	5226.07
10	507.47	35	2913.24	59	5310.56
11	582.80	36	3020.24	60	5392.65
12	660.96	36¼	3047.00	61	5472.12
13	741.73	37	3127.26	62	5548.86
14	825.15	38	3234.18	63	5622.65
15	910.70	39	3340.95	64	5693.60
16	998.43	40	3447.50	65	5760.64
17	1088.20	41	3553.82	66	5823.88
18	1179.82	42	3659.78	67	5882.82
19	1273.13	43	3765.16	68	5937.01
20	1368.11	44	3869.98	69	5985.74
21	1464.53	45	3974.15	70	6028.37
22	1562.11	46	4077.59	71	6063.41
23	1661.17	47	4180.20	72	6088.36
24	1761.46	48	4281.91	72½	6094.00
25	1862.72	49	4382.69		

Dome capacity is 9.914 gallons per inch.

TANK CAR OUTAGE TABLES

Calculated From 0.25 Inch to 5 Inches Out of Shell, at 60° F. Capacity of Car in Gallons at 60° F.

Inches	4,231 Gallons	6,000 Gallons	6,641 Gallons	7,000 Gallons	8,087 Gallons	8,102 Gallons	8,505 Gallons	10,000 Gallons
0.25	3	4	4	4	5	5	5	6
0.5	6	8	8	8	10	10	10	12
0.75	9	13	13	13	16	16	17	19
1.	13	18	18	18	23	23	25	26
1.25	18	24	25	25	31	31	33	36
1.5	23	31	33	33	39	39	45	46
1 75	29	38	41	41	48	48	56	58
2.	35	46	49	50	58	58	67	71
2.25	41	54	58	59	69	69	79	84
2.5	48	63	68	69	80	80	92	98
2.75	55	72	78	79	90	91	105	111
3.	63	82	88	90	103	103	119	125
3.25	71	92	99	101	115	115	133	140
3.5	79	103	110	113	128	128	148	156
3.75	87	114	123	125	141	141	163	171
4.	96	125	134	137	154	154	178	186
4 25	105	136	146	150	167	167	194	203
4.5	114	148	159	163	181	181	211	220
4.75	123	160	172	176	195	195	288	237
5.	133	173	186	190	210	210	244	254

TANK CAR OUTAGE TABLES (Continued)

Outage Table for Standard 6,648 Gallons Capacity Car Tank.

Table for gauging tanks by the inch. Capacity in U. S. Gallons of a 74¼" diameter tank. 29′ ½" long. Official dome capacity, including dish in head, 87.9 gallons.

Inches	Gallons	Inches	Gallons	Inches	Gallons
1	17.35	26	2076.40	51	4883.33
2	47.28	27	2186.05	52	4986.74
3	87.99	28	2296.28	53	5089.50
4	138.36	29	2407.45	54	5190.91
5	195.85	30	2519.24	55	5290.73
6	259.34	31	2631.44	56	5389.40
7	325.55	32	2744.43	57	5485.82
8	394.82	33	2858.07	58	5578.96
9	467.81	34	2972.14	59	5670.70
10	544.49	35	3087.13	60	5759.71
11	623.44	36	3202.94	61	5847.58
12	795.18	37	3319.12	62	5933.25
13	790.00	38	3436.02	63	6014.58
14	877.85	39	3552.30	64	6091.75
15	967.02	40	3668.07	65	6165.89
16	1059.55	41	3782.59	66	6236.98
17	1154.35	42	3895.89	67	6306.66
18	1250.30	43	4008.87	68	6373.20
19	1348.07	44	4120.85	69	6436.49
20	1447.30	45	4232.14	70	6494.53
21	1548.89	46	4343.13	71	6544.95
22	1651.71	47	4453.32	72	6587.26
23	1756.36	48	4562.90	73	6622.29
24	1861.57	49	4670.73	74¼	6643.02
25	1968.52	50	4777.60	74	6647.69

Dome Capacity is 3.06 gallons per inch.

Outage Table for Standard 7,191 Gallons Capacity Car Tank.

Table for gauging tanks by the inch. Capacity in U. S. gallons of an 83" diameter tank. Length of tank 25′.

Inches	Gallons	Inches	Gallons	Inches	Gallons
1	16.50	29	2219.32	57	5242.01
2	44.86	30	2322.74	58	5341.46
3	79.72	31	2427.17	59	5439.84
4	120.47	32	2532.58	60	5537.19
5	167.45	33	2638.98	61	5633.39
6	210.30	34	2746.36	62	5728.54
7	276.14	35	2854.66	63	5822.64
8	337.48	36	2963.76	64	5915.82
9	403.44	37	3073.76	65	6007.92
10	474.27	38	3184.66	66	6098.91
11	550.22	39	3296.31	67	6188.90
12	630.21	40	3408.65	68	6277.35
13	712.19	41	3521.68	69	6364.33
14	795.58	42	3635.18	70	6450.11
15	881.37	43	3748.21	71	6533.50
16	969.07	44	3860.56	72	6615.38
17	1058.47	45	3972.23	73	6695.37
18	1149.46	46	4083.15	74	6772.35
19	1241.56	47	4193.17	75	6843.28
20	1334.68	48	4302.29	76	6909.26
21	1428.73	49	4410.59	77	6970.01
22	1523.83	50	4517.97	78	7025.01
23	1620.03	51	4624.37	79	7073.85
24	1717.33	52	4729.78	80	7114.80
25	1815.68	53	4834.25	81	7145.76
26	1915.19	54	4937.71	82	7173.96
27	2015.49	55	5040.21	83	7191.00
28	2116.84	56	5141.59	....	....

Dome capacity is 9.914 gallons per inch.

TANK CAR OUTAGE TABLES (Continued)

Outage Table for Standard 10,676 Gallons Capacity Car Tank.

Table for gauging tanks by the inch. Capacity in U. S. gallons of an 89½" diameter tank. Official dome capacity, including dish in head.

Inches	Gallons	Inches	Gallons	Inches	Gallons
1	21.32	31	3282.20	61	7751.24
2	60.13	32	3427.51	62	7891.79
3	110.07	33	3573.91	63	8030.85
4	168.83	34	3720.04	64	8169.02
5	235.30	35	3868.20	65	8305.63
6	308.16	36	4017.80	66	8439.87
7	387.04	37	4166.71	67	8572.33
8	471.14	38	4315.69	68	8703.44
9	560.20	39	4466.30	69	8831.89
10	653.72	40	4617.59	70	8958.11
11	751.57	41	4769.17	71	9082.62
12	853.15	42	4920.99	72	9204.69
13	958.45	43	5072.96	73	9323.49
14	1067.06	44	5223.85	74	9439.58
15	1178.93	45	5376.24	75	9553.62
16	1294.34	46	5527.88	76	9663.93
17	1411.24	47	5679.31	77	9770.98
18	1531.95	48	5831.21	78	9874.42
19	1655.37	49	5982.91	79	9974.14
20	1780.97	50	6134.34	80	10069.89
21	1907.80	51	6285.29	81	10161.18
22	2037.89	52	6435.08	82	10247 80
23	2170.01	53	6584.34	83	10329.37
24	2302.82	54	6733.59	84	10405.33
25	2438.48	55	6882.16	85	10475.05
26	2576.04	56	7029.31	86	10537.75
27	2714.82	57	7175.57	87	10592.43
28	2854.15	58	7321.43	88	10637.17
29	2995.93	59	7466.26	89	10668.70
30	3137.84	60	7609.40	89½	10676.28

Dome capacity, 11.532 gallons per inch.

Outage Table for Standard 7,900 Gallons Capacity Tank Car.

Table for gauging tanks by the inch. Capacity in U. S. gallons of an 82⅜" diameter tank. Official dome capacity, including dish in head, 155.6 gallons. Length of tank 27′ 8″.

Inches	Gallons	Inches	Gallons	Inches	Gallons
1	17.91	29	2483.84	56	5718.90
2	50.36	30	2600.79	57	5832.27
3	92.19	31	2718.82	58	5944.38
4	141.43	32	2837.52	59	6055.17
5	196.90	33	2956.90	60	6164.53
6	257.78	34	3076.85	61	6272.41
7	323.66	35	3197.29	62	6378.66
8	393.89	36	3318.29	63	6483.10
9	468.15	37	3439.58	64	6585.79
10	546.16	38	3561.20	65	6686.43
11	627.60	39	3683.09	66	6784.99
12	712.18	40	3805.00	67	6881.33
13	799.82	41	3927.12	68	6975.25
14	890.26	41 3/16	3950.00	69	7066.62
15	983.16	42	4049.19	70	7155.32
16	1078.63	43	4171.20	71	7241.05
17	1176.38	44	4293.11	72	7323.69
18	1276.30	45	4414.89	73	7403.02
19	1378.19	46	4536.28	74	7478.73
20	1481.96	47	4657.37	75	7550.54
21	1587.57	48	4778.04	76	7618.05
22	1694.81	49	4898.23	77	7680.90
23	1803.62	50	5017.81	78	7738.46
24	1913.92	51	5136.76	79	7790.17
25	2025.51	52	5254.99	80	7834 89
26	2138.42	53	5372.40	81	7871.23
27	2252.48	54	5488.83	82	7895.80
28	2367.65	55	5604.40	82⅜	7900.00

Dome capacity is 6.00 gallons per inch.

TANK CAR OUTAGE TABLES (Continued)

Outage Table for Standard 7,920 Gallons Capacity Tank Car.

Table for gauging tanks by the inch. Capacity in U. S. gallons of an 80″ diameter tank. Official dome capacity, including dish in head, 155.6 gallons. Length of tank 28′.

Inches	Gallons	Inches	Gallons	Inches	Gallons
1	18.76	28	2470.39	55	7568.45
2	52.74	29	2591.10	56	5021.64
3	96.50	30	2712.71	57	6936.50
4	149.04	31	2835.18	58	0149.84
5	206.12	32	2958.36	59	6261.58
6	269.85	33	3082.19	60	6371.59
7	338.72	34	3206.53	61	6479.85
8	412.14	35	3331.42	62	6586.18
9	489.83	36	3456.61	63	6690.35
10	571.36	37	3582.21	64	6792.40
11	656.43	38	3708.01	65	6892.03
12	744.91	39	3833.96	66	6989.14
13	836.47	40	3960.00	67	7083.53
14	930.86	41	4086.04	68	7175.09
15	1027.97	42	4211.99	69	7263.57
16	1127.60	43	4337.79	70	7348.64
17	1229.65	44	4463.39	71	7430.17
18	1333.82	45	4588.58	72	7507.86
19	1440.15	46	4713.47	73	7581.28
20	1548.41	47	4837.81	74	7650.15
21	1658.42	48	4961.64	75	7713.88
22	1770.16	49	5084.82	76	7771.96
23	1883.50	50	5208.29	77	7823.50
24	1998.36	51	5328.90	78	7867.26
25	2114.53	52	5449.61	79	7901.24
26	2232.01	53	5569.36	80	7920.00
27	2350.64	54	5687.99	....	....

Dome capacity 6.00 gallons per inch.

Outage Table for Standard 8,050 Gallons Capacity Car Tank.

Table for gauging tanks by the inch. Capacity in U. S. gallons of a 78″ diameter tank. Official dome capacity, including dish in head, 243 gallons. Length of tank, 31′ 10¼″.

Inches	Gallons	Inches	Gallons	Inches	Gallons
1	23.18	27	2447.86	53	5799.53
2	54.59	28	2573.08	54	5920.70
3	100.65	29	2699.27	55	6040.30
4	153 87	30	2826.66	56	6159.02
5	215 71	31	2954.68	57	6275.09
6	282.54	32	3083.27	58	6389.68
7	355.29	33	3212.28	59	6503.05
8	431.29	34	3341.94	60	6615.04
9	511 91	35	3472.16	61	6722.17
10	596 41	36	3603.20	62	6826.81
11	681.52	37	3735.00	63	6929.01
12	775 44	38	3867.38	64	7030.15
13	870.74	39	4000.38	65	7129.00
14	968 59	40	4133.38	66	7223.34
15	1069 73	41	4265 76	67	7314.39
16	1172.93	42	4397.56	68	7402.87
17	1278.57	43	4528.60	69	7487.97
18	1385 70	44	4658.82	70	7569.50
19	1497.69	45	4788.48	71	7646 82
20	1611 06	46	4917.49	72	7721.31
21	1725.65	47	5046.08	73	7789.58
22	1841 72	48	5174.10	74	7854.54
23	1960 54	49	5301.49	75	7911.72
24	2080 04	50	5427.68	76	7962.83
25	2201 24	51	5552.90	77	8000.71
26	2323 93	52	5676.83	78	8033.10

Dome capacity is 11.532 gallons per inch.

TANK CAR OUTAGE TABLES (Continued)

Outage Table for Cars Nos. EIRX-3101 to 3150, inclusive, and 3180 to 3198, inclusive, of Empire Refineries, Inc. Table for gauging 8,060 gallons capacity Car Tank by the half inch. Capacity in U. S. gallons of a 77″ diameter tank. Length of tank 31′ 8″. Official dome capacity, including dish head, 274 5 gallons.

Inches	Gallons	Inches	Gallons	Inches	Gallons
½	8	½	2456	½	5854
1	20	3	2520	5	5916
½	38	½	2584	½	5978
2	57	4	2648	6	6039
½	80	½	2712	½	6100
3	104	5	2776	7	6160
½	131	½	2840	½	6220
4	159	6	2905	8	6280
½	189	½	2970	½	6339
5	221	7	3036	9	6397
½	255	½	3102	½	6455
6	290	8	3168	10	6513
½	326	½	3234	½	6570
7	364	9	3300	11	6627
½	403	½	3366	½	6684
8	443	10	3432	5 feet	6739
½	484	½	3498	½	6794
9	526	11	3564	1	6848
½	569	½	3630	½	6902
10	614	3 feet	3696	2	6955
½	659	½	3762	½	7008
11	706	1	3829	3	7060
½	753	½	3896	½	7111
1 foot	801	2	3963	4	7161
½	849	½	4030 (½ car)	½	7211
1	899	3	4097	5	7259
½	949	½	4164	½	7307
2	1000	4	4231	6	7354
½	1052	½	4298	½	7401
3	1105	5	4364	7	7446
½	1158	½	4430	½	7491
4	1212	6	4496	8	7534
½	1266	½	4562	½	7576
5	1321	7	4628	9	7617
½	1376	½	4694	½	7657
6	1433	8	4760	10	7696
½	1490	½	4826	½	7734
7	1547	9	4892	11	7770
½	1605	½	4958	½	7805
8	1663	10	5024	6 feet	7839
½	1721	½	5090	½	7871
9	1780	11	5155	1	7901
½	1840	½	5220	½	7929
10	1900	4 feet	5284	2	7956
½	1960	½	5476	½	8022
11	2021	½	5348	½	7980
½	2082	1	5412	3	8003
2 feet	2144	2	5540	4½	8040
½	2206	½	5604	½	8052
1	2268	3	5667	5	8060
½	2330	4½	5730	....	....

Dome Capacity is 11.5 gallons per inch.

TANK CAR OUTAGE TABLES (Continued)

Outage Table for Cars Nos. EIRX-2000 to 2016, inclusive, and 2018 to 2034, inclusive, of Empire Refineries, Inc. Table for gauging 8090 gallons capacity car tank by the half inch. Capacity in U. S. gallons of an 83" diameter tank. Length of tank 28′ 2″. Official dome capacity, including dish head, 158 gallons.

Inches	Gallons	Inches	Gallons	Inches	Gallons
		4	2397	8	5809
½	7	½	2456	½	5866
1	18	5	2516	9	5923
½	33	½	2576	½	5980
2	51	6	2636	10	6037
½	70	½	2696	½	6094
3	92	7	2756	11	6150
½	117	½	2816	½	6206
4	143	8	2876		
½	170	½	2936	5 feet	6262
5	198	9	2997	½	6318
½	229	½	3058	1	6374
6	261	10	3119	½	6428
½	294	½	3180	2	6482
7	326	11	3241	½	6533
½	363	½	3302	3	6588
8	399			½	6641
½	435	3 feet	3363	4	6693
9	473	½	3424	½	6745
½	513	1	3486	5	6797
10	554	½	3548	½	6848
½	596	2	3610	6	6898
11	636	½	3672	½	6948
½	678	3	3734	7	6998
1 foot	721	½	3796	½	7046
½	765	4	3858	8	7094
1	809	½	3920	½	7142
½	854	5	3982	9	7189
2	900	½	4045 (½ car)	½	7235
½	917	6	4108	10	7280
3	995	½	4170	½	7324
½	1043	7	4232	11	7368
4	1091	½	4294	½	7411
½	1141	8	4356		
5	1191	½	4418	6 feet	7453
½	1241	9	4480	½	7495
6	1292	½	4542	1	7537
½	1344	10	4604	½	7578
7	1396	½	4666	2	7617
½	1448	11	4727	½	7655
8	1501	½	4788	3	7691
½	1554			½	7727
9	1607	4 feet	4849	4	7762
½	1661	½	4910	½	7796
10	1715	1	4971	5	7829
½	1771	½	5032	½	7861
11	1827	2	5093	6	7892
½	1883	½	5154	½	7920
		3	5214	7	7947
2 feet	1939	½	5274	½	7973
½	1995	4	5334	8	7998
1	2052	½	5394	½	8020
½	2109	5	5454	9	8039
2	2166	½	5514	½	8057
½	2223	6	5574	10	8072
3	2280	½	5634	½	8083
		7	5693	11	8090

Dome Capacity, 6.582 gallons per inch.

TANK CAR OUTAGE TABLES (Concluded).

Outage Table for Standard 10,050 Gallons Capacity Car Tank.

Table for gauging tanks by the inch. Capacity in U. S. gallons of an 87½" diameter tank **(with steam coils).** Official dome capacity, including dish in head, 326 gallons. Length of tank 31′ 6¼″.

Inches	Gallons	Inches	Gallons	Inches	Gallons
1	20.02	31	3172.20	61	7445.20
2	55.90	32	3310.90	62	7578.94
3	102.61	33	3449.61	63	7711.09
4	160.73	34	3589.91	64	7841.63
5	225.73	35	3731.11	65	7970.41
6	300.02	36	3873.26	66	8096.54
7	379.20	37	4016.67	67	8220.57
8	461.47	38	4161.06	68	8342.93
9	548.31	39	4305.62	69	8462.40
10	637.56	40	4450.47	70	8580.25
11	739.72	41	4596.08	71	8695.02
12	826.80	42	4741.74	72	8806.73
13	929.21	43	4887.77	73	8915.39
14	1034.44	44	5033.84	74	9023.22
15	1141.50	45	5180.28	75	9125.44
16	1252.09	46	2326.35	76	9224.51
17	1366.70	47	5471.99	77	9329.18
18	1483.62	48	5617.23	78	9412.58
19	1602.46	49	5762.39	79	9501.30
20	1723.04	50	5906.98	80	9586.34
21	1846.79	51	6050.86	81	9664.76
22	1973.75	52	6194.57	82	9741.15
23	2101.74	53	6336.64	83	9809.25
24	2230.82	54	6478.51	84	9871.97
25	2361.19	55	6619.66	85	9926.75
26	2492.21	56	6760.43	86	9972.59
27	2626.10	57	6900.32	87	10006.52
28	2762.09	58	7039.31	87½	10019.99
29	2898.32	59	7175.36	....	....
30	3034.76	60	7311.17	....	....

Dome capacity is 11.532 gallons per inch.

Outage Table for Standard 10,050 Gallons Capacity Car Tank.

Table for gauging tanks by the inch. Capacity in U. S. gallons of an 87½" diameter tank. Official dome capacity, including dish in head, 326 gallons. Length of tank, 31′ 6¼″.

Inches	Gallons	Inches	Gallons	Inches	Gallons
1	20.02	31	3174.20	61	7477.20
2	55.90	32	3313.20	62	7611.94
3	102.60	33	3453.61	63	7744.09
4	160.73	34	3594.91	64	7874.63
5	225.73	35	3737.11	65	8003.41
6	300.02	36	3880.26	66	8129.54
7	379.20	37	4024.67	67	8253.57
8	461.47	38	4170.06	68	8375.93
9	548.31	39	4315.62	69	8495.40
10	637.56	40	4461.47	70	8613.25
11	729.72	41	4608.08	71	8728.02
12	826.80	42	4754.74	72	8839.73
13	929.21	43	4901.77	73	8948.39
14	1034.44	44	5048.84	74	9056.22
15	1141.50	45	5196.28	75	9158.44
16	1252.09	46	5348.35	76	9257.51
17	1366.70	47	5489.99	77	9353.18
18	1483.62	48	5636.23	78	9445.58
19	1602.46	49	5782.39	79	9534.30
20	1723.04	50	5927.98	80	9619.34
21	1846.79	51	6072.86	81	9697.76
22	1973.75	52	6217.57	82	9774.15
23	2101.74	53	6360.64	83	9842.25
24	2230.82	54	6503.51	84	9904.97
25	2361.19	55	6645.66	85	9959.75
26	2492.21	56	6787.43	86	10005.59
27	2626.10	57	6928.32	87	10039.52
28	2762.08	58	7068.31	87½	10052.99
29	2898.32	59	7205.36	....	....
30	3035.76	60	7342.17	....	....

Dome capacity is 11.532 gallons per inch.

CYLINDRICAL VESSELS, TANKS AND CISTERNS.

Diameter in Ft. and Ins., Area in Sq. Ft. and Capacity in U. S. Gals. for 1 Ft. in Depth.

(1 gallon=231 cubic inches=1 cubic foot/7.4805=0.13368 cubic foot.)

Diameter, Ft.	Diameter, In.	Area, Square Feet	Gallons, 1 Foot Depth	Diameter, Ft.	Diameter, In.	Area, Square Feet	Gallons, 1 Foot Depth	Diameter, Ft.	Diameter, In.	Area, Square Feet	Gallons, 1 Foot Depth
1	0	.785	5.87	5	8	25.22	188.66	19	0	283.53	2120.9
1	1	.922	6.89	5	9	25.97	194.25	19	3	291.04	2177.1
1	2	1.069	8.00	5	10	26.73	199.92	19	6	298.65	2234.0
1	3	1.227	9.18	5	11	27.49	205.67	19	9	306.35	2291.7
1	4	1.396	10.44	6	0	28.27	211.51	20	0	314.16	2350.1
1	5	1.567	11.79	6	3	30.68	229.50	20	3	322.06	2409.2
1	6	1.767	13.22	6	6	33.18	248.23	20	6	330.06	2469.1
1	7	1.969	14.73	6	9	35.78	267.69	20	9	338.16	2529.6
1	8	2.182	16.32	7	0	38.48	287.88	21	0	346.36	2591.0
1	9	2.405	17.99	7	3	41.28	308.81	21	3	354.66	2653.0
1	10	2.640	19.75	7	6	44.18	330.48	21	6	363.05	2715.8
1	11	2.885	21.58	7	9	47.17	352.88	21	9	371.54	2779.3
2	0	3.142	23.50	8	0	50.27	376.01	22	0	380.13	2843.6
2	1	3.409	25.50	8	3	53.46	399.88	22	3	388.82	2908.6
2	2	3.687	27.58	8	6	56.75	424.48	22	6	397.61	2974.3
2	3	3.976	29.74	8	9	60.13	449.82	22	9	406.49	3040.8
2	4	4.276	31.99	9	0	63.62	475.89	23	0	415.48	3108.0
2	5	4.587	34.31	9	3	67.20	502.70	23	3	424.56	3175.9
2	6	4.909	36.72	9	6	70.88	530.24	23	6	433.74	3244.6
2	7	5.241	39.21	9	9	74.66	558.51	23	9	443.01	3314.0
2	8	5.585	41.78	10	0	78.54	587.52	24	0	452.39	3384.1
2	9	5.940	44.43	10	3	82.52	617.26	24	3	461.86	3455.0
2	10	6.305	47.16	10	6	86.59	647.74	24	6	471.44	3526.6
2	11	6.681	49.98	10	9	90.76	678.95	24	9	481.11	3598.9
3	0	7.069	52.88	11	0	95.03	710.90	25	0	490.87	3672.0
3	1	7.467	55.86	11	3	99.40	743.58	25	3	500.74	3745.8
3	2	7.876	58.92	11	6	103.87	776.99	25	6	510.71	3820.3
3	3	8.296	62.06	11	9	108.43	811.14	25	9	520.77	3895.6
3	4	8.727	65.28	12	0	113.10	846.03	26	0	530.93	3971.6
3	5	9.168	68.58	12	3	177.86	881.65	26	3	541.19	4048.4
3	6	9.621	71.97	12	6	122.72	918.00	26	6	551.55	4125.9
3	7	10.085	75.44	12	9	127.68	955.09	26	9	562.00	4204.1
3	8	10.559	78.99	13	0	132.73	992.91	27	0	572.56	4283.0
3	9	11.045	82.62	13	3	137.89	1031.5	27	3	583.21	4362.7
3	10	11.541	86.33	13	6	143.14	1070.8	27	6	593.96	4443.1
3	11	12.048	90.13	13	9	148.49	1110.8	27	9	604.81	4524.3
4	0	12.566	94.00	14	0	153.94	1151.5	28	0	615.75	4606.2
4	1	13.095	97.96	14	3	159.48	1193.0	28	3	626.80	4688.8
4	2	13.635	102.00	14	6	165.13	1235.3	28	6	637.94	4772.1
4	3	14.186	106.12	14	9	170.87	1278.2	28	9	649.18	4856.2
4	4	14.748	110.32	15	0	176.71	1321.9	29	0	660.52	4941.0
4	5	15.321	114.61	15	3	182.65	1366.4	29	3	671.96	5026.6
4	6	15.90	118.97	15	6	188.69	1411.5	29	6	683.49	5112.9
4	7	16.50	123.42	15	9	194.83	1457.4	29	9	695.13	5199.9
4	8	17.10	127.95	16	0	201.06	1504.1	30	0	706.86	5287.7
4	9	17.72	132.56	16	3	207.39	1551.4	30	3	718.69	5376.2
4	10	18.35	137.25	16	6	213.82	1599.5	30	6	730.62	5465.4
4	11	18.99	142.02	16	9	220.35	1648.4	30	9	742.64	5555.4
5	0	19.63	146.88	17	0	226.98	1697.9	31	0	754.77	5646.1
5	1	20.29	151.82	17	3	233.71	1748.2	31	3	766.99	5737.5
5	2	20.97	156.83	17	6	240.53	1799.3	31	6	779.31	5829.7
5	3	21.65	161.93	17	9	247.45	1851.1	31	9	791.73	5922.6
5	4	22.34	167.12	18	0	254.47	1903.6	32	0	804.25	6016.2
5	5	23.04	172.38	18	3	261.59	1956.8	32	3	816.86	6110.6
5	6	23.76	177.72	18	6	268.80	2010.8	32	6	829.58	6205.7
5	7	24.48	183.15	18	9	276.12	2065.5	32	9	842.39	6301.5

GAUGING TABLE FOR STANDARD 50-GALLON OIL BARREL.

Depth of Fluid, Inches	Laying on Side, Gallons	Standing on End, Gallons
1	0.27	1.35
2	1.15	2.74
3	2.64	4.20
4	4.50	5.72
5	6.63	7.29
6	8.93	8.91
7	11.50	10.59
8	14.16	12.31
9	16.90	14.08
10	19.70	15.90
11	22.56	17.76
12	25.49	19.65
13	28.42	21.58
14	31.28	23.53
15	34.08	25.49
16	36.82	27.45
17	39.48	29.40
18	42.00	31.33
19	44.35	33.22
20	46.48	35.08
21	48.34	36.90
22	49.83	38.67
23	50.71	40.39
24	50.98	42.07
25		43.69
26		45.26
27		46.78
28		48.24
29		49.63
30		50.98

CHEMICAL CONSTITUTION OF PETROLEUM.

Petroleum is composed of carbon and hydrogen in chemical combination known as hydrocarbons. In conjunction with the carbon and hydrogen there frequently is oxygen, nitrogen and sulphur in much smaller amounts.

In crude oils the amount of carbon varies from 80 to 89%, the hydrogen from 10 to 15%, oxygen from 0 0 to 5.0%, nitrogen from 0.0 to 1.8%, and sulphur from .01 to 5.0%.

Typical ultimate analyses of petroleum products are as follows:

	Carbon	Hydrogen	Sulphur	Nitrogen	Oxygen
Pennsylvania Crude	86.06%	13.88%	0.06%	0.00%	0.00%
Texas Crude	85.05	12.30	1.75	0.70	0.00
California Crude	84.00	12.70	0.75	1.70	1.20
Mexican Crude	83.70	10.20	4.15	....	....
Oklahoma Crude	85.70	13.11	0.40	0.30	....
Kansas Crude (Towanda)	84.15	13.00	1.90	0.45	....
Kansas Residuum	85.51	11.88	0.71	0.32	0.63
Healdton (Oklahoma) Crude	85.00	12.90	0.76	....	....
Kansas Air Blown Residuum	84.37	10.39	0.42	0.21	4.61
Byerlite Pitch	87.61	9.97	0.55	0.29	1.58
Grahamite	87.20	7.50	2.00	0.20	....
Trinidad Asphalt	82.60	10.50	6.50	0.50	....
Commercial Gasoline	84.27	15.73	0.00	0.00	0.00
Kerosene	84.74	15.26	0.01	0.00	0.00
Lubricating Oil (Paraffin)	85.13	14.87	0.01	....	....
Lubricating Oil (Naphthene)	87.49	12.51	0.01	....	....
Benzol	92.24	7.76	0.00	0.00	0.00

Paraffin (C_nH_{2n+2}) hydrocarbons largely compose the light or more volatile constituents of all petroleum. They are "saturated" hydrocarbons and have a very low ratio of specific gravity to distilling temperature, are not acted upon by concentrated sulphuric acid or by fuming sulphuric acid (oleum), are not nitrated by nitric acid and are extremely resistant to all chemical reactions. The chief differences in petroleum are in the heavy constituents, the heavy hydrocarbons of th paraffin series being found chiefly in Pennsylvania and some Mid-Continent oils.

Naphthenes (C_nH_{2n}), ring or cyclic compounds, are less common hydrocarbons in lighter portions of petroleum, but are commonly found as heavy hydrocarbons of petroleum. They have a higher ratio of specific gravity to distilling temperature than the paraffin compounds, are resistant to the action of sulphuric acid and some types may be distinguished by the "formolit" reaction.* Oils containing light naphthenes are found in Russia and Louisiana. All heavy oils contain naphthenes.

*Holde—Examination of Hydrocarbons.

C_nH_{2n} (NAPHTHENES) POLYMETHYLENE SERIES.

	Formula	Boiling Temperature	Gravity
Cyclopropane	C_3H_6	—35°C = —31°F	....
Cyclobutane	C_4H_8	+12°C = 54°F	.709 = 67.5° Be'
Cyclopentane	C_5H_{10}	49°C = 120°F	.769 = 52.1° Be'
Cyclohexane	C_6H_{12}	81°C = 178°F	.799 = 45.2° Be'
Cycloheptane	C_7H_{14}	117°C = 243°F	.809 = 43.1° Be'
Methyl Cyclopentane	C_6H_{12}	72°C = 162°F	.766 = 52.8° Be'
Dimethyl Cyclopentane	C_7H_{14}	91°C = 196°F	.778 = 50.0° Be'
Methyl Clyclohexane	C_7H_{14}	98°C = 208°F	.778 = 50.0° Be'
Dimethyl Clyclohexane	C_8H_{16}	118°C = 244°F	.781 = 49.3° Be'
Trimethyl Cyclohexane	C_9H_{18}	198°C = 388°F	.787 = 47.9° Be'

Aromatic or Benzene Hydrocarbons ($C_n H_{2n-6}$) exist to some extent in certain California petroleums and have a very high ratio of specific gravity to distilling temperature. Gasoline made from the California petroleum is heavier than light gasoline with the same end point made from Mid-Continent petroleum. The aromatic compounds are acted upon by nitric acid forming nitro products. They are formed from paraffin and naphthene hydrocarbons by pyrogenic decomposition at temperatures above 1000° F. The production of aromatic compounds from petroleum has not been commercially satisfactory on account of incomplete conversion and difficulty of freeing from paraffin hydrocarbons.

Olefines or Ethylenes (C_nH_{2n}) are "unsaturated" hydrocarbons, rarely if ever existing naturally in crude oil, but commonly resulting from its exposure to high temperatures. These compounds contain less hydrogen and more carbon than paraffin hydrocarbons and are capable of taking in more hydrogen. They are removed from aromatic compounds, paraffin compounds and naphthene compounds by the action of concentrated sulphuric acid in the usual process of refining gasoline. These hydrocarbons give gasoline, to a large extent, its disagreeable odor before refining. Their combination with sulphur gives a more intense odor. Each of these groups of hydrocarbons is supposed to exist in a complete series, represented by the general formula given. The paraffin or methane series of "saturated" hydrocarbons has been fairly well worked out and is given in the table on page 186.

According to Hofer, the following olefines have been isolated from "North American" petroleum:

Ethylene......	$C_2 H_4$	Heptylene....	$C_7 H_{14}$	Dodecylene...	$C_{12} H_{24}$
Propylene.....	$C_3 H_6$	Octylene......	$C_8 H_{16}$	Decatrilene...	$C_{13} H_{26}$
Butylene......	$C_4 H_8$	Nonylene.....	$C_9 H_{18}$	Cetene.......	$C_{14} H_{28}$
Amylene......	$C_5 H_{10}$	Decylene.....	$C_{10} H_{20}$	Cerotene......	$C_{15} H_{30}$
Hexylene......	$C_6 H_{12}$	Undecylene...	$C_{11} H_{22}$	Melene.......	$C_{16} H_{42}$

If the residue contains much wax, the crude is known as paraffin base oil, but if naphthenes or similar hydrocarbons predominate, it is an "asphalt" base oil. Practically the "asphalt" is determined by the solubility of the solid hydrocarbons in pentane and by the gravity and physical character of the residue. (See pages 501-2.)

Among the light hydrocarbons of petroleum, either existing naturally or pyrogenically produced, the relation of the specific gravity to the distilling temperature affords a simple and practical method of estimating the amount of olefin, paraffin and aromatic compounds. This relation is set forth in the curves on pages 232 and 236.

The value of crude oil is not measured by its ultimate analysis or by its "base" so much as by the amount of volatile constituents which it contains. The amount of volatile constituents obtained from various crude oils is shown on pages 179 to 190.

PARAFFIN HYDROCARBONS IN PETROLEUM.

Name	Baume' Gravity	Sp. Gr. Liquid 15.5°C	Formula	Melting Point	Boiling Point	Molecular Weight
GASEOUS HYDROCARBONS (Natural Gas)						
Methane	....	.....	$C\ H_4$	—184.0°C	—165.0°C	16.03
Ethane	194	0.432	$C_2\ H_6$	—171.4	— 93.0	30.05
Propane	142	0.525	$C_3\ H_8$	—195.0	— 45.0	44.07
Butane	109	0.585	$C_4\ H_{10}$	—135.0	+ 1.0	58.08
"GASOLINE" HYDROCARBONS						
Pentane	92.2	0.630	$C_5\ H_{12}$	.....	36.3	72.10
Hexane	78.9	0.670	$C_6\ H_{14}$	.....	69.0	86.12
Heptane	70.9	0.697	$C_7\ H_{16}$	.....	98.4	100.13
Octane	65.0	0.718	$C_8\ H_{18}$	.....	125.5	114.15
Nonane	59.2	0.740	$C_9\ H_{20}$	—51.0	150.0	128.16
Decane	56.7	0.750	$C_{10}H_{22}$	— 31.0	173.0	142.18
Undecane	54.2	0.760	$C_{11}H_{24}$	— 26.0	195.0	156.20
HEAVY LIQUID HYDROCARBONS (Kerosene)						
Duodecane	51.8	0.770	$C_{12}H_{26}$	— 12.0	214.0	170.22
Tridecane	46.8	0.792	$C_{13}H_{28}$	— 6.0	234.0	184.24
Tetradecane	45.0	0.800	$C_{14}H_{30}$	+ 5.0	252.0	198.25
Pentadecane	43.5	0.807	$C_{15}H_{32}$	10.0	270.0	212.26
Hexadecane	41.8	0.815	$C_{16}H_{34}$	28.0	287.0	226.27
Heptadecane	40.3	0.822	$C_{17}H_{36}$	22.0	295.0	240.28
Octadecane	38.6	0.830	$C_{18}H_{38}$	28.0	317.0	254.30
HEAVY SOLID HYDROCARBONS					(vacuo)	
Eicosane	37.2	0.837	$C_{20}H_{42}$	37.0	117.5	282.34
Tricosane	36.5	0.841	$C_{23}H_{48}$	48.0	138.0	325.38
Tetracosane	....	.....	$C_{24}H_{50}$	51.0	145.5	338.39
Pentacosane	....	.....	$C_{25}H_{52}$	54.0	152.5	352.41
Hexacosane	....	.....	$C_{26}H_{54}$	56.0	160.0	366.43
Mericyl	....	.....	$C_{27}H_{56}$	59.4	167.0	370.45
Octocosane	....	.....	$C_{28}H_{58}$	60.0	173.5	384.47
Nonocosane	....	.....	$C_{29}H_{60}$	63.0	179.0	398.48
Ceryl	....	.....	$C_{30}H_{62}$	65.6	186.0	422.49
Untriacontane	....	.....	$C_{31}H_{64}$	68.0	193.5	436.52
Duotriacontane	....	.....	$C_{32}H_{66}$	70.0	201.0	450.53
Tetratriacontane	....	.....	$C_{34}H_{70}$	72.0	215.0	478.56
Pentatriacontane	35.4	0.846	$C_{35}H_{72}$	75.0	222.0	492.58

There is no natural petroleum composed exclusively of the paraffin series of hydrocarbons, even Pennsylvania and Garber, Oklahoma, crude oils having members of other series. The main body of the light petroleum is made up of paraffin hydrocarbons and the heavy residues are largely made up of naphthenes.

NATURAL CONTENT OF CRUDE OILS.

(Typical samples, analyses by Kansas City Testing Laboratory)

Source	Specific Gravity	Baume' Gravity	Automobile Gasoline % by Vol.	Naphtha and Kerosene % by Vol.	Fuel Oil Residue
Arkansas—El Dorado	.851	34.8°	30.0%	20.0%	50.0%
California—Heavy	.984	12.3	0.0	12.3	82.7
Santa Maria	.900	25.7	20.0	20.0	60.0
Kansas—Moran, Allen Co.	.871	30.7	15.0	17.5	67.5
Neodesha (Wilson Co.)	.860	33.3	25.0	17.0	58.0
Paola	.873	30.6	20.5	19.5	60.0
Peabody	.860	33.3	20.0	20.0	60.0
Sallyards (Butler Co.)	.835	38.0	30.0	22.5	47.5
Towanda (Butler Co.)	.850	34.7	20.5	27.5	52.0
Kentucky	.876	42.0	40.0	20.0	40.0
Wayne Co	.835	37.7	28.0	21.0	51.0
Louisiana, Homer	.832	38.6	30.0	25.0	45.0
Pine Island	.902	25.4	0.0	25.0	75.0
Mexico—Panuco	.982	12.8	2.0	8.0	90.0
Tuxpan	.935	19.8	15.0	15.0	70.0
Montana—Winnett	.777	50.6	55.0	40.0	5.0
Bozeman (Big Horn Co.)	.942	18.7	2.5	17.5	80.0
Oklahoma—Beggs	.862	32.7	15.0	21.8	63.2
Billings	.812	42.8	40.0	22.5	37.5
Bixby	.845	36.0	25.0	20.0	55.0
Cushing	.823	40.1	35.0	15.0	50.0
Duncan	.857	33.7	20.0	22.5	57.5
Garber, Garfield Co	.780	49.5	55.0	15.8	29.2
Healdton	.920	22.1	8.5	17.5	74.0
Kingwood	.829	39.2	30.0	20.0	50.0
Newkirk	.822	40.3	32.5	24.0	43.5
Osage Co	.836	37.7	25.0	20.0	55.0
Pennsylvania (light)	.802	44.5	37.5	12.7	49.8
Russia	.874	30.2	15.0	20.0	65.0
South Dakota—Mule Creek	.863	32.5	2.5	27.5	70.0
Texas—Beaumont	.912	23.4	4.0	16.0	80.0
Breckenridge	.811	42.0	35.0	25.0	40.0
Burkburnett	.824	40.1	41.0	20.0	39.0
Mexia	.842	36.6	5.0	50.0	45.0
Ranger	.829	39.2	30.0	25.0	45.0
San Antonio	.861	32.8	15.0	21.5	63.5
Wortham	.800	45.5	37.5	35.0	27.5
West Virginia—Cabin Creek	.788	48.0	36.0	24.0	40.0
Wyoming—Big Muddy	.860	33.0	10.0	25.0	65.0
Elk Basin	.805	44.3	45.0	20.0	35.0
Ferris Dome	.831	38.8	30.0	20.0	50.0
Grass Creek	.801	45.1	45.0	20.0	35.0
Hamilton Dome	.891	27.3	17.5	15.0	67.5
Lander Co	.909	24.0	13.0	13.0	74.0
Lance Creek	.815	42.1	32.5	27.5	40.0
Lost Soldier	.865	33.8	0.0	35.0	65.0
Maverick Springs	.918	22.6	0.0	25.0	75.0
Pilot Butte	.836	37.7	20.0	35.0	45.0
Rock Creek	.838	37.4	30.0	15.0	55.0
Salt Creek	.838	37.3	25.0	20.0	55.0
Canada—Fort Norman	.833	38.0	30.0	32.0	38.0

SULPHUR, ASPHALT, CYLINDER STOCK AND GASOLINE IN IMPORTANT CRUDE PETROLEUMS.

The following tables give an index of the constitution of important crude petroleums.

The values are chiefly from the reports of investigations of the Bureau of Mines. The item marked "carbon residue" refers to the carbon determined by the Conradson method on the residue from the distillation. It is an approximate measure of the amount of asphalt in the oil. Asphalt is a very broad term usually in practical testing comprising waxy material. Asphalt with good ductility and cementing properties is obtainable from the petroleums of high carbon content. Cylinder stock of good quality is obtainable from the oils of low carbon and low sulphur content.

Source of Crude	Gravity	Gasoline to 392° F		Carbon Residue	Sulphur
New York—					
Alleghany Co.	.828 =39.1° Be'	30.0%	=57.2° Be'	2.9%	0.10%
Pennsylvania—					
McKean Co.	.823 =40.1° Be'	32.5	=59.4° Be'	2.6	0.10
Venango Co.	.819 =40.9° Be'	29.6	=57.7° Be'	2.1	0.10
Venango Co.	.832 =38.3° Be'	24.4	=54.0° Be'	2.0	0.08
Franklin	.863 =32.2° Be'	9.0	=39.9° Be'	2.2	0.09
Alleghany and Washington Counties	.800 =45.0° Be'	37.8	=61.0° Be'	1.6	0.08
Green Co.	.815 =41.8° Be'	29.0	=57.9° Be'	1.6	0.08
Composite	.811 =42.6° Be'	33.9	=60.7° Be'	3.2	0.08
West Virginia—					
Maryland Pool	.805 =43.9° Be'	38.3	=60.7° Be'	2.1	0.28
Eureka Pool	.806 =43.7° Be'	37.7	=60.7° Be'	2.4	0.24
Cabin Creek	.797 =45.7° Be'	40.5	=61.8° Be'	1.2	0.19
Kelly Creek	.799 =45.2° Be'	39.6	=61.5° Be'	....	0.11
Ohio (East)—					
Washington Co.	.805 =43.9° Be'	33.5	=59.4° Be'	3.1	0.05
Corning	.838 =37.1° Be'	27.8	=59.2° Be'	7.4	0.10
North Lima	.835 =37.7° Be'	31.0	=56.9° Be'	6.2	0.55
Oklahoma—					
Big Heart	.846 =35.5° Be'	28.0	=55.7° Be'	5.3	0.19
Cushing	.828 =39.1° Be'	37.5	=58.4° Be'	6.8	0.12
Kentucky—					
Ross Creek	.838 =37.1° Be'	35.9	=58.2° Be'	8.4	0.12
Cow Creek	.866 =31.7° Be'	19.7	=51.6° Be'	6.5	0.13
Big Sinking	.844 =35.9° Be'	31.2	=56.4° Be'	7.5	0.14
Compton Pool	.842 =36.3° Be'	30.8	=57.4° Be'	5.3	0.23
Wayne Co.	.869 =31.1° Be'	35.9	=56.4° Be'	6.4	0.49
Ragland	.902 =25.2° Be'	12.6	=52.5° Be'	17.7	0.31
Illinois	.863 =32.2° Be'	20.4	=52.1° Be'	10.6	0.24
Indiana—					
Lima Pool	.846 =35.5° Be'	26.0	=55.9° Be'	6.0	0.48
Colorado—					
Florence	.880 =29.1° Be'	8.9	=54.7° Be'	6.0	0.17
Rangely	.819 =40.9° Be'	34.6	=57.2° Be'	2.6	0.06
Kansas—					
Augusta	.865 =31.9° Be'	24.2	=54.0° Be'	10.2	0.41
Sallyards	.836 =37.8° Be'	30.0	=61.0° Be'	6.0	0.40
California—					
Sunset field	.878 =29.5° Be'	21.5	=47.4° Be'	16.4	0.73
Mexico—					
Panuco	.982 =12.6° Be'	6.0	=51.0° Be'	23.0	5.34
Tuxpan	.935 =19.8° Be'	11.0	=60.0° Be'	19.0	.....

SULPHUR, ASPHALT, CYLINDER STOCK AND GASOLINE IN IMPORTANT CRUDE PETROLEUMS—(Continued).

Source of Crude	Gravity	Gasoline to 892° F		Carbon Residue	Sulphur
Montana—					
Winnett	.781 =49.3° Be′	63.2	=57.4° Be′	trace	0.36
Wyoming—					
Hamilton Dome	.903 =25.0° Be′	17.6	=57.7° Be′	19.0	2.09
Shannon	.909 =24.0° Be′	3.1	=37.1° Be′	5.1	0.20
Newcastle	.840 =36.7° Be′	31.6	=55.7° Be′	7.5	0.15
Salt Creek	.841 =36.5° Be′	29.3	=56.7° Be′	6.1	0.18
Rock Creek	.843 =36.1° Be′	31.4	=58.2° Be′	6.8	0.27
Lost Soldier	.875 =30.0° Be′	16.7	=44.1° Be′	6.5	0.11
Mule Creek	.867 =31.5° Be′	11.7	=52.3° Be′	4.8	0.14
Big Muddy	.863 =32.2° Be′	22.2	=53.7° Be′	6.0	0.17
Ferris	.842 =36.3° Be′	31.1	=57.4° Be′	5.5	0.19
Warm Spring	.987 =11.8° Be′	5.4	=49.9° Be′	21.2	2.61
Lander	.913 =23.3° Be′	11.0	=55.4° Be′	15.1	2.62
Dallas	.914 =23.2° Be′	12.8	=51.3° Be′	18.9	2.42
Pilot Butte	.848 =35.1° Be′	24.0	=53.0° Be′	5.5	0.22
Maverick Springs	.922 =21.8° Be′	8.6	=53.0° Be′	17.9	2.46
Plunkett	.846 =35.5° Be′	21.0	=49.7° Be′	2.1	0.55
Greybull	.803 =44.3° Be′	38.6	=59.7° Be′	2.3	0.08
Grass Creek	.809 =43.1° Be′	42.6	=58.9° Be′	4.6	0.14
Elk Basin	.827 =39.3° Be′	40.5	=57.2° Be′	5.3	0.14
Osage	.837 =37.3° Be′	34.8	=57.7° Be′	5.2	0.29
Lance Creek	.823 =40.1° Be′	33.5	=55.7° Be′	2.0	0.18
Missouri—					
Kansas City	.874 =30.2° Be′	16.0	=52.0° Be′	4.3	0.45
Texas—					
Burkburnett	.821 =40.9° Be′	37.5	=60.5° Be′	6.5	.....
Ranger	.829 =39.2° Be′	30.0	=57.4° Be′	2.2	0.10
Mexia	.842 =36.6° Be′	12.0	=53.2° Be′	2.4	0.23
Wortham (Currie)	.800 =45.5° Be′	32.0	=60.8° Be′	1.8	0.08
Groesbeck	.839 =37.2° Be′	17.5	=56.6° Be′	3.5	0.30

COLOR OF CRUDE OILS.

	Gravity	Color
Cabin Creek, W. Va.	48.0° Be′	48
Lander, Wyo	43.4° Be′	100
Stevens Co., Tex	42.0° Be′	150
Grass Creek, Wyo	45.1° Be′	570
Elk Basin, Wyo	44.3° Be′	670
Ranger, Tex	39.2° Be′	1,100
Lance Creek, Wyo	42.1° Be′	1,270
Bull Bayou, La	38.0° Be′	1.350
Winnett, Mont	50.6° Be′	1.350
Garber, Okla	49.5° Be′	1,670
Ferris Dome, Wyo	38.8° Be′	2,250
Homer, La	38.6° Be′	3,020
Pilot Butte, Wyo	37.7° Be′	3,200
Caddo, La	....	3,900
Big Muddy, Wyo	33.0° Be′	4,745
Salt Creek, Wyo	37.3° Be′	5,100
Lost Soldier, Wyo	33.8° Be′	5,100
Healdton, Okla	22.1° Be′	5,420
Rock Creek, Wyo	37.4° Be′	6,550
Edgemont, S. D	32.5° Be′	6,730
Mexia, Tex	36.6° Be′	7,285
Burkburnett, Tex	40.1° Be′	9,000
Pine Island, La	25.4° Be′	10,200
Moran, Kas	29.7° Be′	13,000
Maverick Springs, Wyo	22.6° Be′	39,400
Hamilton Dome, Wyo	27.3° Be′	47,750
Tuxpan, Mexico	19.8° Be′	68,000
Panuco, Mexico	12.8° Be′	156,000
Soap Creek, Mont	18.2° Be′	51,000

See page 427 for method of determining color.

Regional Character of Crude Oils as Shown by the Gravity of the Fraction Distilling from 250° C.-275° C. (482° F.-527° F.).

	Gravity	Saybolt Viscosity at 100° F. (Vacuum Distilled
New York and Pennsylvania.....	0.813 = 42.2° Be′	111
West Virginia................	0.809 = 43.1° Be′	110
Eastern Ohio.................	0.813 = 42.2° Be′	129
Western Ohio.................	0.826 = 39.5° Be′	143
Kentucky.....................	0.836 = 37.5° Be′	151
Indiana......................	0.826 = 39.5° Be′	140
Illinois.....................	0.845 = 35.7° Be′	148
Kansas.......................	0.843 = 36.1° Be′	153
Oklahoma.....................	0.840 = 36.7° Be′	170
Wyoming......................	0.836 = 37.5° Be′	130
California...................	0.878 = 29.5° Be′	470

PROPERTIES USEFUL IN THE DISTILLATION OF IMPORTANT CRUDE PETROLEUMS.

SOURCE OF CRUDE	Specific Gravity	Be′ Gravity	Init. B. P.	5% Temp.	5% Grav.	% 410° F	Gravity % 410° F	Stream 410° F	% 58° Dist.	E. P. 58° Be′	Stream 572° F	% Over 572° F
El Dorado, Arkansas......	.851	34.8	140°	212°	73.6	30.0	60.7°	46.5°	35.3	462°F	35.6°	50.0
Winnett, Montana........	.777	50.6	180°	235°	68.9	65.0	58.2°	47.8°	66.2	412° F	38.5°	93.9
Homer, Louisiana........	.832	38.6	98°	194°	80.6	30°0	63.4°	50.2°	37.5	473° F	41°1.	44.8
Pine Island, Louisiana....	.902	25.4	365°	471°	37.2	2.0	39.0°	38.0°	0.0	......	28.5°	25.5
Sallyards, Kansas........	.836	37.8	84°	179°	78.7	31.3	59.8°	46.8°	37.8	454° F	35.8°	53.0
Cushing, Oklahoma.......	.824	40.2	120°	179°	75.0	37.5	59.3°	49.9°	41.2	437° F	37.0°	58.8
Moran, Kansas...........	.877	29.7	180°	342°	56.4	13.3	52.9°	44.5°	2.5	300° F	36.8°	36.6
Garber, Oklahoma........	.780	49.9	110°	165°	81.0	57.5	58.8°	42.4°	61.2	425° F	34.0°	75.0
Kingwood, Oklahoma.....	.829	39.2	140°	220°	68.8	30.5	58.0°	47.1°	30.5	410° F	38.4°	50.0
Billings, Oklahoma.......	.812	42.8	116°	191°	76.9	42.0	59.7°	46.7°	47.5	450° F	36.9°	62.5
Bixby, Oklahoma.........	.845	36.0	121°	213°	72.1	25.1	58.0°	46.6°	25.1	410° F	37.3°	45.0
Bristow, Oklahoma.......	.824	40.2	100°	183°	78.8	39.5	50.2°	46.3°	45.0	455° F	35.4°	62.5
Burkburnett, Texas.......	.821	40.9	121°	197°	74.8	40.0	59.7°	46.5°	44.9	437° F	36.7°	62.4
Ranger, Texas...........	.829	39.2	154°	239°	69.2	31.7	57.0°	47.0°	28.4	385° F	37.0°	58.0
Wortham, Texas.........	.800	45.5	100°	237°	75.1	37.5	59.4°	50.4°	43.0	448° F	41.5°	71.0
Groesbeck, Texas........	.839	37.2	130°	293°	62.9	20.0	55.7°	49.9°	13.5	365° F	39.0°	54.0
Mexia, Texas	.842	36.6	220°	314°	55.4	15.0	52.5°	49.2°	....	......	39.6°	50.0
Big Muddy, Wyoming....	.860	33.0	165°	210°	61.8	20.8	54.5°	45.0°	14.5	350° F	36.0°	38.0
Osage, Wyoming.........	.819	41.3	110°	186°	75.1	33.0	58.0°	52.2°	33.0	410° F	36.6°	55.0
Lance Creek, Wyoming....	.815	42.1	170°	216°	70.1	33.0	58.0°	46.8°	33.0	410° F	38.6°	57.5
Salt Creek, Wyoming.....	.838	37.1	119°	218°	71.2	27.5	57.3°	45.7°	26.0	392° F	37.6°	51.2
Grass Creek, Wyoming....	.801	45.1	110°	178°	74.2	44.0	59.1°	45.1°	47.5	454° F	36.2°	65.0
Elk Basin, Wyoming......	.805	44.3	88°	170°	78.4	45.0	59.0°	45.1°	48.0	390° F	36.0°	65.0
Ferris Dome, Wyoming...	.831	38.8	94°	192°	75.7	28.5	59.6°	46.2°	32.5	441° F	38.0°	49.5
Lost Soldier, Wyoming....	.864	33.8	172°	282°	53.5	18.7	46.5°	39.4°	0.0	......	32.4°	40.0
Rock Creek, Wyoming....	.838	37.4	96°	194°	76.6	28.7	58.5°	44.8°	30.0	426° F	37.0°	46.0
Lander, Wyoming.	.809	43.4	95°	187°	76.9	37.3	58.5°	44.5°	38.5	420° F	36.6°	60.0
Tuxpan, Mexico...... ...	.934	20.0	135°	184°	67.0	15.0	57.5°	47.2°	14.4	395° F	36.0°	32.5
Panuco, Mexico.	.982	12.6	....	.....	....	8.3	49.8°	.....	2.5	......	......	....

Typical Refinery Practice.

There is much variation in the practice of petroleum distillation in different refineries. This depends to a large extent upon the character of the crude oil used, the market to which the refiner sells and the ability of the refiner as to knowledge and equipment.

The following outlines the progressive distillation and treatment of crude oil in a typical refinery: (See figures 23 and 24).

Crude **Benzine (Gasoline and Naphtha)** includes all of the light distillate which vaporizes up to 410°F. In the ordinary Mid-Continent or Texas petroleum, 420°F indicates a gravity of the stream of distillate from the condenser in the receiving house of 46.5° Be′ to 47.0° Be′. The gravity of the total distillate at this point varies with different types of crude. In some crudes this will be as high as 64.0° gravity, in others as low as 50°. For example, Burkburnett crude distilled up to 410°F has a gravity of 59.7° Be′ of the total benzine and a stream gravity of 46.5° Be′; Bixby, Okla., crude benzine at 410°F has a gravity of 58 0° Be′ and a stream gravity of 46.7° Be′; Cushing, Okla., crude benzine at 410°F has a gravity of 59.7° and a stream gravity of 47.0° Be′; Billings, Okla., crude gives a gravity of 60° Be′ at 410°F and a stream gravity of 46.5° Be′; Ranger, Tex., crude oil gives a benzine gravity at 410°F of 56.6° Be′ and a stream gravity of 46.7° Be′. The gravity of crude benzine depends upon the initial boiling point of the crude, the relative proportion of the different paraffin constituents and the chemical series of hydrocarbons to which the crude belongs. (See page 236.)

The crude benzine is run off with direct fire under the still, though after a temperature of 220°F is reached some open steam may be put in. The steam decidedly sweetens the product and brings over the benzine at a lower temperature. In the use of steam, the distillation must be entirely governed by the gravity of the stream in the receiving house and not by temperatures. In cases where the crude is of good quality, it is not necessary to treat the benzine as it may merely be redistilled with steam coils. In many cases the refiner puts a good dephlegmator over on his crude still and makes a marketable gasoline without either treating it with acid or redistilling it with steam.

When a high sulphur or low grade petroleum is treated, the distillate is put into an agitator with sulphuric acid, the mixing being perfected by blowing air through the acid in the bottom of the agitator, thus contacting it with all portions of the benzine. The acid is drained out and the benzine washed with water. Caustic soda or "doctor" solution is added to neutralize the acid and the benzine is thoroughly washed to remove the last traces of caustic or sulfonates. The benzine is redistilled in a steam still to give a gasoline of 58 to 60 gravity and about 430 end point, this depending largely upon the perfection of the dephlegmator. The last portion of the distillate is naphtha if a gasoline of high Baume′ is desired. High gravity crudes are blended with low gravity crudes to eliminate the naphtha fraction.

Kerosene or Water White Distillate comes over just after the crude benzine, with the gravity of the stream in the receiving house

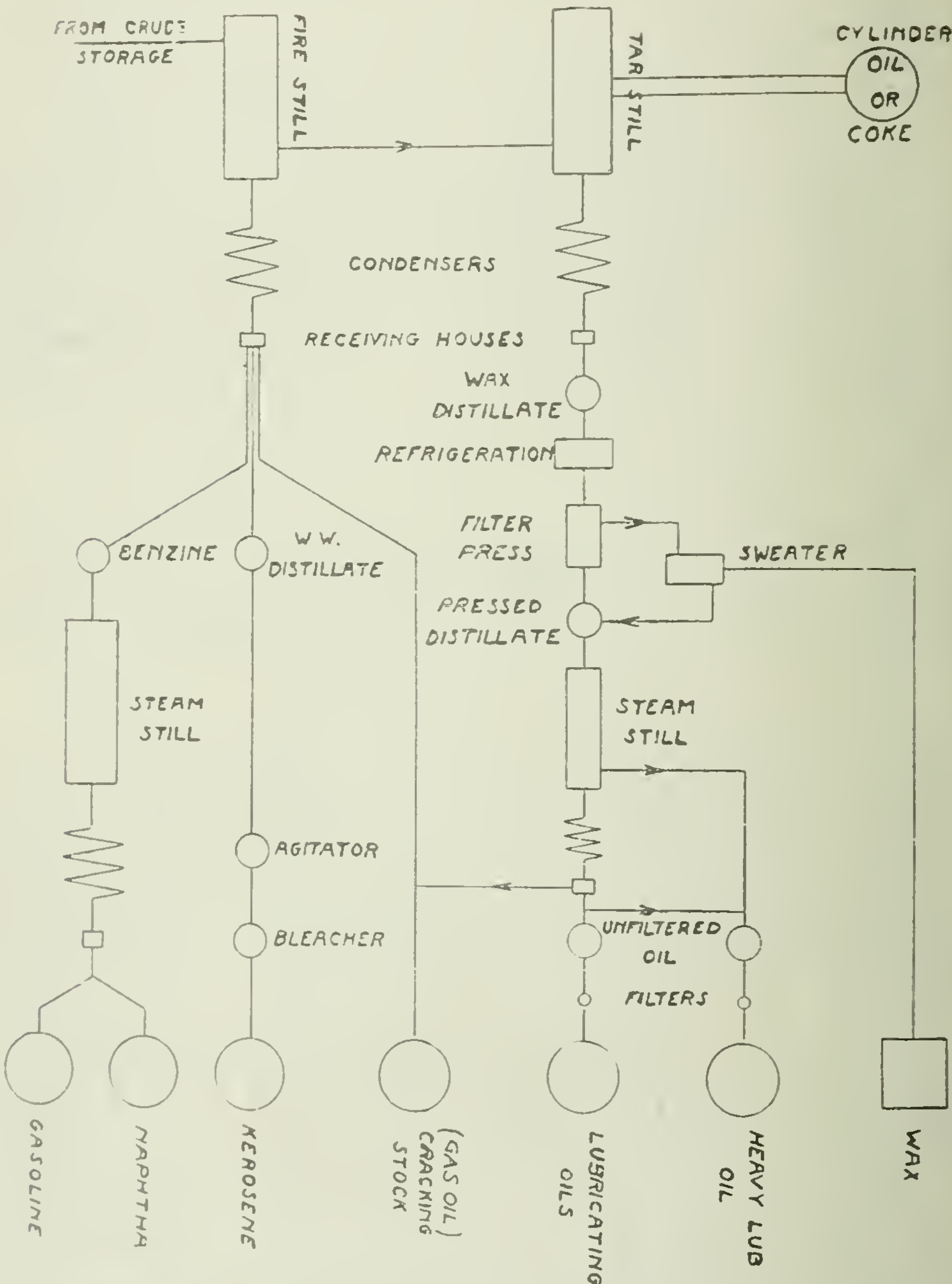


Fig. 23—Flow Sheet for Complete Petroleum Refinery.

at about 37.0° and a vapor temperature of 572° F. This will give a kerosene ordinarily of a 41° gravity, but this again varies greatly with the type of the oil. For example, a certain Wyoming crude oil under these conditions gives a 31.0° kerosene, whereas Cushing, Okla. and Bixby, Okla., crude oils give a 41.0° to 42.0° gravity kerosene. Pine Island cracked oil gives a 33-34° Be' kerosene and Wortham, Tex., light crude gives a 46° Be' gravity kerosene. In distilling kerosene from the crude it is desirable to stop before there is discoloration from decomposition or cracking. Cracking may be very largely prevented and kerosene very greatly sweetened by using open steam throughout the entire distillation. The water white distillate or first run kerosene is now treated with acid and caustic in the agitator and exposed to heat, air and light in a shallow tank or bleacher in which all water is settled out. If the kerosene after treatment is not water white or has too high an end point, it may be redistilled with superheated open steam. The residue in the still may be mixed with the solar oil.

Solar Oil or Distillate Oil is taken out immediately following the kerosene, being a crude distillate not subjected to refining and sold for use in explosion engines, as a high grade special fuel oil or for cracking stock. The making of this product depends upon the market. It may be about a 36 gravity product or it may be combined with gas oil or straw oil.

Gas Oil is taken immediately following the distillate oil or kerosene and its distillation is continued until the residuum in the still has a gravity of 23 to 26° Be'. It is distinctly a destructive distillation and the yield depends largely upon the method and rate of firing. Gas oil is used in making gas and contains a considerable amount of olefins and cracked products, and is not refined except for special purposes. It is also used as cracking stock. By the Burton process or the Cross process, gas oil commercially yields 60 to 65 per cent of gasoline. If a gas oil fraction low in olefins (straw oil) is desired, it is necessary to distill using open steam and direct fire. Straight firing gives a more fluid residue on account of cracking.

Residuum or tar is sold as **fuel oil** or it may be used to produce lubricating oil. In the latter case, it may be put into tar or tower stills and run down to coke (see figure 25). If the crude oil contains no wax, then the lubricants may be made by vacuum, steam or gas distillation, and the distillate is only filtered through Fuller's earth for use.

Wax distillate is collected following the gas oil and furnishes the stock from which lubricating oils and wax are made. Wax distillate usually has a gravity of 30-32° Be', viscosity 50-80 at 100° F and a cold test of 55-100° F. The amount from different crudes varies from none up to 35 per cent. About 10 per cent is a usual amount.

The wax distillate is cooled and the solidified wax pressed out at a low temperature under a high pressure. The wax-free oil, known as "pressed distillate" is then reduced in a still to the desired viscosity lubricating stock. When reducing, considerable steam is used in the distillation in order to prevent the oil from "cracking" or as stillmen frequently say, from "burning." Heavy benzine, gas oil

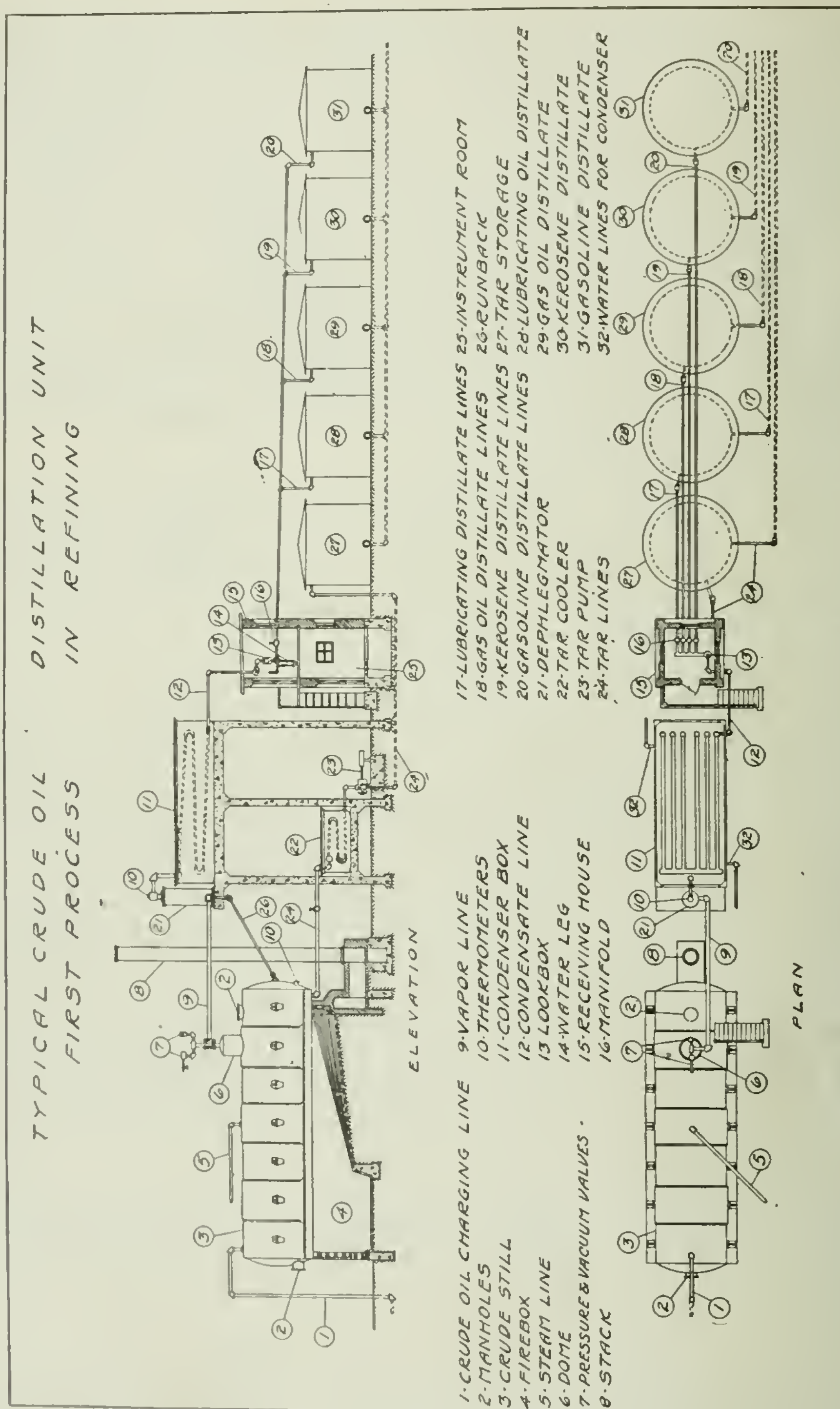


Fig. 24—Main Features of the Crude Oil Distillation Unit.

and light lubricating distillate are obtained as overhead products, the residue being the base for the heavy lubricating oil. The light lubricating distillate contains volatile products, which must be removed. This is performed by reducing as before with fire and steam to the viscosity desired.

The reduced lubricating stocks are further refined by treating and filtering. The oils are agitated, by means of air, with strong sulphuric acid in large agitators. It has been found that better results are obtained if the acid is added in small portions instead of adding the acid all at once. A small quantity, known as "water acid" usually one pound per barrel of oil treated, is added and agitated with the oil for a short time. The agitation is then discontinued and the acid sludge is permitted to settle, after which it is drawn off. Then about four pounds of new acid, known as the "first body acid" is agitated with the oil. The agitation is again stopped and the acid sludge drawn off. The larger portion of the acid, "second body acid" is then added. This quantity varies with the nature of the oil treated but is frequently 4 to 10 pounds per barrel of oil. This is then agitated an hour or more with the oil, after which a sufficient quantity of water is added to coagulate the asphaltic material in the oil. This operation is known as "coking." The acid sludge is drawn off as quickly as possible and the asphaltic material or "coke" permitted to settle. If the proper quantity of water is not added, the asphaltic material becomes finely divided and is difficult to separate from the oil. The oil which is still acid is pumped into another agitator where it is neutralized with caustic soda, a 5° Baume' solution being used. After the acid has been neutralized, the caustic soda is permitted to settle and is drawn off. The oil is then freed of moisture by heating to about 120 to 140° F and then blowing with air until the oil is bright. During the neutralization, the oil sometimes becomes emulsified. The emulsion is often broken by heating or sometimes by heating and agitating with a demulsifying compound. The oil should be treated in such a manner that a minimum quantity of salts are formed during this process as these cause the finished oil to have a poor emulsion test. Th acid treatment the finished oil to have a poor emulsion test. The acid treatment meet color specifications. The oil is then filtered through Fuller's earth until the desired color is obtained. The filtering also improves the emulsion test. After filtering, the oil is ready for the market.

Refiners frequently manufacture two grades of lubricating oil, a light and a heavy oil. These oils generally have the following tests:

	Light Oil	Heavy Oil
Gravity	25 0—32.0° Be'	20.0—27.0° Be'
Flash point	300—400° F	375—425° F
Fire test	400—460° F	460—500° F
Viscosity at 100° F	50—150	200—400
Cold test	10— 30° F	20— 35° F
Color (N. P. A.)	2	3, dark red

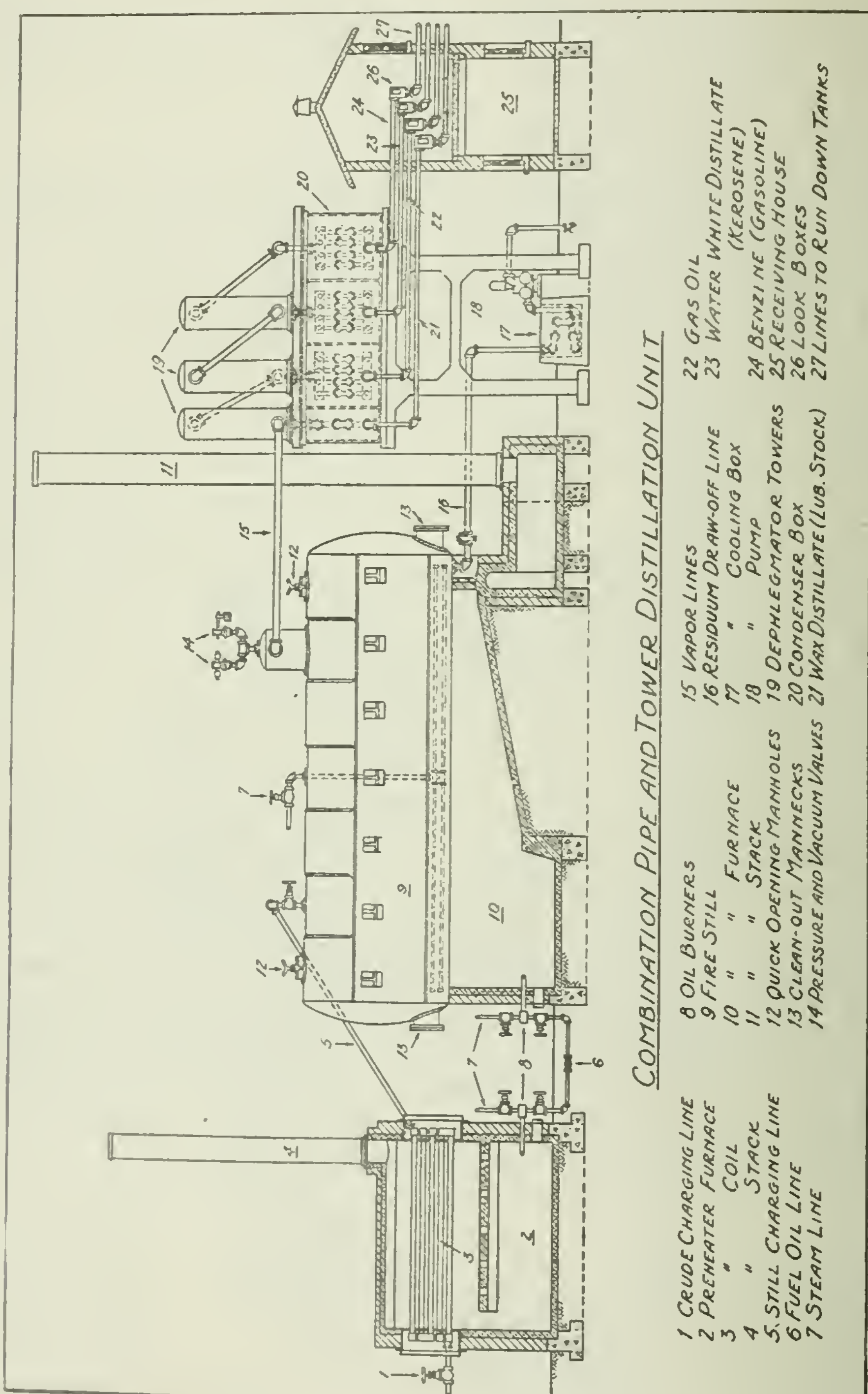


Fig. 25—Combination Pipe and Tower Still.

All lubricating oils should have a fair emulsion test and a low carbon residue. Many purchasers of lubricating oils demand a light colored oil, but a good color does not necessarily signify a good lubricant.

Paraffin Wax is also obtained from the wax distillate cut. The wax distillate is cooled to about 5° F in chillers by means of a cold brine solution. The solidified mass is granulated and carried forward to the presses by a helicoid conveyor. The wax is then separated from the oil by forcing the cooled mass of oil and wax through filter presses under a high pressure, approximately 350 pounds per square inch. The crude wax remains upon the canvas filter and the oil drops into the pan below.

The crude wax known as "slack wax" is removed from the press and conveyed to a tank where it is melted. The slack wax contains a large percentage of oil, which must be removed. This is done by a process known as "sweating." The "sweaters" are large shallow pans which contain wire screens a few inches above the bottom. Sufficient water is placed in the pan to cover the screen. The melted wax is then pumped on the water and permitted to solidify slowly. When solid, the water is drawn off at the bottom of the pan, the cake of wax being supported by the screen. The temperature of the sweater room is gradually increased by means of steam in closed steam coils.

The oil known as "foots oil" first separates from the wax followed by the low melting point or "intermediate wax." The wax from the sweater is known as "scale wax." The scale wax usually has a yellow color, which is removed by treating and filtering. The scale wax is melted and treated with a few pounds of 66° Baume' sulphuric acid, usually with 1 and 3 pounds in succession. The acid is drawn off and the remaining acid in the wax neutralized with 1 to 3° Baume' caustic soda. The alkali is settled from the wax, the temperature being maintained at about 140° F during the entire process. The melted wax is then filtered through Fuller's earth to the desired color. Wax has a specific gravity of about 0.9, a melting point of 120 to 140° F and not more than 1 per cent of oil and moisture.

After the wax distillate has been removed from the crude oil, a fraction containing considerable amorphous wax, known as "wax tailings" distills over. The wax tailings are not passed through the condenser coils, but are permitted to pass directly from the vapor line to a small tank known as the "wax pot." They are of little value but may be used for cracking stock.

Crude oil which has a bright green color is distilled with considerable steam in order that a heavy oil may be obtained after the gas oil and a portion of the wax distillate have been removed. This product is known as **Cylinder Stock.** Cylinder stock should have a high flash and fire test; the color should be green to red, not brown nor black. If a brighter color is desired, the oil is treated and filtered.

Cylinder stock from Mid Continent crude oils usually has the following tests:

Gravity	19.0—23.0° Be′
Flash point	490—600° F
Fire test	575—700° F
Cold test	40— 70° F
Viscosity at 212° F	130—250
Color	brown or green

When asphalt is desired the residue from the gasoline and kerosene may be distilled by blowing superheated steam through it until the desired consistency is reached. Asphalt base oils or cracked paraffin base oils are necessary to make first class asphalt. An outline of the methods used for producing asphalts and road oils is given on page 367. Frequently, particularly for road oils, the stock remaining after cracking heavy gas oil is run down to a semi-solid or solid consistency. This gives a specially valuable road oil on account of its high asphalt content, good hardening or drying properties, low viscosity and excellent penetration.

For refining by cracking see pages 204 to 242.

For illustration of a refinery operation, see flow sheets on pages 23 and 222.

Color and Odor in Refined Petroleum.

Most distillates from petroleum contain sufficient foreign matter to give an undesirable odor or a yellowish to red color.

The odor in natural distillates is due ordinarily to sulphur compounds, characteristic of which is hydrogen sulphide. Gasoline or light hydrocarbons produced by cracking have a more or less offensive odor even though sulphur is not present in appreciable quantity. In a general way, color is present in proportion as the odor is more disagreeable. The color of petroleum products is thought to be partly due to nitrogen compounds. Light hydrocarbons produced by cracking have a higher color the larger the amount of nitrogen in the heavy oils cracked, as a general rule. Cracked products from paraffin hydrocarbons such as those from Oklahoma give a yellowish color in the distillate above 300° F though they may be colorless below 300°F. California and Mexican cracked gasoline gives a red color, which is not noticeable immediately upon distilling, but becomes more intense as the gasoline is exposed to the action of the air. This coloring matter on standing largely settles out or is oxidised so that the redistilled gasoline may be free from color.

Kerosene, the first refined product of petroleum marketed on a large scale, was a yellow or dark red liquid. It was first produced from coal, and it was found in 1857 that "coal oil" could be deodorized and decolorized by treatment with sulphuric acid and this is the process that is in general use at the present time. 66° Be' sulphuric acid is ordinarily used, as it reacts upon the unsaturated compounds, the sulphur compounds and the nitrogenous compounds in the oil by forming substances which dissolve largely in the sulphuric acid. The shrinkage of the oil treated may vary from almost nothing up to 10 per cent, depending upon the character of the oil being refined. In ordinary natural distillates, one pound of acid per barrel is commonly sufficient, but with cracked oil as much as 10 pounds of acid are often required. Even then the treatment is often not sufficiently severe and oleum or Nordhausen sulphuric acid, which contains an excess of sulphur trioxide is necessary. This is the case with California oil. After treatment with sulphuric acid, thorough washing and neutralization with caustic soda is always necessary. Other substances used for neutralizing the acid and acid sulfonates are soda ash, lime, silicate of soda and sodium plumbite.

Other chemicals may be quite successfully used in removing the odor of cracked gasoline, among these being sodium plumbite, copper oxide, manganese dioxide, potassium permangate, sodium chromate, aluminum chloride, chlorine and stannic chloride.

Dry hydrochloric acid gas (hydrogen chloride, HCl) and aluminum chloride are often highly effective in treating gasoline to remove the color.

The "bloom" or fluorescence of mineral oils is supposed to be due to the presence of asphalt-like or pitchy material in colloidal condition. This is overcome by the use of mono-nitro-naphthalene $C_{10}H_7NO_2$) in small amounts.

The most useful agent in the improvement of the color of refined petroleum oil is fuller's earth. Chemically, fuller's earth is a hydrous silicate of alumina, containing small quantities of other substances such as calcium, magnesia, and iron. Usually it contains about 15 per cent of combined water.

The ability of fuller's earth to remove color from oil is purely physical in character. Fuller's earth is not a definite chemical compound and many varieties of fuller's earth will give equally varying results. A sample of fuller's earth which is perfectly satisfactory for bleaching vegetable oils may not be satisfactory for the bleaching of mineral oils. Some fuller's earths have so marked an oxidizing action on vegetable and animal oils that they cause the oil to catch fire spontaneously when air is blown through the filter presses to remove the adhering oil. This type of fuller's earth is of course not satisfactory for vegetable oils but is quite satisfactory for mineral oils. This is why the Florida earth is almost exclusively used for bleaching mineral oils.

Fuller's earth for refining petroleum oil is usually bolted to definite sized grains and is placed on the market on the basis of 15-30 mesh, 30-60 mesh, 60-80 mesh, etc. The coarser sizes are in greatest demand for the reason that after treatment of the oils, they are easier to clarify. The finer sizes are more effective in bleaching but are more difficult to clarify. The fine material may be used for the decolorization of gasoline. Fuller's earth is ordinarily used but slightly for decolorizing kerosene, though it is customary to treat kerosene with a small proportion of fuller's earth to aid in removing the turbidity.

In its use, fuller's earth of the grade chosen is placed in a tall cylindrical percolator with closed, rounded ends. Through this column about 15 feet in height, the oil is forced under sufficient pressure to allow it to run freely from the bottom. The fuller's earth is classified according to the color which comes through. The percolator carries ordinarily from 18 to 25 tons at one time. The decolorization capacity of fuller's earth varies from 30 barrels for one ton of earth down to 7 barrels for one ton of earth on each treatment. Since fuller's earth may be used satisfactorily from 10 to 16 times, the amount of fuller's earth consumed varies from one ton of fuller's earth to 500 barrels of oil down to one ton of fuller's earth for 60 barrels of oil. In each treatment, when the fuller's earth has become useless for decolorizing, the percolator is blown out with air to remove as much of the oil as is possible and the residue is washed with naphtha to recover the oil adhering to the particles. The extractor is then blown out with steam to remove the residual matter. The naphtha is recovered by distillation and the residual oil is retreated in the following batches. The recovered fuller's earth is conveyed to a rotary kiln similar to those used in burning Portland cement. The earth is heated at a low red temperature, about 900°F, to revivify the earth. About 3 per cent of the material is lost in burning. It is usual to burn the earth before using it for bleaching, thus removing all of the moisture and water of hydration. Great care must be taken that the temperature of incipient fusion is not reached.

Fuller's earth is also highly effective in the treatment of off color naphthas, benzines and gasolines where fairly good results can often be had by treatment in the same manner as in the case of illuminating and lubricating oils. The best results can be had by distilling while agitating with fuller's earth. In this manner, yellow pressure distillates, such as are obtained in cracking, can be decolorized completely by one distillation if proper towers are used. While this makes water white gasoline it does not greatly improve the odor and the usual treatment is necessary for eliminating the odor. On the other hand, a very light dilute acid treatment may be used for improving the odor and this may be followed by the distillation with fuller's earth.

Good results may be had by the use of Bentonite* in the decolorization of petroleum. This material is a hydrous silicate of alumina or zeolite. The material used for examination was greenish white in its natural state with a greasy consistency and formed a perfect suspension with water. The samples used for test were dried at 300° F. After drying the material was white. The composition is as follows.

	Natural	Dried	Ignited
Moisture	35.33%	0.00	0.00
Combined water	4.61	7.13	0.00
Silica	38.70	59.85	64.45
Alumina	15.49	23.96	25.80
Iron Oxide	2.18	3.38	3.64
Lime	0.83	1.29	1.39
Magnesia	1.81	2.80	3.01
Sulphur	0.71	1.07	1.15
Alkalies	0.34	0.52	0.56

By distilling pressure benzine of very dark color once with this material of 100 mesh fineness a water white gasoline is obtained.

*See Engineering and Mining Journal, Vol. 112, p. 819, November 19, 1921 and Vol. 112, Page 860, November 26, 1921.

*See A. Seidell J. Am. Chem. Soc., Vol. 40, p. 312, January, 1918.

Petroleum Emulsions and Their Dehydration.

Producers of petroleum are usually little concerned with the refining of petroleum except as they receive a price dependent upon the refining properties. Often particularly in the case of asphaltic or heavy waxy crude oils a large amount of water, brine and colloidal mineral matter is suspended in the oil. Oil in such condition may contain as much as 60 to 90 per cent of water. These emulsions are variously spoken of as B. S., sediment, roily oil, cut oil and tank bottoms. Much of this B. S. is often asphaltic and waxy matter precipitated by the mixing of crudes or the lowering of the temperature when the oil exudes from the sand due to the release of pressure. Most crude oil as it comes from the ground carries some water but anything less than 2 per cent is accepted by the pipe line companies or the refineries. The actual production of emulsions probably occurs when the oil and the water mix as they exude through the fine interstices in the sand.

The main emulsifying agents are probably hydrous silicates of alumina which though in very small quantities form colloids with water, asphaltenes or naphthenic acid which form colloidal solutions with the oil and colloidal oxide of iron which separates out from oil bearing brines. Any finely divided solid may, however, act as an emulsifying agent. The chief requirement for a stable emulsion is that the solid substance insoluble in one fluid and insoluble or slightly soluble in the other, separate on the surface of the globule constituting the internal phase. A common condition is that the liquid in which the emulsifying agent is less soluble constitutes the internal phase. For example, metal soaps such as calcium oleate and copper oleate are more soluble in oil than in water and the oil is therefore in the external phase. Even in these cases, however, the emulsion may separate into two layers of emulsion, in the lower of which, the water is in the external phase and the upper of which, the water is in the internal phase. If the crude oil as naturally existing in the oil sand and containing a small amount of naphthenic acid or similar substance while being forced by pressure through the interstices in the sand is brought into contact with water containing calcium bicarbonate, the corresponding calcium soap is precipitated and forms a film on the globules of water, thus tending to produce a more or less permanent emulsion.

There are two general methods of removing water from oil in which it is emulsified. One is by vaporization of the water, the other is by encouragement of the coalescence of the water globules. Vaporization is usually the method employed and merely consists in heating the oil in pipes to a temperature of approximately 300° F and discharging it into a hot still or vaporizing container. The water thus goes completely into the vapor phase and condenses in the coil together with any light oil. This condensate shows no tendency whatever to again emulsify, on account of the absence of emulsifying agents and on account of the low viscosity of the oil.

The same effect may be accomplished without coils by heating the oil to a pressure of about 100 pounds and condensing the vapors including all of the water vapor at the same pressure. This is the same method as that for producing synthetic gasoline by pressure distillation. At the ordinary refinery, the oil is heated to a temperature not exceeding 212° F and the water separates and is drawn out through the tar plug. This, however, can only be done in the case of the lighter crudes.

Various methods are used to induce coalescence of the water globules. In all of these, the oil is heated. Often by heating alone, there is sufficient settling out of the water to make the oil acceptable. A temperature of 160° F is commonly used. As an aid to this sedimentation, chemicals are frequently successfully employed. A common formula is the use of a sodium soap containing resin, wax and sodium silicate in small quantity. Sodium carbonate alone is occasionally sufficient. The most recent method of coalescing the water globules is the application of the centrifuge. This is used in many large producing plants in the Gulf Coast and Mid Continent region. The Cottrell Electric Precipitation method is claimed to be quite effective and it is stated that it requires a consumption of only about 100 watts of electricity per barrel of oil treated.

References on Dehydration of Petroleum.

C. V. Fornes, Petroleum Age, 10, 33, 1921.

E. E. Ayres, Petroleum World, 18, 406, 1921; 18,401.

J. H. Wiggins, National Pet. News, 13, No. 26, 59, 1921.

C. P. Buck, Oil and Gas Journal, 20, 80, 1921.

Chemical Nature of Cracking of Oil.

When crude oil is subjected to ordinary distillation by fire the light products naturally present in the oil are distilled off as such up to a temperature of about 300° C (572° F) comprising both the gasoline and the kerosene. Above this temperature, the hydrocarbons undergo partial decomposition while distilling, with the result that some light products are produced and distilled along with the heavy products. Olefins as well as paraffin compounds of lower molecular weight than the oil being heated are formed. By vigorous firing the entire oil residue may be distilled, leaving only a variable amount of residual carbon as a product of decomposition. The amount of carbon and gas formed by this pyrogenic decomposition is greater with the asphaltic or naphthene petroleums than with the paraffin base petroleums. A typical heavy Mid Continent petroleum gives 4.5 per cent of carbon and 4.0 per cent of gas on distillation to coke or carbon. With pure paraffin base oils the amounts of carbon and gas formed are comparatively slight. Mexican oils from Panuco give 20 per cent of coke.

This property of all heavy petroleums in decomposing into hydrocarbons of lower molecular weight by heating is generally known as cracking. The chemical reactions involved in cracking are not definite. It was originally supposed that cracking involved the formation of a large amount of olefins according to the following reaction: (Redwood)

$$C_nH_{2n+2} = C_{n-m}H_{2(n-m)+2} + C_mH_{2m}$$

a specific illustration of which would be

$$C_{15}H_{32} = C_8H_{18} + C_7H_{14}$$

Pentadecane +Heptylene =Octane

This reaction does not, however, accord with the facts, since gas and carbon are always formed in varying amount. A reaction which corresponds to the yields as experimentally found under certain conditions is the following:

$$2C_nH_{2n+2} = 2\ C_{n-m}H_{2(n-m)+2} + mCH_4 + mC$$

or as a specific illustration

$$C_{15}H_{32} = C_8H_{18} + 7\ CH_4 + 7\ C$$

Pentadecane = Octane + Methane + Carbon

Yet under certain other conditions the amount of gas formed is very small, indicating that the following reaction was partly carried out.

$$(2m+2)\ C_nH_{2n+2} = (2n+2)\ C_mH_{2n+2} + 2(n-m)\ C$$

or as an illustration

$$9\ C_{15}H_{32} = 16\ C_8H_{18} + 7\ C$$

Pentadecane = Octane + Carbon.

This last reaction is also indicated by the large yields of gasoline obtained from some crude oils.

Pure paraffin wax of melting point of 130° F and specific gravity of 0.892 on repeated cracking confined under pressure up to 57 atmospheres at temperature of 400° C and with a vapor space twice the volume of the liquid, yielded 32.5 per cent by volume of gasoline of 0.724 = 63.4° Be' gravity or 29.1 per cent by weight by each treatment or a total of 91.7 per cent by weight, or 104 per cent by volume.

The amount produced on first six treatments was as follows:

First	29.1%	by weight of original paraffin
Second	19.9%	by weight of original paraffin
Third	14.5%	by weight of original paraffin
Fourth	9.9%	by weight of original paraffin
Fifth	6.8%	by weight of original paraffin
Sixth	4.7%	by weight of original paraffin
	84.9%	

The gasoline produced consisted of paraffin hydrocarbons as shown in fig. 42.

That the cracking of oil is not simply a decomposition of the hydrocarbon molecules is shown in fig. 44. These curves show the relation between the distilling temperature and the specific gravity of water white Cabin Creek distillate. Before cracking, it had an end point of about 540° F and its heaviest ends had a specific gravity of 0.815. After cracking, the end point was above 640° F and the end gravity above 0.900. Both heavier and higher boiling hydrocarbons as well as lighter and lower boiling hydrocarbons were produced simultaneously. There must have been polymerization to yield hydrocarbons of both higher boiling point and higher specific gravity. By continued cracking there may be made from water white distillate, solid and ductile asphaltic cement of typical conchoidal fracture.

The gases produced by cracking likewise are not simple split-off hydrocarbons but vary according to the method of cracking. In liquid phase cracking, the chief variation is in the olefin and hydrogen content. In a general way, there seems to be a tendency for low percentages of hydrogen to be associated with low percentages of olefins. A typical gas made in a Burton still has the following composition:

Methane and Ethane (C_nH_{2n+2})	=82.0%
Olefins	= 8.5%
Hydrogen	= 9.5%

One of the problems in cracking is to limit the amount of hydrogen. This has been partially done by allowing the hydrogen to remain in contact with the cracked distillate under high pressure and at a temperature somewhat below the ordinary temperature of cracking (see U. S. Patent 1,255,138). (See Figs. 72 and 73.)

Figures 39 and 40 shows some of the relative properties of light hydrocarbons made by various processes used more or less in a commercial way for the production of gasoline from heavy oil.

Classification of Systems of Cracking.

I—Vapor Phase.

A. Atmospheric pressure.

(1) High temperature. Oil gas, Pintsch gas at very high temperature. Blaugas and liquefiable gas at high temperature (1200° F). Gasoline substitutes such as Greenstreet process—cherry red temperature.

(2) Low temperature (700-900° F).

B. Increased Pressure.

(1) High temperatures. Rittman at 950° F and 200-300 pounds. Hall at 1100° F and 75 lbs.

(2) Low temperatures (750-900° F).

II—Liquid Phase.

A. With distillation (distillation necessary).

(1) Atmospheric pressure.

(a) Without chemicals. Atwood (1860)—illuminating oil practice.

(b) With chemicals. Aluminum chloride and related chemicals (McAfee, Gray).

(2) Above atmospheric pressure—no differential pressures. Dewar & Redwood, Dubbs, Burton, Bacon & Clark, E. M. Clark, Jenkins, Fleming.

(3) Very high pressure—distilling at reduced pressure. Benton.

B. Without distillation (necessarily high pressure).

(1) Intermittent. Palmer, Snelling, Hubbard.

(2) Continuous.

(a) Identical heating and reaction zones.

(b) Separated heating and reaction zones.

The above outline of the general systems of cracking gasoline is not based upon any general mechanical arrangement. Most of the patents relating to the cracking of oil cover mechanical arrangement. Of more than 1,000 patents on this subject, very few of them are basic.

Those systems that heat the oil vapor at atmospheric pressure are principally used for making gas. On account of the low specific heat of the oil vapor the temperatures are very high and are not subject to exact control. The result is that the product contains a large percentage of olefins and aromatics and a large proportion of the heavy oil stock is converted into fixed gas. Possibly the only chance of making a first class gasoline according to these systems is to heat the vapor at a temperature of from 700 to 900° F. This involves a very large apparatus or one in which the oil vapor is put through at a very high rate of speed. The difficulties in temperature control are so great that they have not yet been satisfactorily overcome, although some experimental work is being done in the design of furnaces for holding the vapors at the limited temperature required.

Much of the pioneering work in the cracking of oil was done in heating in the vapor phase under increased pressure. These also have the fault that the temperatures are ordinarily kept too high; 1100° F and a pressure of 75 pounds are typical. Increase of pressure is of interest because of the deceased cost of operation. Likewise low temperatures of from 750 to 900° F with vapor phase cracking might prove successful but the question of carbon deposition on the walls of the tubes present a new difficulty.

The really successful processes that have proved profitable are those in which the cracking is accomplished by applying the heat to the liquid phase of the oil. The original work on cracking by Atwood in 1860 was done at atmospheric pressure and it has been the practice ever since that time to increase the amount of illuminating oil by refluxing while distilling. This method, however, does not accomplish enough in the production of gasoline unless some chemical agent is added which causes the reaction of cracking to go on at a lower temperature. The most common chemical used for this purpose is technical dry aluminum chloride, the operation of which is explained more fully further on. By this process, completely refined gasoline may be made with one operation. Other chemicals such as tin chloride, ferric chloride, manganic chloride, zinc chloride and phosphorus pentoxide have the same effect but to a lesser degree.

The method by which a large proportion of the synthetic gasoline is now made is by distillation at pressures considerably above the atmospheric pressure. The reaction and distillation take place in the same still. An enormous amount of refluxing is necessary and the gasoline must be removed as fast as it is formed. An enormous amount of heat is lost by reason of this refluxing and the reaction is considerably retarded, but nevertheless, the distillation is a necessity as otherwise excessive pressure would develop.

By the use of very high pressure, more reaction can be accomplished in a shorter time and methods exist whereby this is done followed by distillation at a lower pressure.

The most recent development, however, has been the accomplishment of the cracking without distillation as a separate and distinct refinery operation. This is necessarily carried on at a high pressure and most of these processes provide for intermittent operation. Intermittent operation is of course not commercial in handling a cheap material like petroleum as a very long period of time is necessary for cooling between operations. Continuous systems have been devised in which the heating zone and the reaction zone have been one and the same. This brought on difficulties in continuing the operation for long periods of time without the formation of an excess of carbon. Possibly one of the most basic patents has been developed in which the heating zone is separate and distinct from the reaction zone. This allows an operation to be continuous for a period of from 3 to 15 days without the necessity of cleaning carbon as the reaction zone may be changed without interfering with the heating zone.

Electrical processes continue to attract considerable attention chiefly because of their novel claims rather than because of any

(No Model.)

G. L. BENTON.

PROCESS OF REFINING CRUDE PETROLEUM OIL.

No. 342,564. Patented May 25, 1886.

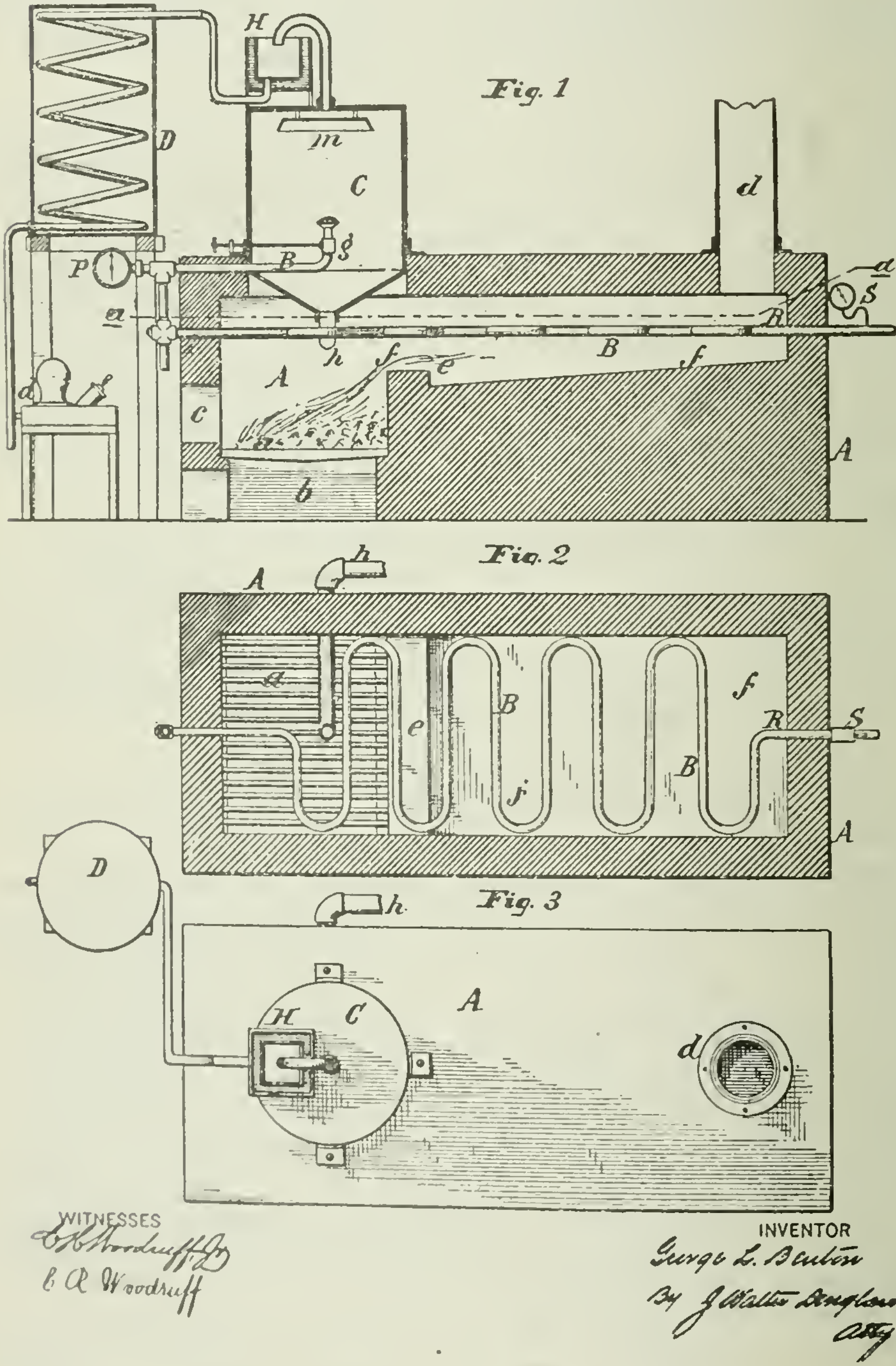


Fig. 26—Benton Process for Cracking.

virtues which they possess. Electrical processes have not been demonstrated as having any commercial value though heat from electrical sources is doubtless as effective in cracking as heat from cheaper sources. No true catalytic processes have been developed for the cracking of oil. No substance has been found which will cause the cracking reaction to go on any more rapidly than occurs in the case of cracking in the liquid phase with high pressure and without distillation. The highest speed probably attained by the use of aluminum chloride is 5 per cent conversion per hour whereas with high pressure and without distillation, conversion can readily be carried out at the rate of 2 per cent per minute. Many chemical substances, however, are effective in producing a sweeter and whiter product.

Advantages of Liquid Phase Cracking.

All processes of making gasoline which have not involved the treatment of the oil strictly in the liquid phase are said to have met with only a questionable degree of success.

While the cracking of oil in the vapor phase would be highly desirable if the product and other conditions were satisfactory, it has been claimed by many that the advantages of applying the heat to the liquid phase are as follows:

1. A lower temperature is sufficient to induce cracking.
2. The rate of reaction is greatly increased, being greater the higher the pressure within certain limits.
3. A product containing smaller amounts of olefins and aromatics is produced.
4. A higher yield of refined gasoline is obtained.
5. There is a better economy of heat.
6. There is a selective action on the oil or heavy portions of the petroleum by reason of the automatic conversion of the desired product into the vapor phase, thus freeing it from further liability to decomposition.
7. There is a high oil capacity with small plant dimensions.
8. There is a perfect control of temperatures.
9. There is a rapid and more complete absorption of heat from the furnace and less tendency to local overheating on account of the much higher specific heat of oil than of the oil vapor.
10. There is the possibility of operating either by intermittent charging or by continuous treatment and distillation.
11. The carbon is deposited in a suspended condition in the oil and not on the retaining walls.
12. There is the possibility of the use of the automatically developed pressure for mechanical and condensing purposes.

The chief disadvantage in cracking oil in the vapor phase and under high pressure seems to be the danger attendant upon a possible failure of steel parts, but this is entirely overcome with proper design.

The following special physical properties of hydrocarbons enter into the considerations of liquid phase cracking:

Gasoline Hydrocarbons.

	Critical Temperature	Critical Pressure Atmospheres
Pentane	390° F.	24
Hexane	450° F.	22
Heptane	515° F.	20
Octane	565° F.	18
Nonane	640° F.	16
Decane	680° F.	15
Undecane	720° F.	14
Kerosene Hydrocarbons.		
Duodecane	760° F.	13
Tridecane	860° F.	10.5
Tetradecane	900° F.	9

The critical temperatures are somewhat increased by the presence of the heavier hydrocarbons so that at pressures above about 150 lbs. per square inch only gasoline and gaseous hydrocarbons would be removed from the liquid phase. With pressures below this there would be some difficulty in maintaining the lighter kerosene in the liquid phase.

References: See Fig. 41 on vapor pressure of gasoline. Denig, Chem. & Met. Engr., Vol. 25, p. 751; Young, Sci. Proc. Roy. Dub. Soc., 12, 374.

(No Model.)

J. DEWAR & B. REDWOOD.

APPARATUS FOR THE DISTILLATION OF MINERAL OILS AND LIKE PRODUCTS.

No. 426,173. Patented Apr. 22, 1890.

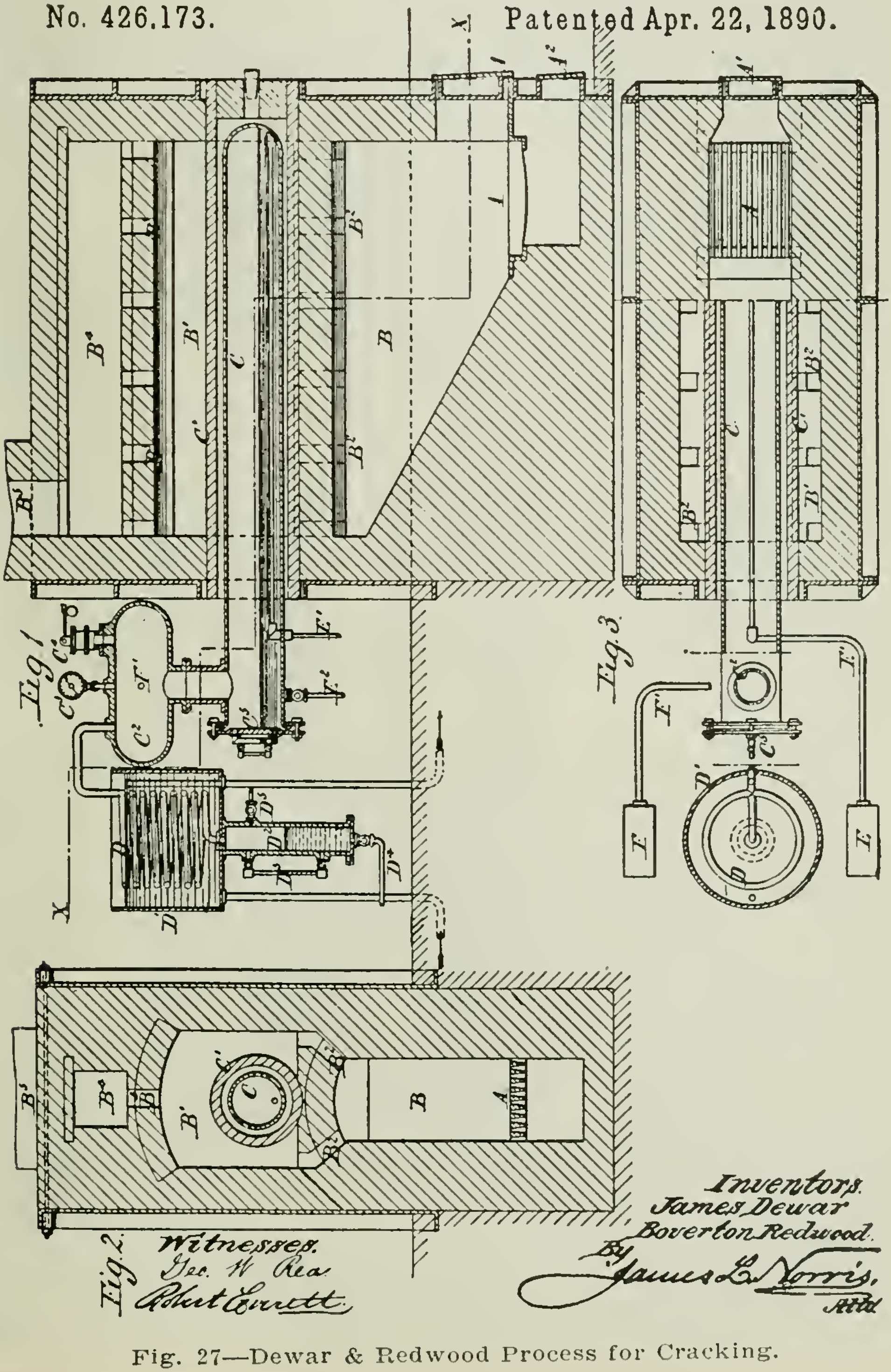


Fig. 27—Dewar & Redwood Process for Cracking.

Development of Commercial Practice in Cracking of Oil.

It has been stated that the commercial cracking of oil was accidentally discovered in the winter of 1861 by a stillman at Newark, New Jersey. However, this is probably not the case, since a patent was granted to Luther Atwood, of New York, May 15, 1860, No. 28,246, in the U. S. Patent Office, which provides for the production of light hydrocarbon illuminating oils from heavy oils, paraffin, etc. The apparatus provides for the cooling of the heavy oil vapors and their return to the still for further cracking. This is all carried out at atmospheric pressure.

The first record of pressure distillation is apparently set forth by James Young in his patent, No. 3,345 (English) of 1865, in which a distillation is described as being conducted in a vessel having a loaded valve or a partially closed stop-cock through which the confined vapors escape under any desired pressure. Under these conditions, distillation takes place at higher temperatures than the normal boiling points of the heavy hydrocarbons and partial cracking results. The patent was taken out for treatment of shale oil and in practice a pressure of 20 pounds to the square inch was recommended.

The first extremely high pressure process was that of Benton, U. S. Patent No. 342,564, May 25, 1886. In this the oil is heated at a temperature of from 700° to 1,000° F. through a pipe leading to a low pressure expansion chamber, where it was vaporized, and then the vapors were condensed. The pressure used was as high as 500 pounds per square inch.

A very important patent in the present development of cracking processes is that issued to Dewar & Redwood, which is partly described as follows:

Specifications and Claims of Dewar and Redwood.

"In distilling mineral oils—such as natural petroleum or similar oil made from shale, coal or other bituminous substances—in order to separate the lighter oils, suitable for lamps and other purposes, from the heavier oils, there is frequently a very large residue of heavy oil. Attempts have been made to obtain lighter oils from such residues or from heavy natural petroleums by causing the vapor generated in the still-boiler to pass a heavily-loaded valve, so that the vaporization takes place under considerable pressure. It has also been proposed to arrange the still-boiler with its upper part cooled, so that the less volatile portion of the vapor may become more or less condensed and fall back into the hot liquid below, this mode of operating being commonly termed 'cracking.' Both these methods are objectionable, the former on account of the irregularity of the distillation and the latter on account of the waste of heat in conducting the cracking process and the slowness and insufficiency of the results.

"Our invention relates to a method of conducting the distillation by suitable apparatus in such a manner that we get the benefit of regular vaporization and condensation under high pressure, and that we may at the same time get such advantage as can be obtained from

W. M. BURTON.
MANUFACTURE OF GASOLENE.
APPLICATION FILED JULY 3, 1912

1,049,667. Patented Jan. 7, 1913.

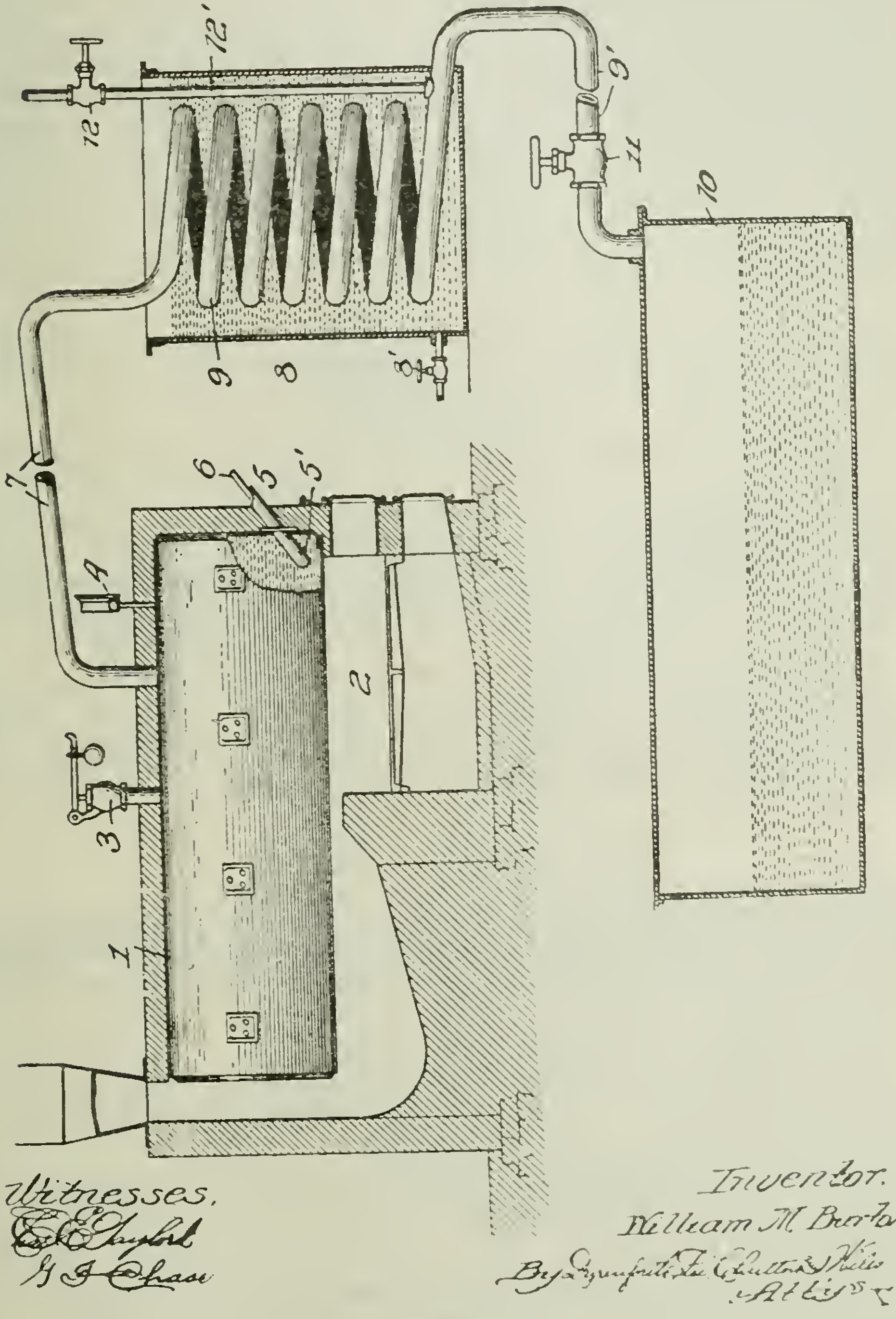


Fig. 28—Burton Process for Cracking.

cracking. For this purpose, we arrange a suitable boiler or retort, and a condenser in free communication with one another, without interposing any valve between them; but we provide a regulated outlet for condensed liquid from the condenser. We charge and keep charged the space in the boiler or retort and condenser that is not occupied by liquid with gas under considerable pressure, it may be with air or it may be with carbonic-acid gas or other gas that cannot act chemically on the matter treated. The distillation and condensation being thus conducted under considerable pressure, which can be regulated at will, we obtain from the heavy residue a quantity of more or less light oil suitable for illuminating and other purposes, which cannot be obtained by distillation under atmospheric pressure. We may also arrange the still-head or upper part of the boiler or retort so as to operate according to the cracking method above referred to, the cracking in this case taking place under high pressure instead of being carried on under atmospheric pressure."

"The apparatus for effecting distillation in the manner described may be arranged in various ways. The accompanying drawings show one form of apparatus for this purpose.

"By a pipe and cock or a suitably loaded safety-valve D_5, gas may be withdrawn from the space above the liquid in the column D_2.

"By regulating the heat and pressure to which the retort is subjected, the character of the distillate may be varied and thus oils more or less light can be obtained to suit various uses. Also the proportions of the parts may be varied, and if necessary, means of cooling may be applied to the still-head C_2.

"Having thus described the nature of our invention and the manner of carrying the same into effect, we claim—the herein-described method of distilling mineral oils and like products, which consists in both vaporizing them and condensing the generated vapor under a regulated pressure of air or gas substantially as specified."

THE BURTON PROCESS.

This is the process by which much of the artificial gasoline now on the market is made. Dr. Wm. Burton states that the total Burton still capacity is eight million gallons with an output of two million gallons of gasoline per day in 1921.

The drawing in the patent is shown in fig. 28.

In the practical operation of this process, a very hot furnace is required on account of the very great radiation of heat from the return conduit 7.

Novelty in this process is claimed to lie in the maintenance of pressure on the condenser, though this is done in the Dewar & Redwood process with inert gas. The fact is, however, that the Burton process is being successfully operated on a large scale and presumably with profit. In one of the Burton patents (1,105,961) it is claimed that 63½% of the original charge of oil is converted into gasoline.

The actual operation of the Burton process has been described as follows:

The stills have a capacity of 200-250 barrels each, and are heavy, horizontal steel cylinders, with walls one-half inch thick, thoroughly insulated with asbestos. From the top of the still are long run-backs, exposed to the air, which return for cracking any undecomposed oil. The stills, the run-backs and the condenser are all maintained under a pressure of about eighty-five pounds per square inch, the oil being heated to a temperature of about 750° F. Each still is charged every forty-eight hours, the yield being about 50% of 48-52° "pressure distillate." The carbon tends to be of a granular or mealy nature, rather than hard and adherent, and is cleaned out after each run.

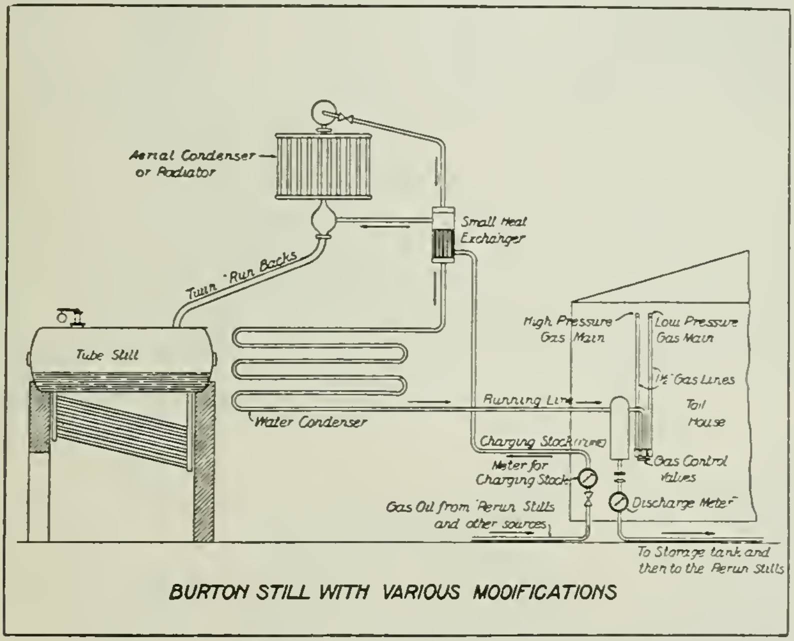


Fig. 29—Modified Burton Still Practice.

Important modifications of the Burton process are shown in the Clark patents, 1,119,496, 1,129,034, and 1,132,163; A. S. Hopkins, 1,199,464; R. E. Humphreys, 1,122,002, 1,122,033, and 1,119,700.

One of the Clark modifications allows the application of heat to tubes and seeks to overcome the danger of heating a large bulk of oil directly.

The Hopkins patent provides for introducing fresh oil supply into the run-back 7 with a heat exchanger effect.

One of the Humphreys patents provides for plates in the bottom of the still to prevent the bad effect of carbon and to give a large metallic heating area. One provides for starting stills under pressure.

The original Burton claims are as follows (Patent 1,049,667, filed July 3, 1912):

"1. The method of treating the liquid portions of the paraffin series of petroleum distillation having a boiling point upward of 500° F. to obtain therefrom low-boiling point products of the same series, which consists in distilling at a temperature of from about 650 to about 850° F. the volatile constituents of said liquid, conducting off and condensing said constituents and maintaining a pressure of from about 4 to about 5 atmospheres on said liquid of said vapors throughout their course to and while undergoing condensation.

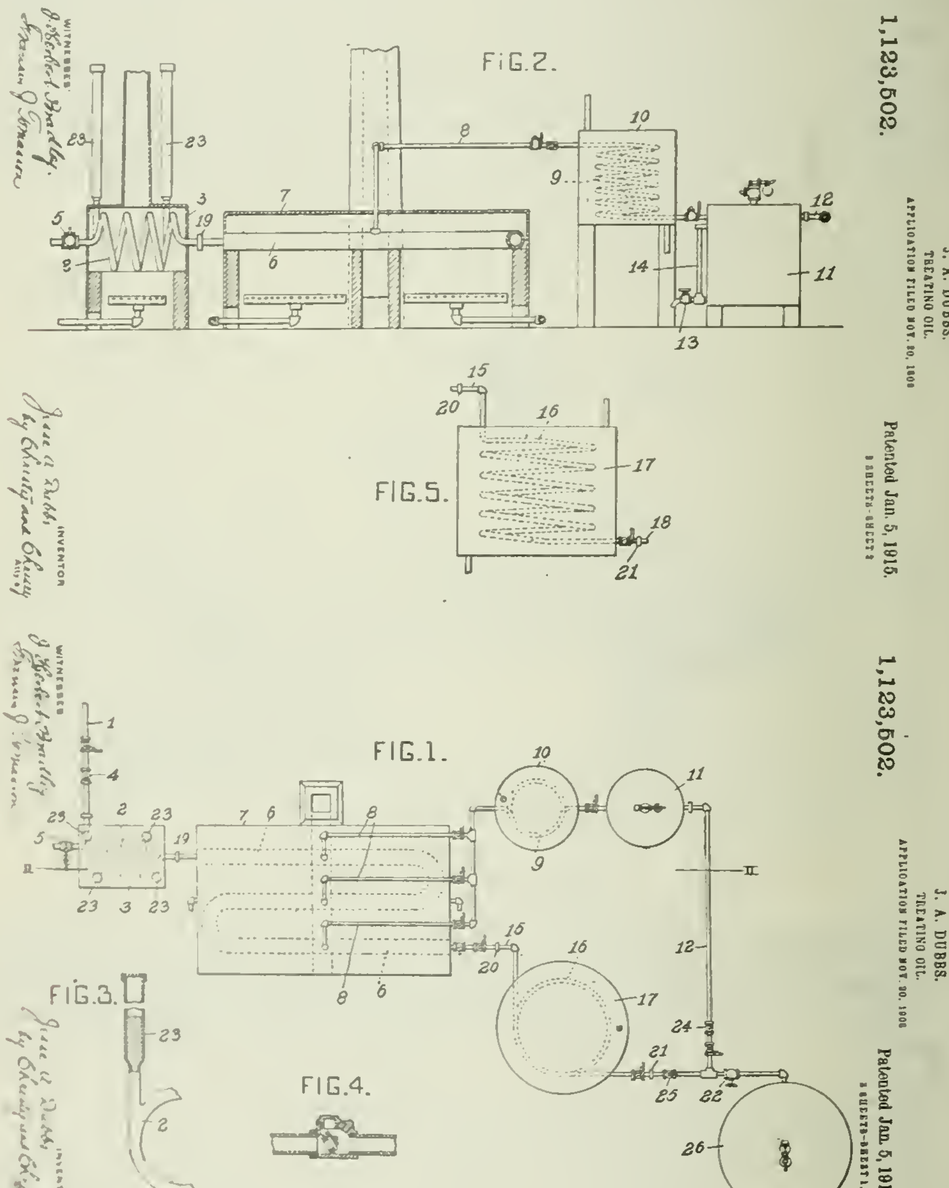


Fig. 30—Dubbs Process for Cracking.

THE DUBBS PATENT.

Jesse A. Dubbs, Patent No. 1,123,502, Patented Jan. 5, 1915. Application filed November 20, 1909.

The following are excerpts from the specifications and the claims of the Dubbs Patent which discloses a method of making gasoline.

This patent is claimed to be a prior invention to that of W. M. Burton:

"This invention relates to improvements in treating oil and refers more particularly to a process of subjecting the oil to heat and pressure.

"Among the salient objects of the invention are to provide an improved method of treating oil wherein both the vaporization and condensation take place under the pressure of the generated vapors; to provide a method which is particularly adapted for the removal of the finely divided particles of water from emulsified hydrocarbon oils; to provide a method which will permit of the oil being continuously subjected to the required heat and pressure in both the still and condenser without the interruption of its flow. . .

"As for example, in oil containing about 28% of water (which is the case of oil of the Santa Maria field of California), a pressure of about 25 pounds, and a temperature of 325° F., more or less, has given very good results, as regard the segregation of the water, although I have performed my operation under pressure ranging from three to two hundred and fifty pounds above atmospheric. . .

"Claim 9. The herein described process of treating hydrocarbon oil which consists in subjecting such oil in a receptacle to a temperature in excess of 300° F., permitting the volatilized products generated from the oil under treatment to pass freely to a condenser where they are condensed, and maintaining substantially the entire pressure exceeding ten pounds to the square inch in both the receptacle and condenser during the whole process solely by the vapors generated from the material under treatment."

ILLUSTRATIVE COMMERCIAL OPERATION OF DUBBS PROCESS.

(Furnished by Gustav Egloff of Universal Oil Products Co.)

A. On Fuel Oil.—Two typical runs on fuel oil were a 15.6 Baume Gravity Mexican Fuel resulting from the topping of a southern field Mexican crude oil and a fuel oil of 25 Baume Gravity from a mixture of Healdton, Peabody and Cushing crude oil were cracked in a coil, thirty-six continuous tubes, each twenty feet long 4-in. diameter and heated in a furnace. The liquid from the last tube passes into one end of a 30-in. expansion chamber, the vapors from which enter a dephlegmator, where they are partially condensed and the reflux returned to heating coil. The pressure distillate condensed passes on to a run-down tank from the receiver. The residuum from the expansion chamber is continuously drawn off during operation. The operating pressure of the Mexican Fuel Oil was 110 pounds and for the Mid-Continent Fuel Oil 135 pounds. It is noteworthy that in the illustrative runs the carbon produced on the Mid-Continent Fuel Oil was 2.77 tons while the Mexican Fuel Oil produced 5.86 tons of carbon, and that these amounts were successfully handled and were deposited outside of the heating zone where no damage to the apparatus was possible. The detailed data of the two illustrative runs follows:

	Mexican Fuel Oil	Mid-Continent Fuel Oil
Hours fire to steam	3	4½
Hours on stream	13	21
Pressure (pounds)	110	135
Total Charge (gallons)	21,054	30,213
Pressure Distillate	10,834	18,355
Percent Pressure Distillate	51.45	60.75
Residuum	7,906	10,348
Percent Residuum of Charge	37.55	34.25
Percent Gasoline (Navy Spec.)	26.23	26.3
Baume Gravity	58.4	59.6
	(Gallons Per Hour)	
Raw Oil	1,620	1,439
Pressure Distillate	833	874
Gasoline	425	379
Tons Carbon Produced	5.86	2.77
Percent by Weight Oil Cracked to Carbon	6.69	2.44
Raw Oil, per Day	452	486
Gasoline, per Day	118	128

B. On Gas Oil.—The Gas Oil runs were made in a cracking unit composed of forty-eight 4-in. diameter tubes 20-ft. lengths in coils of twelve each connected to a common header. The heated oil passed into a 16-in. diameter expansion chamber, from which the vapors traveled to the bottom of a dephlegmator, wherein they are fractionated and the reflux condensate returned to the cracking coils, while pressure distillate oil is collected in a receiver from which it passes on to a run-down tank. While pressure distillate oil is being collected, the residuum from the 16-in. expansion chamber is being drawn off and collected in a run-down tank. Four typical runs in the commercial unit are tabulated as follows:

MID-CONTINENT GAS OIL (35.3 BAUME GRAVITY).

Hours Fire to Stream	9	16	14¼	13¾
Hours on Stream	196½	336	263½	154¼
Pressure (Pounds)	135	135	135	135
Total Charge (Gallons)	87,031	139,684	123,550	105,352
Pressure Distillate	54,578	86,053	77,485	64,747
Percent Pressure Distillate	62 71	61.61	62.7	61.5
Residuum	30,664	54,566	46,345	42,398
Percent Residuum of Charge	35.23	39.06	37.5	40.2
Percent Gasoline (Navy Spec.)	33.16	26.23	28.9	26.2
Baume Gravity	58.5	58.3	58 0	58.0
	(Gallons Per Hour on Stream)			
Raw Oil	443	416	469	683
Pressure Distillate	278	256	294	420
Gasoline	147	119	136	179
Tons Carbon Produced	1.0	0.5	1.1	1.
Percent by Weight Oil Cracked (to Carbon)	0.4	0.16	0.3	0.21
Raw Oil, per Day	240	228	252 5	334
Gasoline, Bbls. per Day	79.4	58.8	73	87

THE CROSS PROCESS.

This process is a system of producing a synthetic crude oil. The patents thoroughly cover that type of process in which there is no material distillation and in which the reaction zone and the heating zone are separate and distinct. Distillation is avoided to prevent retardation of the cracking. The heating zone is free from carbon as the oil is discharged into the reaction zone before carbon can separate out.

A test run on 10,000 bbls. of 33° Be' gas oil was as follows:

Gas oil used	10,475 bbls.	= 100.00%
Gasoline	6,789 bbls.	= 64.8 %
Fuel oil residue	2,600 bbls.	= 24.8 %
Loss—gas and carbon	1,086 bbls.	= 10.4 %

Some important facts about the operation of the Cross process are as follows:

1. Heat is applied to the oil in tubes arranged in series. The tubes are placed horizontally in a heavily constructed, well insulated furnace in such manner that should a tube fail, the only damage is from loss of the tube as the small amount of oil discharged is burned and mostly goes up the chimney or is discharged into a tank.

2. The oil is pumped through the tubes in one direction only and no oil that has undergone reaction with the separation of carbon is returned to the tubes.

3. Decomposition does not take place in the tubes sufficiently to deposit an excessive amount of carbon.

4. The heated oil is passed from the tubes to a reaction chamber where conversion of the heavy oil into gasoline takes place and where the carbon is deposited.

5. No heat is applied to the reaction chamber but this chamber as well as all parts of the plant are heavily insulated against losses of heat to the atmosphere.

6. No distillation takes place from the reaction chamber or from any portion of the system as this would retard the conversion by reason of its cooling effect.

7. A small amount of oil is in the apparatus at one time.

8. About one-half barrel of oil is pumped through per minute. About 15 minutes is required for the reaction. Seven hundred barrels of oil are treated per day in one unit of the process.

9. The treated oil and the gas produced come out together, any gasoline in the vapor phase being absorbed back into the oil when cooled together, or distillation of the hot oil is carried out in the ordinary tower still without cooling and with very little additional firing.

10. Plant operation is very simple, requiring careful observation but little manipulation by the attendants.

11. No oil level devices are required. Pressure relief valves regulate the oil level at the point of discharge.

12. The treated oil or synthetic crude requires no more treatment than the pressure distillate and bottoms as made in the pressure distillate system of cracking.

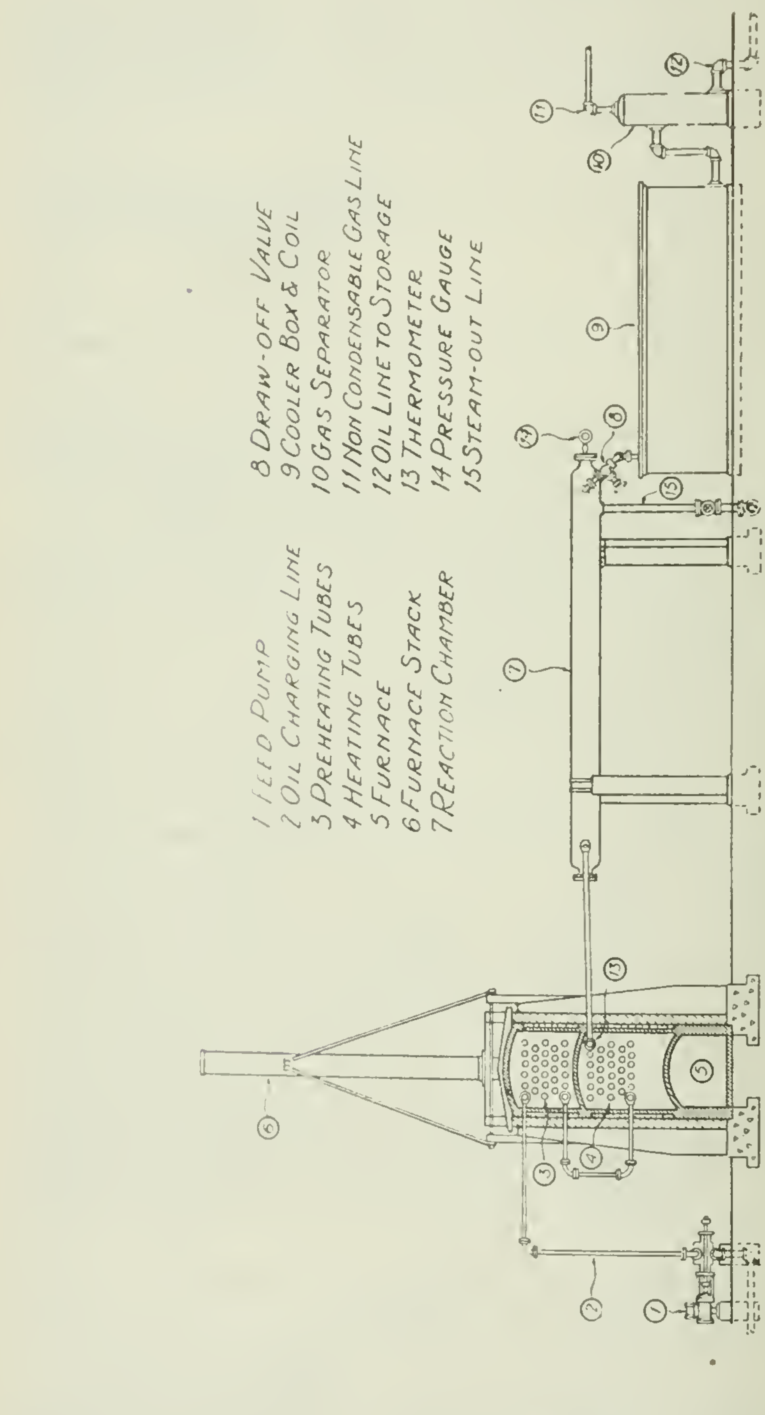


Fig. 32—Diagram of Cross Operating System.

13. The factors of safety on the steel stresses in the different parts of the plant are approximately 5:1.

14. The fittings on the end of the tubes are outside of the furnace and the openings of these tubes are quickly closed and opened without loss of time.

15. In the normal operation, the plant is kept on stream for 6 days and is cleaned on the 7th day. The complete cycle is 1 week with the treatment of about 4,500 barrels of oil.

16. One or more units of the Cross process may be added to any refinery merely as an adjunct without any change in ordinary refinery operation. With this process added, a greater still capacity is necessary for a given amount of crude oil or greater yields may be obtained with the same still capacity and with a smaller amount of crude oil available.

The scheme of operation is shown by the diagram in figure 32.

The steam pump (1) forces the charging stock against the pressure in the apparatus through line (2) passing it from above dawnward through the preheating tubes (3) in the upper part of the furnace. No decomposition or cracking takes place in these upper tubes since they merely serve as fuel economizers while the pressure in the apparatus is sufficient to maintain the oil in the liquid condition. The oil passes from these preheater tubes into the lower furnace tubes (4) starting in at the bottom. In this furnace, the main absorption of heat takes place. The oil temperature is registered as it issues from the heating tubes at the point (13). The temperature of the oil and the character of the oil under treatment govern the rate of pumping At the point (13) all of the heat has been applied to the tubes but the oil has not yet been converted as the time element is lacking It is therefore discharged into the reaction chamber (7) where it is held a sufficient length of time for an equilibrium to be reached between the vapor phase and the liquid phase. Ordinarily, this requires less than 15 minutes. The discharge line through the valve (8) is set at the liquid level and perfectly controls this level without any other automatic device than an ordinary relief valve. The oil is then discharged out through the cooling coil (9) line under a pressure of approximately 40 pounds and into the gas separator (10) from which the gas goes out through the line (11) and the oil is discharged through the line (12) to storage. This synthetic crude is run in the ordinary skimming plant in the usual manner.

A flow sheet for a complete gasoline plant in which all of the crude is made into gasoline and fuel oil is shown in figure 33. It is of course not advisable to run all of the residue into gasoline as a point is eventually reached at which the fuel oil becomes so heavy that the gasoline yields are relatively poor. The yields that can be obtained from various crudes may be calculated from the formulae on page 242.

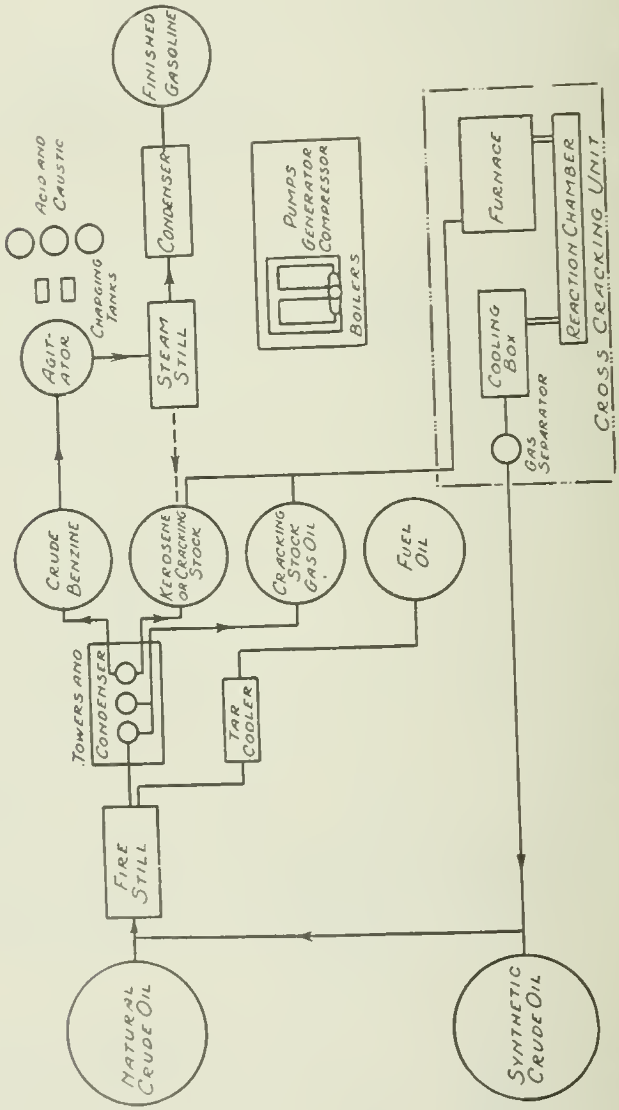


Fig. 33—Flow Sheet Showing Relation of Cracking Unit to Skimming Plant.

CROSS PROCESS PLANT No. 1 (Small Reaction Chamber).
Run No. 44, Jan. 21, 22, 23, 24, 25, 1922.

3,030 bbls. oil used.
2,909 bbls. cracked oil delivered.
727 bbls. gasoline produced.
91 bbls. fuel used.
⅛ bbl. fuel used per bbl. of gasoline produced.
96 hours on stream.
98 hours on fire.
31.5 bbls. cracked per hour.
.95 bbl. fuel per hour
915°F maximum oil temperature.
900°F average oil temperature.
1,375°F maximum furnace temperature.
765°F maximum stack temperature.
700°F average stack temperature.

RESULTS OF ONE UNIT CROSS PROCESS PLANT No 1 (Small Reaction Chamber) For Month of January, 1922.

CHARGES:	
15,427 bbls. gas oil used @ $1.575	$24 297.53
420 bbls. fuel used @ $1.575	661.50
Total payroll charge for month	1,363.79
Storeroom charges for month	55.78
Fixed charge, 31 days @ $32 00	992 00
Steam, air, etc., 31 days @ $20 00	620.00
Distilling and treating 14,852 bbls. @ $0.35	5,201.70
Total charge	$33,192.30
CREDITS:	
4,186 bbls. gasoline @ $6.09	$25,492.74
10,622 bbls. oil returned @ $1 47	15,614.34
Total credits	$41,108.08
Less charges	33,192.30
Estimated profit for month	$ 7,914.78

COMPARATIVE COSTS OF MAKING GASOLINE.

While there is much variation in the absolute cost of making gasoline by any process, the following outlines comparative costs of operation of one unit of three principal systems: No satisfactory information is available for vapor phase processes.

	Synthetic crude system	Pressure distillate system	Aluminum chloride system
Labor	$0 30	$0.90	$0 90
Materials	0.16	0.20	2.60
Fuel oil at $1.00 per bbl	0.10	0 40	0.40
Overhead	0 20	0.20	0.20
Fixed charges	0 25	0.75	0 60
Re-running	1.20	1.20	0.00
Gas oil equivalent to converted gasoline	1.25	1.25	1.25
Refining loss	0 20	0.20	0.20
Degrading of gas oil	0.06	0.06	0.60
License charges	0.20	0.20	0.20
Cost per bbl	$3.92	$5 36	$6.95

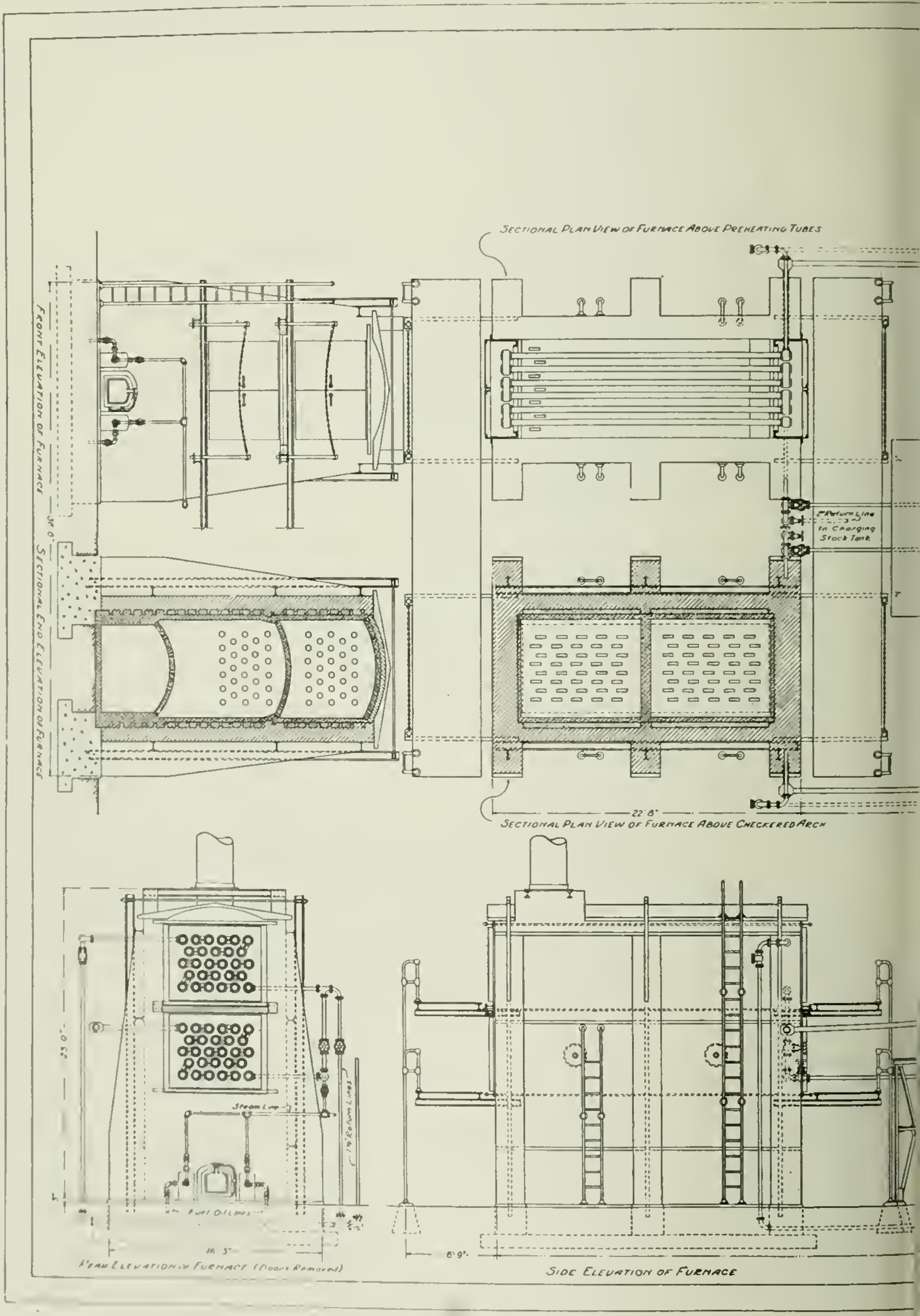


Fig. 34—Double Unit Cross Process Plant.

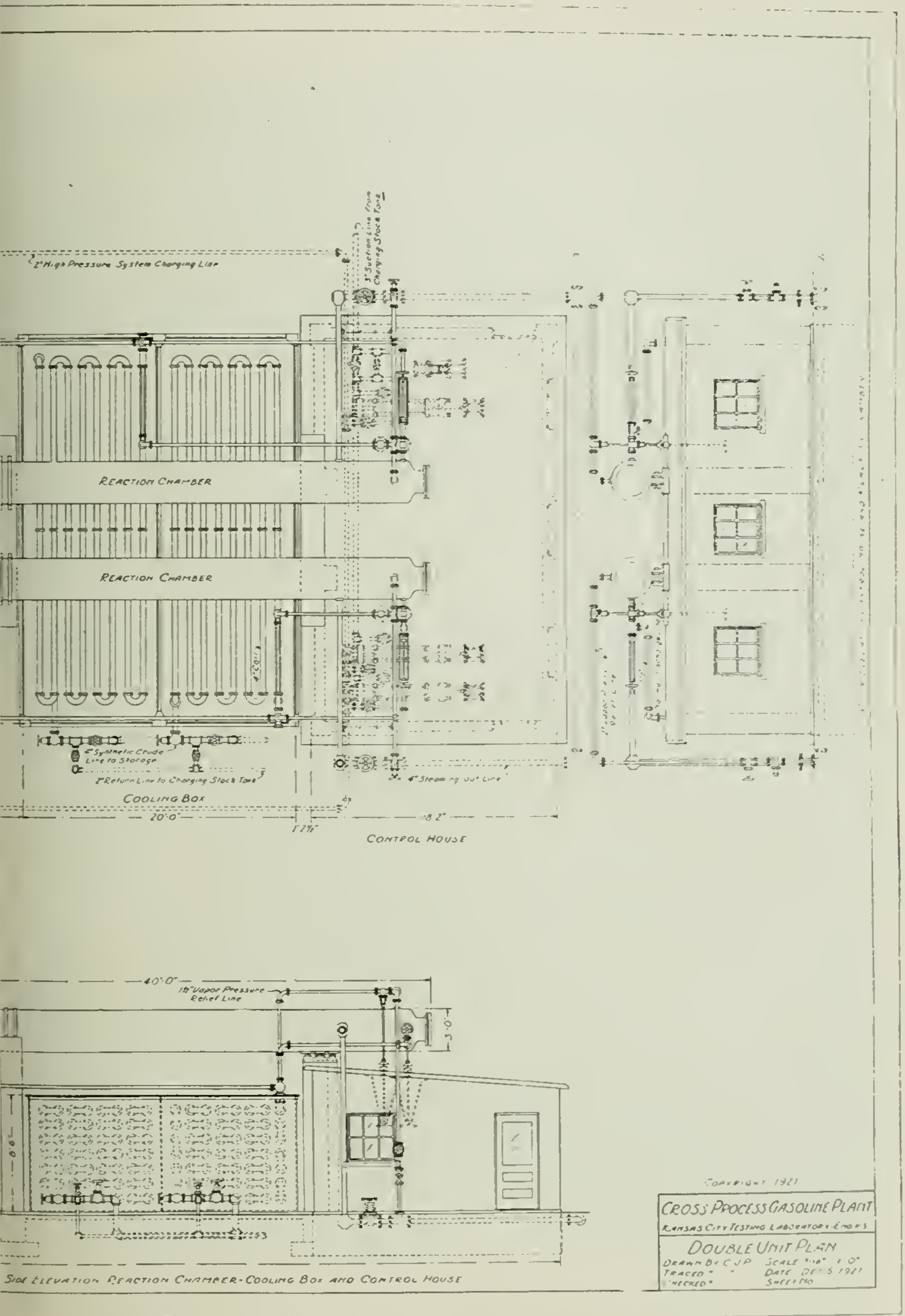


Fig. 34—Double Unit Cross Process Plant (continued).

Refinery Engineering Data on Distilling and Cracking of Petroleum.

The total capacity of a horizontal still is approximately 0.14 d^2l, d being the diameter and l the length of the still in feet.

The heating area of a horizontal still is 1.0472 d l on the assumption that one-third of the shell is fired. In continuous stills a larger area may be fired on account of a higher minimum oil level.

Continuous stills give a greater crude oil capacity than batch stills on account of the time required for charging and discharging batch stills. The amount of benzine or crude gasoline distilled is 1.5 d l barrel per day with continuous operation and with no other products distilled.

The approximate amount of gasoline from crude oil stills per day per square foot of still bottom area not including charging time or time for bringing to distillation temperature is 1.0 barrel. This may vary according to the intensity of firing and the character of the crude.

The approximate total fuel consumption in producing one gallon of 58° Be′ gasoline in a still by cracking at 85 pounds pressure is 50,000 B.T.U. or 0.4 gallon of fuel oil.

The total fuel consumption by cracking in tubes at 600 pounds pressure in producing one gallon of 58° Be′ gasoline is 26,000 B.T.U. or 0.20 gallon of fuel oil.

The report of the Western Petroleum Refiners' Association of September, 1919, on a pressure distillation process operating at 135 pounds per square inch pressure may be analyzed as follows:

0.164 gallons of 58° Be′ gasoline was produced per square foot of heating area per hour after the oil was brought to the cracking temperature.

0.8 gallon of fuel oil equivalent to 112,000 B.T.U. was required to produce 1 gallon of 58° Be′ gasoline.

200 cubic feet of gas was produced for each barrel of 58° Be′ gasoline.

7.0 pounds of still carbon was produced per barrel of 58° Be′ gasoline.

A typical composition of the so-called carbon deposited in cracking stills is as follows. This sample was extracted with 70° Be′ petroleum naphtha before testing:

Moisture (volatile at 105°C)	0.00%
Volatile (500°C)	13.08
Fixed carbon	80.42
Ash	6.50
	100.00%
Sulphur	1.83%
Iron	2.76%

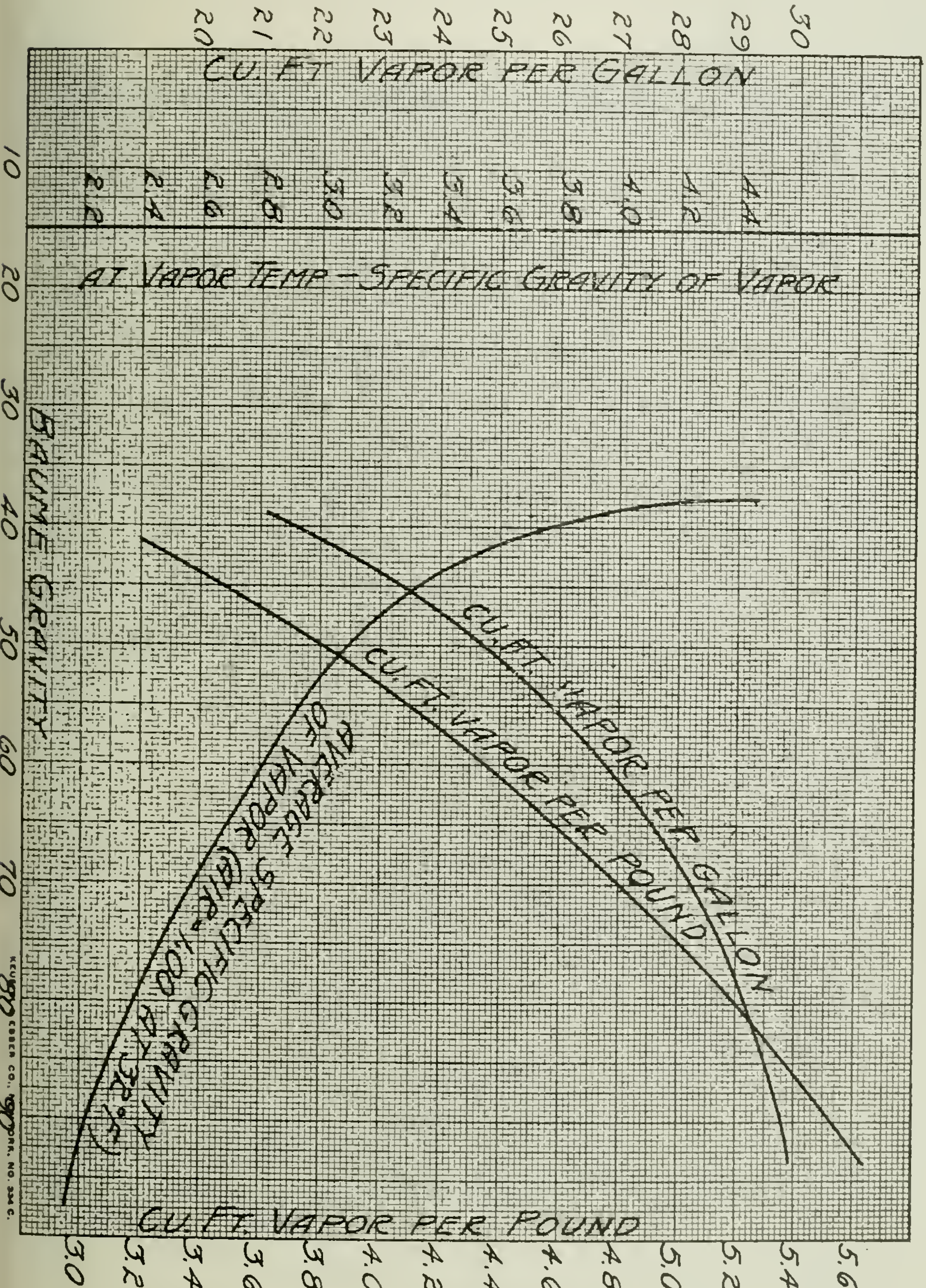


Fig. 35—Volume of Oil Vapors at Different Temperatures.

The following data represents the operation covering a long period of time of a very extensively used process for cracking oil, based on one still.

Gallons of oil charged	8,000
Gallons of oil run in	1,800
Gallons of oil treated	9,800
Average time feeding in oil	15 hours
Total hours distilled	37 hours
Pounds coal used to distill	11,000 lbs. per run
Total distillate produced	5,295 gallons
Total 58.5° gasoline produced	3,018 gallons
% distillate	54 04%
% 58.5° Be' gasoline in distillate	57.0 %
% 58.5° Be' gasoline of oil treated	30.8 %
Amount of distillate per hour of distilling	143.1 gallons
% distillate of total charge per hour of distillation	1.46%
Amount of 58.5° Be' gasoline per hour of distilling	81 6 gallons
% of 58.5° Be' gasoline per hour of distilling	0.83%
Area of still bottom	270 sq. ft.
Gallons of 58.5° Be' gasoline per hour per sq. ft. of heating area	0 302
Pounds of coal per gallon of gasoline (58.5° Be')	3.625 lbs.
Equivalent gallons of fuel oil per gallon of 58.5° Be' gasoline	0.25

CALCULATION OF HEAT EXCHANGES IN REFINERY CONDENSERS.

In calculating amount of water required for condenser, use the following formula:

$$w = \frac{200\ g}{t_2 - t_1}$$

w = gallons of water required per hour.
t_1 = incoming temperature of condensed water.
t_2 = outgoing temperature of condenser water.
g = gallons of gasoline to be condensed per hour.

Heat absorbed in condensing 1 gallon of gasoline to 60°F = 1,550 B.T.U.

Heat absorbed in condensing 1 gallon of kerosene to 60°F = 2,400 B.T.U.

Heat absorbed by oil in distilling off 50% from it as gasoline and kerosene is 2,100 B.T.U. per gallon of crude oil.

Heat absorbed by oil in distilling to coke is approximately 3,000 B.T.U. per gallon.

Amount of condenser surface required to properly condense one gallon of gasoline per hour = 2 sq. ft.; 1 gallon of kerosene per hour = 1 sq. ft. This is lessened with cold water and with larger quantities of water and varies with the length and cross section of the condenser tubes.

The cross section of the vapor line should be .05 sq. in. per gallon of gasoline per hour. The cross section of the condenser tubes may be reduced ½ after first ⅓ of length and ¼ more after second ⅓ of length.

The same water used for condensing the benzine or gasoline fraction in crude distillation may be used to condense the kerosene fraction.

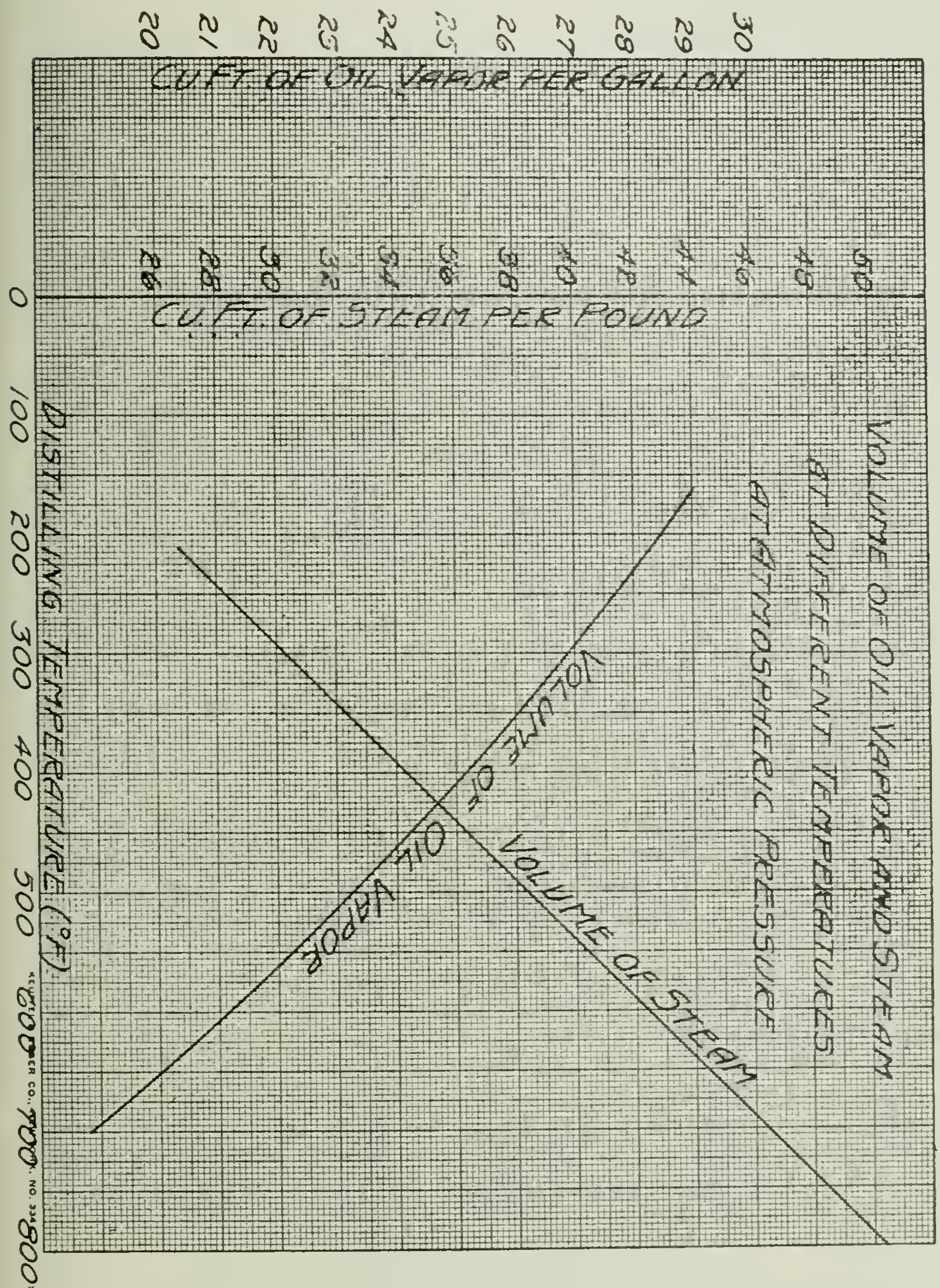


Fig. 36—Volume of Oil Vapors and Steam at Different Temperatures

Aluminum Chloride in the Production of Gasoline.

When the heavy fractions of petroleum distillates such as kerosene, gas oil, lubricating oils or paraffins are slowly heated with a small quantity of perfectly dry aluminum chloride, the salt dissolves, imparting a dark color to the solution. If this dark liquor is then submitted to slow fractional distillation at a temperature below that at which aluminum chloride volatilizes, a sweet water white, light distillate is obtained having all of the properties of high grade light gasoline that has been subjected to complete refining with sulphuric acid.

The first use of aluminum chloride for its "catalytic" action in hastening the synthesis or decomposition of hydrocarbons is set forth in the well known Friedel & Crafts reaction in a British patent of 1877. Aluminum chloride has long been known to have special action on various types of hydrocarbons in forming complex compounds of the hydrocarbons with the aluminum chloride. The heating of aluminum chloride with unsaturated hydrocarbons or olefins such as amylene leads to the formation of saturated hydrocarbons or paraffins of the series C_nH_{2n+2}. This series of hydrocarbons is the one which predominates in refined gasoline made from paraffin base petroleum. This is set forth in a paper by Engler & Routala in 1909 in which amylene gives yields of pentane, hexane, heptane, octane and decane by the action of aluminum chloride. These are the usual paraffin hydrocarbons in gasoline. The nature of artificial gasoline obtained by the use of aluminum chloride varies with the nature and origin of the petroleum products treated.

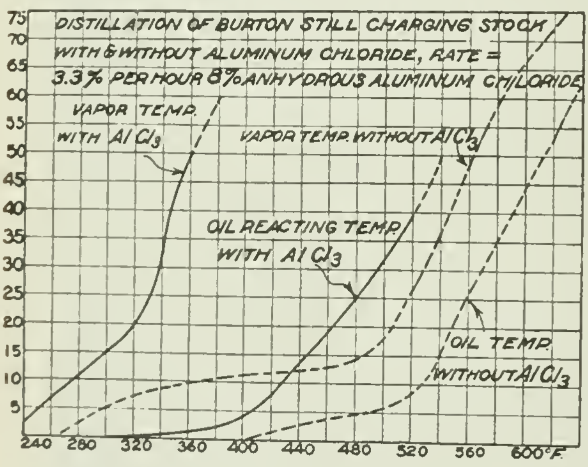


Fig. 37—Yields on Distillation of Heavy Oils in the Presence of Aluminum Chloride.

According to Pictet, kerosene oil of Galicia furnishes 50% and Russian oil, 40% of its weight in the form of light gasoline. The practical use of aluminum chloride as a means of refining petroleum and producing gasoline has been set forth by A. M. McAfee in U. S. Patent No. 1,127,465 of February 9, 1915. The character of the McAfee patent is set forth by the following claim:

CLAIM 14: "In the treating of petroleum oil, the process which comprises heating such oil with aluminum chloride for 36 to 48 hours while removing vapors of secondary gasoline, cooling and separating oil and aluminum chloride."

It has been the experience of the writer that the action of aluminum chloride at high pressures is not effective in producing gasoline at any faster rate or with any greater facility than with the use of high temperature and pressure alone. However, when the light gasoline is removed as rapidly as it is formed by distillation at atmospheric pressure or slightly above, the rate of formation of gasoline is infinitely increased over that obtainable in exactly the same condition without the use of aluminum chloride.

At very high pressures, heavy hydrocarbons may be converted into gasoline at a rate of 1% per minute or a 30% conversion in one-half hour.

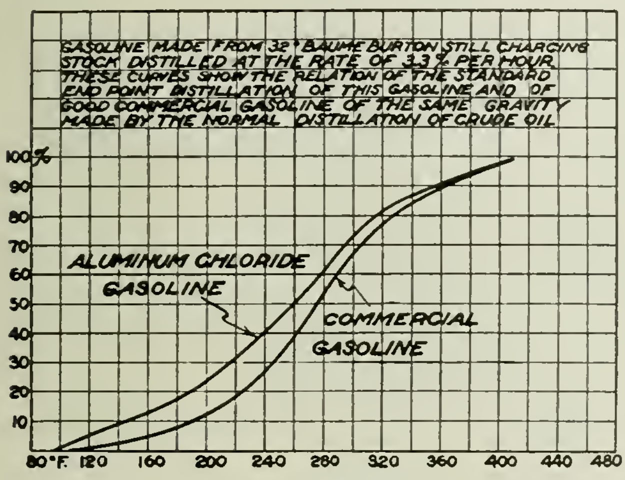


Fig. 38—Comparison of Distillation Curves of Aluminum Chloride Gasoline with Natural Gasoline.

In the experiments set forth herewith, it was assumed that 3.3% of gasoline produced per hour would be a practical rate for a large still. The amount of aluminum chloride considered necessary for attaining this rate is from 5% to 10% and in these tests 8% or 24 pounds per barrel of freshly prepared anhydrous aluminum chloride were used. The stock used for the test was the same as that used in charging the Burton pressure stills, being a mixed gas oil containing about 15% of olefins.

The following table shows the normal distillation of this gas oil without aluminum chloride and at the rate of 3.3% per hour.

Distillation of Burton Still charging stock at rate of 3.3% per hour without the use of aluminum chloride. Gravity of original charge = .864 = 32.3° Be′.

%	Time	Temp. ° F.	Gravity of Fraction	Gravity of Total Over	Oil Temp., ° F.
0	11:06	262	....	....	410
5	12:30	300	52.7° Be′	52.7° Be′	480
10	1:00	370	41.1	46.7	530
15	1:30	490	39.0	44.1	540
20	3:00	499	37.8	42.6	550
25	4:00 P.M.	508	36.2	41.3	560
30	9:07 A.M.	518	35.2	40.2	570
35	9:21	530	33.8	39.2	580
40	9:27	542	33.4	38.6	585
45	9:35	550	32.8	38.0	595
50	9:47	558	32.5	37.4	610
55	10:00	570	31.9	36.8	625
60	10:06	582	31.1	36.4	640
65	10:13	598	30.4	36.0	655
70	10:15	612	29.8	35.4	670
75	10:21	628	29.3	35.0	680
80	10:34	636	28.2	34.6	690

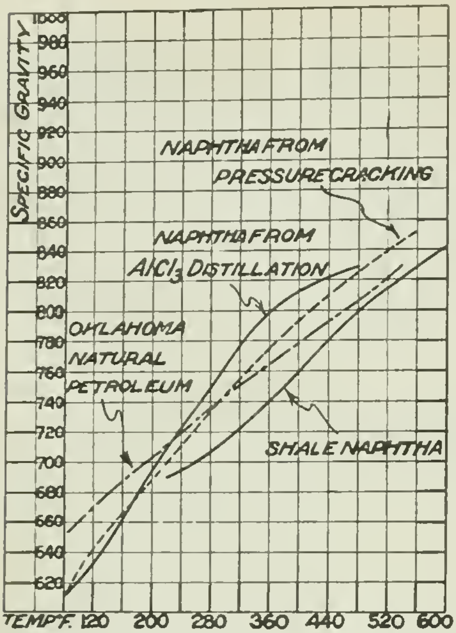


Fig. 39—Comparison of Gravity of Fractions of Aluminum Chloride Gasoline and Gasoline from Other Sources.

The next table shows the distillation of the same oil with the 8% of aluminum chloride. In the distillation with aluminum chloride, the rate of 3.3% per hour was fairly closely adhered to until such a temperature was obtained in the oil at which the aluminum chloride began to volatilize. To prevent this, a temperature was maintained from this point on, such that the aluminum chloride would not volatilize. At approximately 60%, it was not possible to get further gasoline distillate without carrying over tarry matter or aluminum chloride compounds. 30% of 58.2° Be' gasoline, water white and free from olefins was obtained and 60% of 55° Be' water white naphtha was obtained.

Distillation of Burton Still Charging Stock at rate of 3.3% per hour with the use of 8% of aluminum chloride. Gravity of original charge = .864 = 32.3° Be'.

%	Temp. °F.	Gravity of Fraction	Gravity of Total Over	Color	Total Time	Interval
	70	Start		Water		
0	220	Initial B.P.	....	White	0	
5	250	69.1° Be'	69.1° Be'	White	15′	15′
10	274	62.0	65.4	White	105′	90′
15	300	57.9	62.9	White	200′	95′
20	320	54.7	60.9	White	290′	90′
25	330	54.5	59.5	White	375′	85′
30	335	52.3	58.2	White	455′	80′
35	340	52.5	57.4	White	540′	85′
40	345	52.0	56.9	White	680′	140′
45	350	50.9	56.2	White	800′	120′
50	360	52.1	55.2	White	920′	120′
55	366	53.5	55.1	White	1105′	185′
60	380	50.0	55.0	White	1410′	305′
				White	1795′	385′

Distillation was carried on at rate of 3.3% per hour as long as possible. Distillation was then continued at the fastest possible rate that would allow cracking without volatilizing the aluminum chloride.

In Fig. 37 is a graph showing the vapor and oil temperature at different stages of the distillation with and without the use of aluminum chloride.

Fig. 38 shows the quality of the gasoline made by the use of aluminum chloride compared with the quality of normal gasoline of the same end point.

Fig. 39 shows the relation of the specific gravity of various naphthas or gasoline compared with the naphtha or gasoline produced with the use of aluminum chloride. It is to be noted in these curves that the lower specific gravity and lower boiling point fractions are much the same as the corresponding paraffin hydrocarbons from other sources but that at specific gravity of about 800 the product by use of aluminum chloride is more strictly of a paraffin nature.

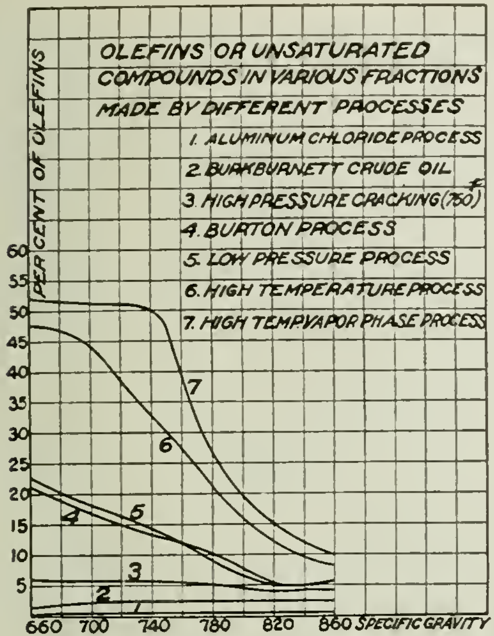


Fig. 40—Olefins in Aluminum Chloride Gasoline.

Fig. 40 sets forth the olefin content of gasoline made by different processes for treating heavier petroleum hydrocarbons.

Curve No. 1 is that using aluminum chloride which is essentially free from olefins.

Curve No. 2 shows the olefin content of Burkburnett crude oil.

Curve No. 3 shows the olefin content of gasoline produced by very high pressure cracking.

Curves No. 4 and No. 5 shows the olefin content of gasoline made by cracking at 80 to 100 pounds.

Curves No. 6 and No. 7 show the olefin content of gasoline produced by cracking at high temperature, such as vapor phase processes.

Important Literature on the Subject.

Friedel & Crafts—Aluminum chloride for chemical reactions. British Patent No. 4,769—1877.

C. Engler & O. Routala—The action of aluminum chloride on amylene. Ber. 42—pages 4,613-20—1909.

Wm. Steinkopf & Michael Freund—The formation of naphthenes and paraffins from olefins by synthesis of the latter with aluminum chloride—Ber. 47—pages 411-20—1914.

A. M. McAfee—Aluminum Chloride in the production of gasoline and its recovery. U. S. Patents Nos. 1,099,096, 1914; 1,127,465, 1915; 1,144,304, 1915; 1,202,081, 1916; 1,277,092, 1918; 1, 277, 328-9, 1918.

Pictet & Lerczynska—The action of aluminum chloride on petroleum. Bull. Soc. Chim. No. 19, pages 326-34—1914.

A. M. McAfee—Improvements of high boiling petroleum oil and manufacturing of gasoline by the action of aluminum chloride. Journal of Industrial & Engineering Chemistry, Sept., 1915.

W. E. Henderson & W. C. Gangloff—Action of anhydrous aluminum chloride upon unsaturated compounds. Journal of American Chemical Society No. 38, pages 1,382-4—1916. Journal of. Am. Chem. Soc. No. 39, pages 1,420-7—1917.

A. M. McAfee—Manufacture of gasoline. Metallurgical & Chemical Engineering No. 13, pages 592-7—1915.

G. W. Gray—Manufacture of gasoline by the use of aluminum chloride. U. S. Patents No. 1,193,540-1—1916.

Alexander and Taber—Producing low boiling hydrocarbons by heating vapors with $Al Cl_3$, $Fe Cl_3$, or $Zn Cl_2$—U. S. Patent, 1,381,098—June 14, 1921.

Danckwardt—Pat. No. 1,373,653—Apr. 5, 1921.

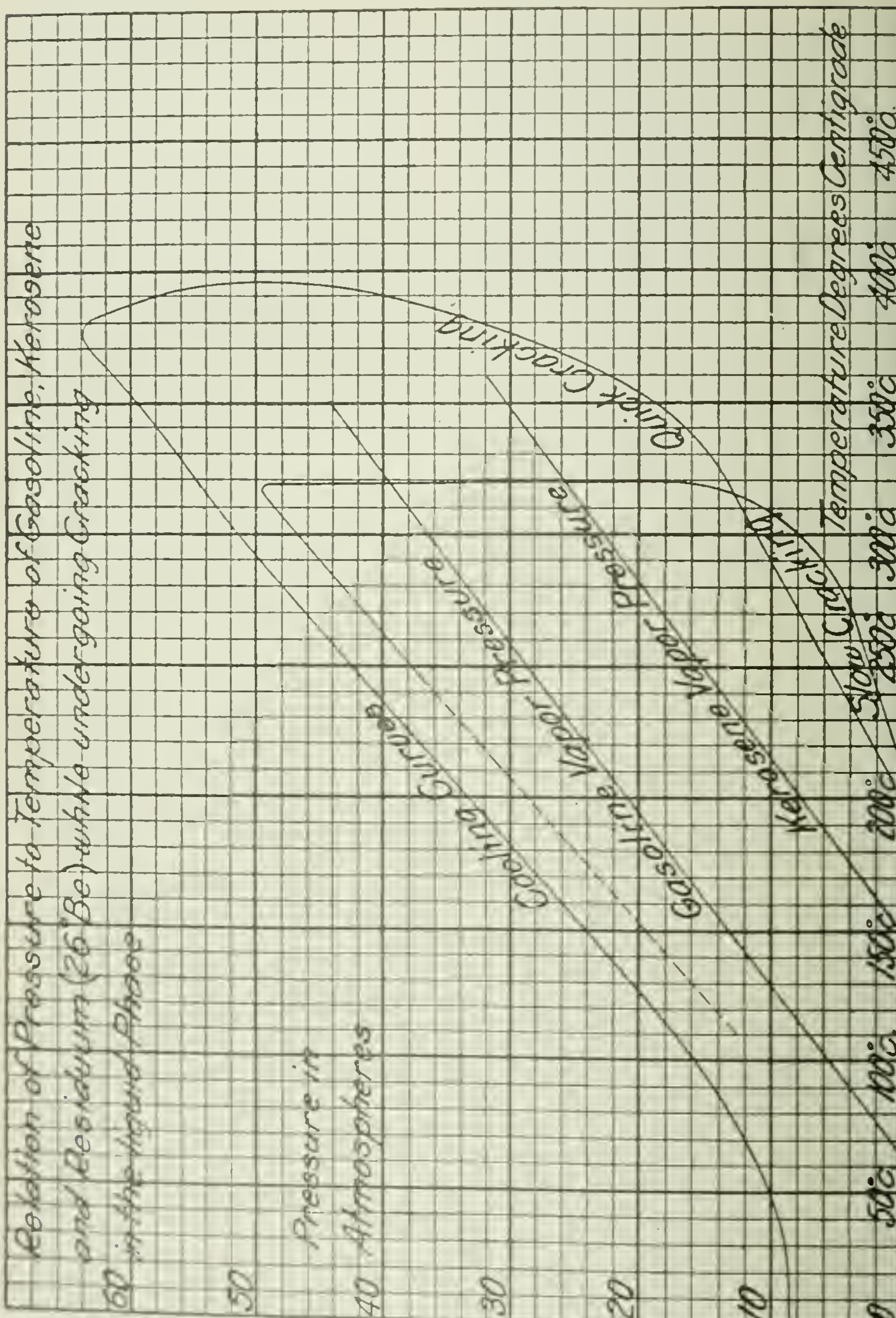


Fig. 11—Vapor Pressure of Heavy Oils and Gasoline Under Cracking Temperatures.

Equilibrium Cracking Tests on Different Heavy Petroleum Hydrocarbons.

Oil used	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
Specific gravity	0.912	0.935	0.868	0.820	0.953	0.946	0.889	0.820	0.886	0.994
Baume gravity	23.5	19.7	31.3	40.8	16.9	18.0	27.5	40.8	31.6	10.8
Amount, cc	500	500	500	500	500	500	500	500	500	500
Viscosity at 70° F	810	3360	183	Solid	5400	1038	272	34	66	14500
Max. Pressure, Atmos	59	60	58	58	56	58.5	59.5	59.5	61	50
Maximum Temperature, °C	417	420	420	420	390	412	415	420	414	410
Pressure @ 400° C., Atms	54	55	56	54.5	55	54.5	54.5	53.0	55.0	45.0
Pressure after cooling	10	10	9.5	6.0	11.5	11.5	9.5	6.0	9.0	12.5
Gas, % by weight	7	7	6.8	4.5	8.0	8.0	6.8	5.0	6.3	8.5
Oil recovered, cc	465	460	495	493	440	442	470	482	470	350
Specific gravity	0.862	0.862	0.824	0.775	0.917	0.887	0.861	0.803	0.842	0.898
Baume gravity	32.4	32.4	39.9	50.6	22.6	27.8	32.6	44.3	36.2	25.9
Viscosity @ 70° F	47	47	38	38	100	47	42	34	37	110
% Volume	93.0	92.0	99.0	98.6	88.0	88.4	94.0	96.4	94.0	70.0
% Shrinkage	7.0	8.0	1.0	1.4	12.0	11.6	6.0	3.6	6.0	30.0
Gasoline (E.P. 410° F.)	127 cc.	139.5	147	180.7	135.5	118	157	199	173	109
% Volume	25.4	27.9	29.4	36.1	27.1	23.6	31.4	39.8	34.6	21.8
Specific gravity	0.743	0.746	0.745	0.724	0.753	0.753	0.754	0.767	0.748	0.746
Baume gravity	58.4	57.6	57.9	63.3	55.9	55.9	55.6	52.5	57.1	57.6
Residuum, % Volume	67.6	64.1	69.6	62.5	60.9	64.8	68.6	56.6	59.4	48.2
Specific gravity	0.926	0.926	0.886	0.820	0.962	0.944	0.911	0.845	0.925	0.982
Baume gravity	21.2	21.2	28.0	40.8	15.5	18.3	23.6	35.6	21.3	12.6
Viscosity @ 70° F	135	178	70	104	414	218	88	38	86	530

No. 1 = Mid-Continent fuel oil average of 48 cars on Kansas City market.
No. 2 = Heavy Kansas crude oil from Allen County.
No. 3 = Garber residuum from Enid, Okla.
No. 4 = Paraffin wax.
No. 5 = California crude oil.
No. 6 = California heat treated and skimmed.
No. 7 = Healdton crude.
No. 8 = Mid-Continent kerosene.
No. 9 = Mid-Continent gas oil.
No. 10 = Mexican flux oil (natural).

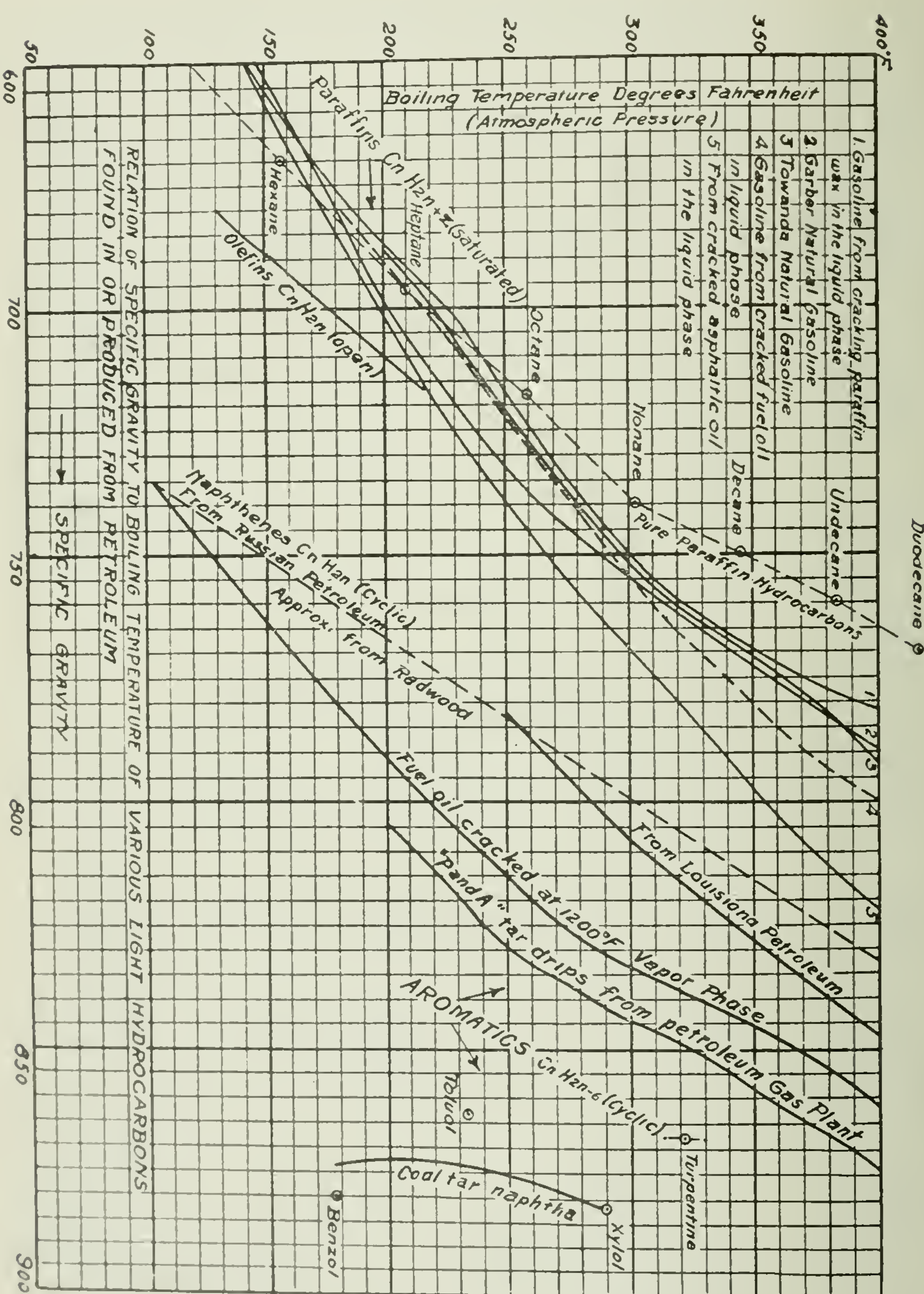


Fig. 12—Properties of Various Types of Synthetic Gasoline.

Effect of Varying Pressure on the Products of Cracking.

KEROSENE.

Using kerosene of specific gravity 0 8155 in vessel with relation of vapor space to oil of 2 to 1.

Pressure, atmospheres	30	40	55	75	90
% distillate to 410°F	28.0	32.5	38 0	43.7	45 9
Shrinkage, volume %	0.0	0.4	2.4	5.0	7.0
Specific gravity of cracked oil	.810	.808	.807	.806	.805
Specific gravity of residue	.828	.833	.845	.871	.888
Cold pressure, atmospheres	2.5	4.0	6 5	10.0	11.8

FUEL OIL.

Fuel oil with specific gravity of 0.908 in vessel with relation of vapor space to oil of 2 to 1.

Pressure, atmospheres	30	40	55	75	90
% distillate to 410°F	14.3	22.3	25.4	32 5	38.7
Shrinkage, volume %	3 0	3.3	9.0	12.0	14.0
Specific gravity of cracked oil	.879	.869	.862	.837	.818
Specific gravity of residue	.914	.918	.926	.930	.932
Cold pressure, atmospheres	5	6	10	13	15.5

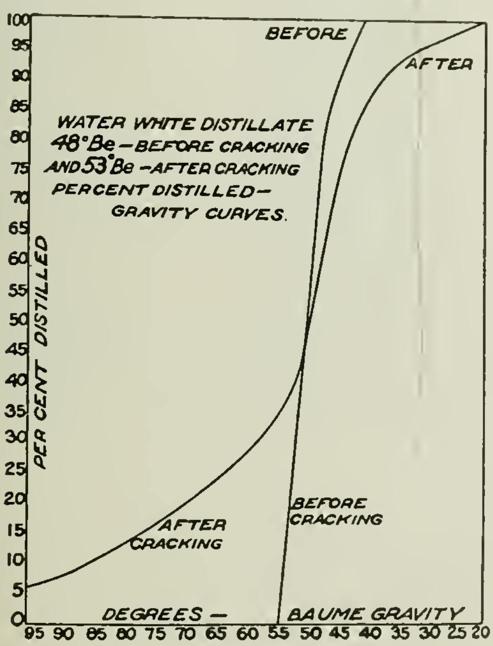


Fig. 43—Relation of Gravity to Percent Distilled of Water White Distillate Before and After Cracking.

Properties of Water White Kerosene Distillate Before and After Cracking.

	Distilling Temperature		Gravity of Stream	
%	Before Cracking	After Cracking	Before Cracking	After Cracking
0	294° F.	Room	....	....
2.5	355	Room	....	....
5.0	363	80° F.	.766=53.2° Be′	.614=98.9° Be′
7.5	366	105	.767=52.9° Be′	.634=91.7° Be′
10.0	367	130	.768=52.7° Be′	.654=84.8° Be′
12.5	370	158	.769=52.5° Be′	.6 7=80.6° Be′
15.0	379	188	.770=52.2° Be′	.680=76.6° Be′
17.5	381	218	.771=52.0° Be′	.695=72.1° Be′
20.0	382	237	.772=51.8° Be′	.710=67.8° Be′
22.5	384	256	.773=51.5° Be′	.720=65.0° Be′
25.0	391	269	.774=51 3° Be′	.730=63.3° Be′
27.5	395	282	.774=51.3° Be′	.739=59.9° Be′
30.0	399	296	.775=51.0° Be′	.749=57.4° Be′
32.5	402	310	.776=50.8° Be′	.756=55.6° Be′
35.0	406	319	.777=50.6° Be′	.764=53.7° Be′
37.5	408	328	.777=50.6° Be′	.769=52.5° Be′
40.0	410	340	.778=50.3° Be′	.775=51 0° Be′
42.5	414	352	.779=50.1° Be′	.777=50.6° Be′
45.0	417	359	.780=49.9° Be′	.780=49.9° Be′
47.5	420	366	.780=49.9° Be′	.782=49.4° Be′
50.0	423	371	.781=49.6° Be′	.785=48.7° Be′
52.5	425	376	.782=49.4° Be′	.787=48.3° Be′
55.0	431	386	.783=49.2° Be′	.790=47.6° Be′
57.5	433	396	.784=48.9° Be′	.792=47.1° Be′
60.0	437	405	.785=48.7° Be′	.793=46.9° Be′
62.5	440	414	.786=48.5° Be′	.795=46.4° Be′
65.0	444	418	.787=48.3° Be′	.798=45.8 Be′
67.5	448	422	.788=48.0° Be′	.798=45.8° Be′
70.0	453	429	.789=47.8° Be′	.800=45.4° Be′
72.5	457	436	.790=47.6° Be′	.802=44.9° Be′
75.0	462	443	.792=47.1° Be′	.805=44.2° Be′
77.5	468	450	.793=46.9° Be′	.808=43.6° Be′
80.0	473	459	.794=46.7° Be′	.812=42.7° Be′
82.5	479	468	.795=46.4° Be′	.817=41.7° Be′
85.0	485	484	.797=46.0° Be′	.823=40.4° Be′
87.5	493	500	.800=45.3° Be′	.830=38.9° Be′
90.0	506	523	.803=44.7° Be′	.837=37.5° Be′
92.5	516	547	.807=43.8° Be′	.851=34.7° Be′
95.0	533	600	.812=42.7° Be′	.866=31.9° Be′
97.5	560	648	....	.936=19.6° Be′
100.0	608	700	....	....
Gravity of sample			.7845=48.9° Be′	.766=53.2° Be′

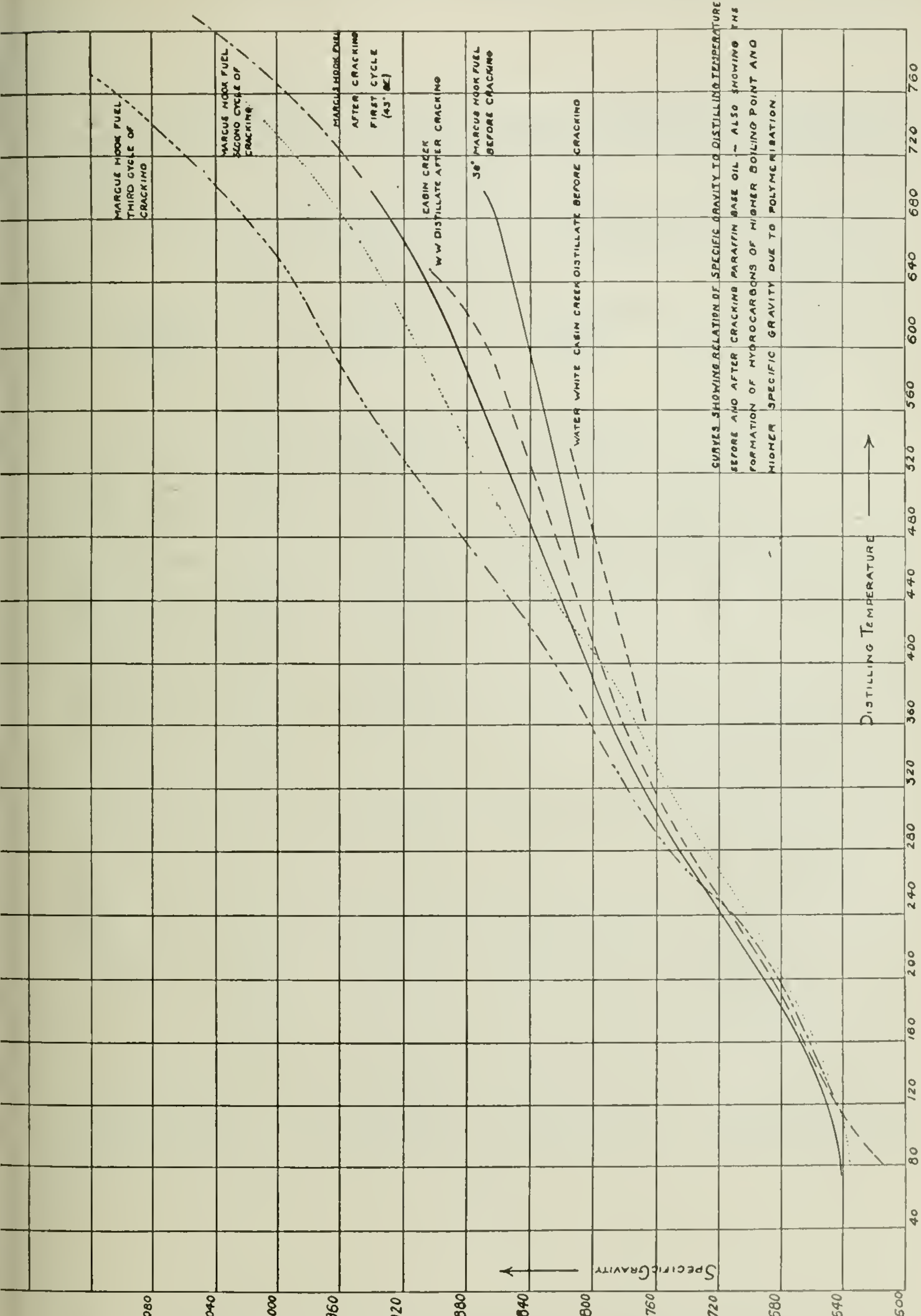


Fig. 44—Relation Between Gravity and Distilling Temperature of Paraffin Base Oils Before and After Cracking.

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF COAL TAR BENZOL.

Laboratory Number, 44118; Specific Gravity, 0.880; °Be′ U. S., 29.0°; Cold Test, 40°G.

%	Time	Temp. °F.	Gravity of Fraction	Gravity of Total Over	Gravity of Stream
	3:25				
0	3:31	173			
		178			
5	3:37	179	0.882=28.9° Be′	0.882=28.9° Be′	0.881=29.1° Be′
		180			
10	3:42	180	0.881=29.1° Be′	0.881=29.1° Be′	0.882=28.9° Be′
		180			
15	3:47	180	0.883=28.7° Be′	0.882=28.9° Be′	0.882=28.9° Be′
		180			
20	3:51	180	0.882=28.9° Be′	0.882=28.9° Be′	0.882=28.9° Be′
		180			
25	3:56	180	0.882=28.9° Be′	0.882=28.9° Be′	0.882=28.9° Be′
		180			
30	4:00	181	0.882=28.9° Be′	0.882=28.9° Be′	0.882=28.9° Be′
		181			
35	4:05	182	0.882=28.9° Be′	0.882=28.9° Be′	0.881=29.1° Be′
		182			
40	4:10	182	0.881=29.1° Be′	0.881=29.1° Be′	0.881=29.1° Be′
		182			
45	4:15	182	0.881=29.1° Be′	0.881=29.1° Be′	0.881=29.1° Be′
		182			
50	4:19	182	0.881=29.1° Be′	0.881=29.1° Be′	0.880=29.3° Be′
		183			
55	4:23	183	0.880=29.3° Be′	0.881=29.1° Be′	0.880=29.3° Be′
		183			
60	4:28	184	0.880=29.3° Be′	0.881=29.1° Be′	0.880=29.3° Be′
		184			
65	4:33	184	0.880=29.3° Be′	0.881=29.1° Be′	0.880=29.3° Be′
		185			
70	4:38	186	0.880=29.3° Be′	0.881=29.1° Be′	0.880=29.3° Be′
		186			
75	4:43	187	0.880=29.3° Be′	0.881=29.1° Be′	0.880=29.3° Be′
		188			
80	4:48	189	0.880=29.3° Be′	0.881=29.1° Be′	0.879=29.4° Be′
		190			
85	4:53	192	0.879=29.4° Be′	0.880=29.3° Be′	0.879=29.4° Be′
		196			
90	4:57	199	0.879=29.4° Be′	0.880=29.3° Be′	0.877=29.8° Be′
		205			
95	5:01	216	0.876=30.0° Be′	0.888=29.3° Be′	0.876=30.0° Be′
100	5:10	225	0.876=30.0° Be′	0.880=29.3° Be′	0.876=30.0° Be′

FRACTIONAL GRAVITY DISTILLATION ANALYSIS

of Benton Process Gasoline; Specific Gravity, 0.758; °Be' U. S., 54.7 °Be' Tag, 55.1°; Olefins, 16.0%.

%	Time	Temp. ° F.	Gravity of Fraction	Gravity of Total Over	Gravity of Stream
	10:09				
0	10:14	85			
		155			
5	10:22	164	0.694=72.4° Be'	0.694=72.4° Be'	0.694=72.4° Be'
		171			
10	10:28	176	0.695=72.1° Be'	0.694=72.4° Be'	0.689=71.2° Be'
		184			
15	10:35	188	0.701=70.3° Be'	0.696=71.8° Be'	0.705=69.2° Be'
		193			
20	10:42	199	0.710=67.8° Be'	0.700=70.6° Be'	0.714=66.6° Be'
		206			
25	10:48	211	0.718=65.5° Be'	0.704=69.5° Be'	0.722=64.4° Be'
		216			
30	10:54	222	0.727=63.1° Be'	0.707=68.6° Be'	0.731=62.0° Be'
		228			
35	10:58	234	0.735=61.0° Be'	0.711=67.5° Be'	0.738=60.2° Be'
		238			
40	11:03	244	0.742=59.2° Be'	0.715=66.4° Be'	0.745=58.4° Be'
		248			
45	11:09	254	0.748=57.6° Be'	0.719=65.3° Be'	0.751=56.9° Be'
		258			
50	11:14	264	0.755=55.9° Be'	0.722=64.4° Be'	0.758=55.1° Be'
		270			
55	11:19	278	0.761=54.4° Be'	0.729=62.6° Be'	0.770=52.2° Be'
		283			
60	11:25	290	0.767=52.9° Be'	0.729=62.6° Be'	0.770=52.2° Be'
		297			
65	11:29	306	0.773=51.5° Be'	0.732=61.8° Be'	0.776=50.8° Be'
		312			
70	11:34	320	0.779=50.1° Be'	0.736=60.7° Be'	0.781=49.6° Be'
		328			
75	11:41	336	0.784=48.9° Be'	0.739=59.9° Be'	0.788=48.0° Be'
		348			
80	11:46	362	0.793=46.9° Be'	0.742=59.2° Be'	0.797=46.0° Be'
		371			
85	11:53	388	0.801=45.1° Be'	0.746=58.1° Be'	0.808=43.6° Be'
		406			
90	11:59	428	0.815=42.1° Be'	0.749=57.4° Be'	0.823=40.4° Be'
		460			
95	12:05	492	0.832=38.5° Be'	0.754=56.1° Be'	....

Remarks: 36 cc. residuum; loss, ½%.

Formulae for Calculating the Cost of Manufacture of Natural and Synthetic Gasoline.

Key to Symbols.

Be′ = gravity of crude oil in degrees Baume′.
n = per cent of natural gasoline of 58 gravity in the crude.
c = value of crude oil at refinery in dollars per bbl.
f = value of fuel oil at refinery in dollars per bbl.
s = value of gas oil at refinery in dollars per bbl.
a = per cent of artificial or synthetic gasoline in crude.

(1) % artificial gasoline obtainable by commercial cracking:

$$a = \frac{[100 - n]\ [25 + 1.45\ (Be - 10 - .3n)]}{100}$$

Total gasoline = n + a

(2) Cost of gasoline per gallon when made by skimming only =

$$\frac{c + 35 - f\ (.95 - .01\ n)}{.42\ n}$$

(3) Cost of gasoline per gallon when made by cracking and skimming =

$$\frac{c + .40 + a\ (.0202 + .015\ f) - f\ (.95 - .01\ n)}{.42\ (a + n)}$$

(4) Cost of gasoline per gallon when made by cracking gas oil =

$$\frac{\$2.02 + 1.41\ s - .05\ f}{42}$$

ILLUSTRATION OF ABOVE FORMULAE.

(1) Total gasoline from crude oils.

	Gravity	Natural	Artificial	Total
Mexia, Texas crude	37°Be′	5	68	73
Burkburnett, Texas	40	40	37	77
Ranger, Texas	38	25	49	74
Mexico, Panuco	12	5	34	39
Tuxpan, Mexico	17.5	15	32	47

(2) Cost of gasoline by skimming only—

c = \$2.00 per bbl.
n = 25% Be′ = 37
f = \$1.00 per bbl.

$$\frac{2.35 - (.95 - .25)}{.42)\ (25)} = 15.7c \text{ per gallon}$$

(3) Cost of gasoline by skimming and cracking—using values given above.

$$\frac{2.00 + .40 + 47.4\ (.0202 + .015) - (.95 - .25)}{.42\ (47.4 + 25.0)} = 11c \text{ per gallon}$$

(4) Cost of gasoline made from gas oil.

With s = \$1.25 and f = \$1.00

Cost of cracked gasoline.

$$\frac{\$2\ 02 + 1.75 - .05}{42} = 8\ 9c \text{ per gallon}$$

Costs of Refining Petroleum.

(By Benner in "Petroleum," May, 1920)

COST

(Figured on Daily Basis)

2,000 barrels crude per day @ $3.75 per barrel	$7,500.00
Pipe line charges, 30c per barrel	600.00
Salaries and labor	250.00
Fuel, power and water	200.00
Taxes and insurance	30.00
Incidentals	50 00
Plant depreciation	50.00
	$8,680.00

OUTPUT

(Figured on Daily Basis Burkburnett Crude)

Gasoline, 34 per cent, 28,560 gals. @ 21c per gal. (wholesale)	$ 5,997.60
Kerosene, 12 per cent, 10,080 gals. @ 14c per gal. (wholesale)	1,411.20
Fuel oil, 50 per cent, 1,000 bbls. @ $2.60 per bbl. (wholesale)	2,600.00
	$10,008.80
Loss, 4 per cent.	
Daily profit	1,328.80
Yearly profit	478,440 00

Profits from Petroleum Refining.

(By F. W. Freeborn in Oil & Gas Journal, 1920)

Profits of Skimming Plant (1916)
Based on Market Price Aug., 1916, and Charging 2,500 Bbls. of Crude Oil Per 24-Hour Day.

YIELD PER DAY.

Gasoline	30%	31,500 gal.	@ $0.18½	$5,827.50
Kerosene W. W.	6%	6,300 gal.	@ .08	504.00
Kerosene P. W.	9%	9,450 gal.	@ .06	567.00
Gas oil	5%	5,250 gal.	@ .04½	236.25
Fuel oil	48%	50,400 gal.	@ .04½	2,268.00
Loss	2%	2,100 gal.		0.00
	100%	105,000 gal.		
Total sales per day				$9,402.75

COST PER DAY.

Crude oil run 2,500 bbls. @ $2.05	$5,125.00	
Fuel oil to burners & stills, 397 bbls. @ $1.89	750.33	
Electric light & power for motors	10.00	
Chemicals for treating oil and water	15.00	
Salaries charged @ 2.7c per barrel	67.50	
Total cost per day		$5,967.83
Net profit per day		$3,434.92
Net profit per barrel		1.37
Cost to refine one barrel of crude		.338

Profits of Skimming Plant, 1920 (Freeborn)

Based on Market Prices April, 1920, and Charging 2,500 Barrels of Crude Oil Per 24-Hour Day.

Yield Per Day.

Gasoline	30%	31,500 gals. @ $0.21½	$ 6,772.50
W. W. Kerosene	6%	6,300 gals. @ .12	756.00
P. W. Kerosene	9%	9,450 gals. @ .10½	992.25
Gas oil	5%	5,250 gals. @ .09	472.50
Fuel oil	48%	50,400 gals. @ .0725	3,654.00
Loss	2%	2,100 gals.	0.00
	100%	105,000 gals.	
Total sales per day			$12,647.25

Cost Per Day.

Crude oil run, 2,500 barrels @ $4.00	$10,000.00	
Fuel oil to stills & boilers, 397 bbls. @ $3.05	1,210.85	
Light & Electric power for motors	13.00	
Chemicals for treating oil & water	18.75	
Salaries charged to operation	249.38	
Total cost per day		11,491.98
Net profits per day		$ 1,155 27
Net profit per barrel		.47
Cost to refine one barrel crude		.597

Profits From Lubricating and Paraffin Plant (1920).

Based on market pricesof April, 1920, and handling distillate from 2,500 barrels of crude oil per day. Distillate handled 33% of crude run. (Freeborn.)

Yield Per Day.

Light lubricating oil	15%	8,347.5	gals.	@ $0.35	$ 2,921.63
Medium lubricating oil	11%	6,121.5	gals.	@ .35	2,142.52
Heavy lubricating oil	9%	5,008.5	gals.	@ .45	2,253.83
Heavy motor oil	5%	2,782.5	gals.	@ .60	1,669.50
Paraffin wax	6%	3,339	gals.		
		22,026	lbs.	@ .08	1,762.08
Fuel oil	48%	26,712	gals.	@ .0725	1,936.62
Loss	6%	3,339	gals	@ .60	0.00
	100%	55,650	gals.		
Total sale per day					$ 12,868.18

Cost Per Day.

Fuel oil 1,325 barrels @ $3.95	$4,041.25	
Fuel oil to boilers & stills 154 bbl. $3.05	469.70	
Electric light & power	15.00	
Chemicals and fuller's earth	250.00	
Salaries charged to operation	300.00	
Total costs per day		5,075.95
Net profit per day		$ 7,610.23
Net profit per barrel		5.74
Cost to refine one barrel		.78
Net profit per year on 80% operating time		2,222,187.16

PROFITS OF COMPLETE REFINERY (FREEBORN).

Based on Market Price April, 1920, and Charging 2,500 Bbls. of Crude Oil Per 24-Hour Day.

Yield Per Day.

Gasoline	30%	31,500 gals. @ $0.21½	$	6,772.50
W. W. Kerosene, 45°	6%	6,300 gals. @ .12		756.00
P. W. Kerosene, 42°	9%	9,450 gals. @ .10½		992.25
Gas oil	5%	5,250 gals. @ .09		472.50
Paraffin Dist.	25%	26,250 Return stock for lub. oils and wax		
Flux	22%	23,100 gals. @ .0725		1,674.75
Loss	03%	3,150 gals.		000.00
	100%			

2,500 bbls. crude oil charged.............100%
625 bbls. of paraffin distillate.......... 25% off

Light lubricating oil	28%	7,350 gals. @ $0.35		2,572.50
Medium lubricating oil	24%	6,300 gals. @ .35		2,205.00
Heavy lubricating oil	16%	4,200 gals. @ .45		1,890.00
Heavy motor oil	14%	3,675 gals. @ .60		2,205.00
Paraffin wax	12%	20,790 lbs. @ .08		1,663.20
		3,150 gals.		
Loss	6%	1,575 gals.		
	100%	26,250 gals.		
Total sales			$	21,203.70

Total Costs.

Crude oil run 2,500 bbls. @ $4.00	$10,000.00	
Fuel oil to boilers & stills, 432 bbls. @ $3.05	1,317.60	
Electric light for power and motors	25.00	
Chemicals and fuller's earth	265.00	
Salaries charged to operation	550.00	
Total costs		12,157.60
Net profits per day		$ 9,046.10
Net profit per barrel		3.61
Cost to refine one barrel		.86
Net profit operating on 80% time basis		2,641,461.20

Profits From Filtering and Cold Settling Plant (Freeborn).

Filtering and Cold Settling Plant for making Bright Stocks from Cylinder Stock, installed in conjunction with Skimming Plants having a charging capacity of 2,500 bbls. of crude per day. Yield of Cylinder stock from crude will average from 10% to 20%. The following figures based on 15%:

15% of 2,500—375 bbls. or 15,750 gallons to be handled. Co'd settled stock, 15% or 15,750 gal. @ $0.75		$11,812.50
Cost to produce:		
Fuel oil—375 bbls. @ $3.05	$1,113.75	
Steam and electric power	10.00	
Chemicals and fuller's earth	175.00	
Salary charged to operation	95.00	
Loss of 56° naphtha in mix and wash	141.00	
General maintenance, etc	100.00	$ 1,664.75
Total net profit per day		10,147.75
Net profit per barrel		27.06
Cost to refine one barrel		1.39
Net profit per year figuring on operating 80% or 292 days		2,963,143.00

The necessary equipment to be added to a skimming plant to make bright stocks from cylinder stocks, such as refrigerating plant, filtering plant, cold settling tanks and steam stills for reclaiming naphtha from cold settled stocks and filter wash, will cost approximately $151,146.25.

Net profits per day $10,147. 75x292 days. 80% time—$2,963,143.00.

Cost of Construction (Freeborn).

This represents a profit on the investment of much more than 1000%.

The question is often asked, what will a refinery cost? We are giving below in a general way these costs. These include neither tank cars nor working capital but only cost of refinery ready to operate.

We have assumed a capacity of 2,500 barrels and will say that a smaller plant will cost a little more and a larger one a little less per barrel.

Topping plant 2,500 bbls. @ $100 per barrel or	$250,000.00
Complete refinery, 2,500 bbls. @ $300 per barrel or	750,000.00
Complete lubricating plant—Added to present topping plant of 2,500 bbls. would be $800 per bbl. of lubricants which is 625 bbls. or..	500,000.00
Filtering and cold settling plant—Added to 2,500 bbl. topping plant, $400 per bbl. for 400 bbls. or	160,000.00

COSTS OF REFINING IN 1922.

In 1922 (April) it may be assumed that a skimming plant will cost $100 per barrel per day capacity including limited storage but not including pipe lines outside of refinery or tank cars. It costs approximately 50 cents to distill a barrel of crude oil to coke. The cost of making 1 barrel of gasoline by cracking is $2 to $5 and 1¼ to 1¾ barrels of gas oil is required to make it. With gas oil at $1.40 per barrel, the total cost of a barrel of cracked gasoline is $3.75 to $10.00. With fuel oil at $1.00 and gas oil at $1.26 a plant in Illinois is able to make 600 barrels of gasoline per day at a total cost of $3.70 per barrel.

The profit derived from a refinery depends upon:

The price of crude oil.

The location of the particular refinery in respect to availability of crude oil and the markets for the refined products.

The general market for refined products.

The quality of the crude oil available.

The amount of fuel oil, gas oil and unprofitable products.

The method of refining and refinery management.

The working and reserve capital.

The refinery making the most profit as a general rule is the one that makes the greatest amount of gasoline and lubricating oils as they are the most stable products of petroleum.

COST OF REFINING CALIFORNIA PETROLEUM.

(Report of Federal Trade Commission, 1921)

The cost of refining crude petroleum is shown in detail for five companies named for the period 1916—June 30, 1919, and for two companies from 1914 to the latter date. The cost of refining a barrel of crude petroleum including the cost of the crude for all companies combined increased from $0.738 per barrel in 1916 to $1.259 for the first half of 1919. The crude petroleum costs are taken at the actual cost of production, or at purchase price, if bought. There was a wide range in the costs for individual companies. In 1916, the lowest cost for a particular company was $0.602 and the highest $0.845. In 1919, the lowest cost was $0.95 and the highest $1.631. The companies showing high costs are those purchasing a large proportion of the crude petroleum they refine.

The principal element of cost for a barrel of refined petroleum products is the raw material—crude petroleum—even when the crude is charged to the refinery at its cost of production plus transportation cost. On this basis, the raw material represented 79.4% of the total cost in 1914 and about 74% in 1919. The refinery operating expense was about 13.5% in 1914 and 17.7% in 1919, while the general and administrative and depreciation combined were 7.1% in 1914 and 8.3% in 1919. The refining labor cost is a very small factor in the cost of a barrel of refined petroleum products, and during the period covered, it varied from only $0.012 in 1914 to $0.046 in 1919.

STANDARD STILLS.

Actual Capacity	Dimensions	Weight	Typical Cost	
275	8x30	22,000	$2,120.00	
349	9x30	24,000	2,250.00	
423	10x30	28,000	2,550.00	
573	10x40	36,000	3,225.00	
698	11x40	39,000	3,685.00	
640	12x30	36,000	2,810.00	K. D.
610	12x30	36,000	3,580.00	Riveted

AGITATORS.

Actual Capacity	Dimensions	Weight	Typical Cost
230	10x25	19,500	2,085.00
300	10x30	22,000	2,260.00
450	15x25	34,000	2,500.00
600	15x30	36,000	2,680.00
750	15x35	44,400	3,120.00
1000	20x30	55,000	3,845.00
1250	20x35	61,000	4,260.00

STANDARD CONDENSER BOXES.

Size	Compartments	Weight	Selling Price
Riveted Up.			
8x8x27		10,000	$ 855.00
10x6x30		10,700	920.00
10x8x30		12,700	1,100.00
Knocked Down.			
20x8x30	2	22,600	1,450.00
30x8x30	3	32,400	2,040.00
40x8x30	4	42,000	2,610.00

Gasoline.

Gasoline as now found on the market is a mixture of petroleum hydrocarbons, having an initial boiling point of from 70°F to 140°F, an end boiling point of from 360°F to 450°F, gravity of 55° to 61° Be'.,

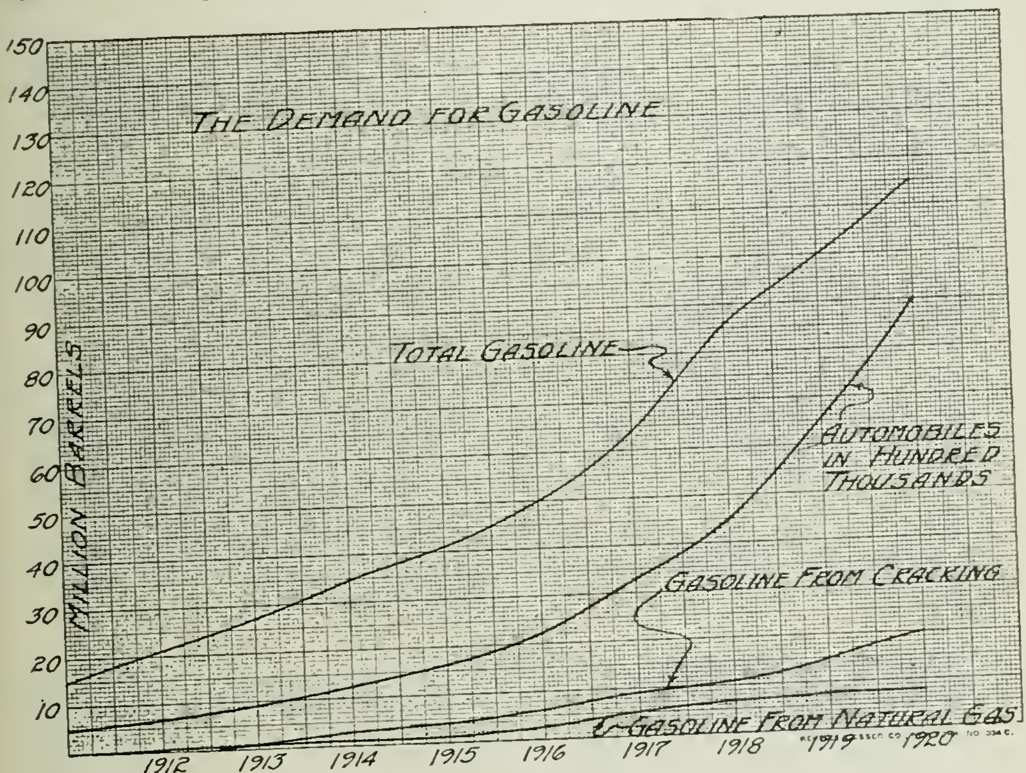


Fig. 47—The Demand for Gasoline.

a sweet to oily aroma, a water white color, specific heat of 0.50, and heat of vaporization of 130 B.T.U. per pound.

The particular hydrocarbons composing it belong to a general group known as the paraffins. Other types of hydrocarbons are occasionally present in a very small amount. These are known as olefins and as benzenes or aromatics. The olefins are removed by a thorough treatment with sulphuric acid, but the benzenes remain if originally present.

Ordinary gasoline made by the natural distillation of Mid-Continent crude oil will contain several or all of the following substances:

Name	Boiling point	Specific gravity	Baume' gravity	Heat of vaporization calories per gram
1. Pentane	97°F	0 630	92.2°	84 0
2. Hexane	156°F	0.670	78.9°	80.5
3. Heptane	209°F	0 697	79.9°	74.0
4. Octane	258°F	0.718	65.0°	71.5
5. Nonane	302°F	0.740	59.2°	67.5
6. Decane	343°F	0.750	56.7°	64.5
7. Undecane	383°F	0.760	54.2°	61.5

The following aromatic compounds are produced by pyrogenic decomposition of heavy hydrocarbons and rarely exist naturally in crude petroleum.

They are produced by the cracking of oil in the vapor phase and at high temperatures and occur in artificial or what has been called "synthetic" gasoline. Their chief origin is in byproducts from the coking of coal.

Name	Boiling Point	Specific gravity	Baume' gravity
Benzol (C_6H_6)	176°F	0.880	29.1°
Toluol ($C_6H_5CH_3$)	232°F	0.872	30.6°
Xylene ($C_6H_4(CH_3)_2$	291°F	0.882	28.7°

A small amount of these hydrocarbons in commercial gasoline very materially affects the gravity.

The character of gasoline is governed almost entirely by its use for automobiles. It is also used to some extent for stove gasoline and for cleaning purposes, in which case it has lower end point and a higher Baume' gravity.

Gasoline originates from one or more of the following sources:

1. The natural product distilled from crude oil. This constitutes about 70% of the total on the market (1921).

2. As a condensate from natural gas and known as casinghead gasoline. This constitutes about 5% of all gasoline and is always incorporated with heavy hydrocarbons such as naphtha or with gasoline distilled from a heavy crude or with gasoline made by cracking.

3. The light hydrocarbons produced by the pyrogenic decomposition of heavy petroleum residua. This constitutes about 25% of the market gasoline and tends to have a slight amount of aromatic compounds.

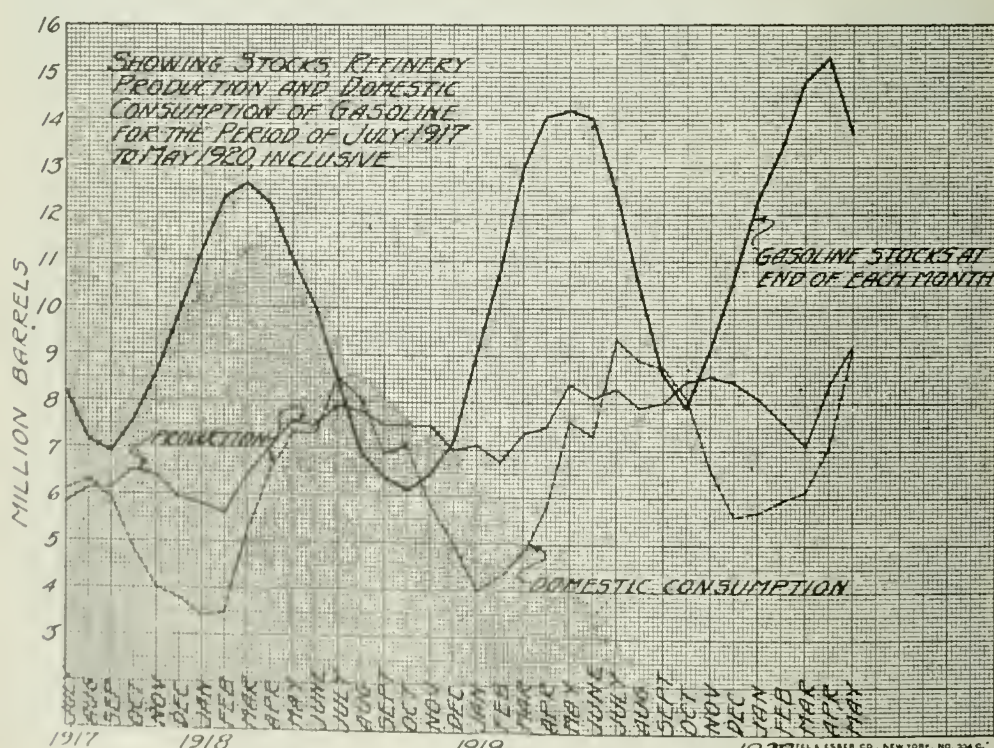


Fig. 18—Production, Consumption and Stocks of Gasoline.

The most desirable properties of gasoline are low end point and a low initial boiling point, the usual refiner's practice being to call everything gasoline which distills up to a temperature of 410°F. This practice in a light crude gives a 58° Be' product, although in the unusually light crudes a 61° product is obtained and in heavy crudes a gravity as low as 54° may be obtained. Light crudes such as those from Mexia, Tex., give as high as 20% of naphtha without any gasoline but when this naphtha is blended with about 25% of casinghead gasoline it gives a good motor gasoline.

Figure 39 shows the relation of the boiling point to the specific gravity of ordinary market gasoline. Gasolines containing considerable olefins, aromatics or naphthenes have a higher relation of specific gravity to boiling point than do gasolines composed entirely of paraffin hydrocarbons.

Figure 49 shows the relation of the boiling temperature to the percentage distilled over in ordinary commercial gasoline. These curves show that the gravity alone is not a good measure of the quality of a gasoline. For example, a 58° gravity gasoline in one case has an initial boiling point of less than 100°F and in another case has an initial boiling point of 190°F. A naphtha blended with casinghead will have a very high gravity test, but will show a very low initial boiling point and a very high end point.

COMPARISON OF GASOLINE SAMPLES COLLECTED BY BUREAU OF MINES.

January, 1921 and July, 1921.

District	Date	First Drop	20%	50%	90%	End Point	Avg. B. P.
New York	Jan., 1921	117	206	264	363	417	265
	July, 1921	125	208	265	365	422	268
Difference		+8	+2	+1	+2	+5	+3
Washington	Jan., 1921	118	201	259	385	439	270
	July, 1921	130	204	263	387	442	274
Difference		+12	+3	+4	+2	+3	+4
Pittsburgh	Jan., 1921	92	171	248	391	430	244
	July, 1921	112	181	247	382	435	259
Difference		+20	+10	—1	—9	+5	+15
Chicago	Jan., 1921	117	191	248	387	439	264
	July, 1921	125	202	261	389	444	273
Difference		+8	+11	+13	+2	+5	+9
New Orleans	Jan., 1921	123	211	270	366	428	272
	July, 1921	131	214	279	376	427	279
Difference		+8	+3	+9	+10	—1	+7
St. Louis	Jan., 1921	114	202	271	381	444	274
	July, 1921	128	205	268	383	441	276
Difference		+14	+3	—3	+2	—3	+2
Salt Lake City	Jan., 1921	112	206	282	397	439	285
	July, 1921	126	200	256	353	401	259
Difference		+14	—6	—26	—44	—38	—26
San Francisco	Jan., 1921	121	210	267	355	417	265
	July, 1921	129	206	258	356	421	265
Difference		+8	—4	—9	+1	+4	Same
8 Districts	Jan., 1921	113	197	261	378	431	265
	July, 1921	125	201	261	376	432	269
Difference		+12	+4	Same	—2	+1	+4
Federal Specifications	Nov. 25, 1919	140	221	284	374	437	

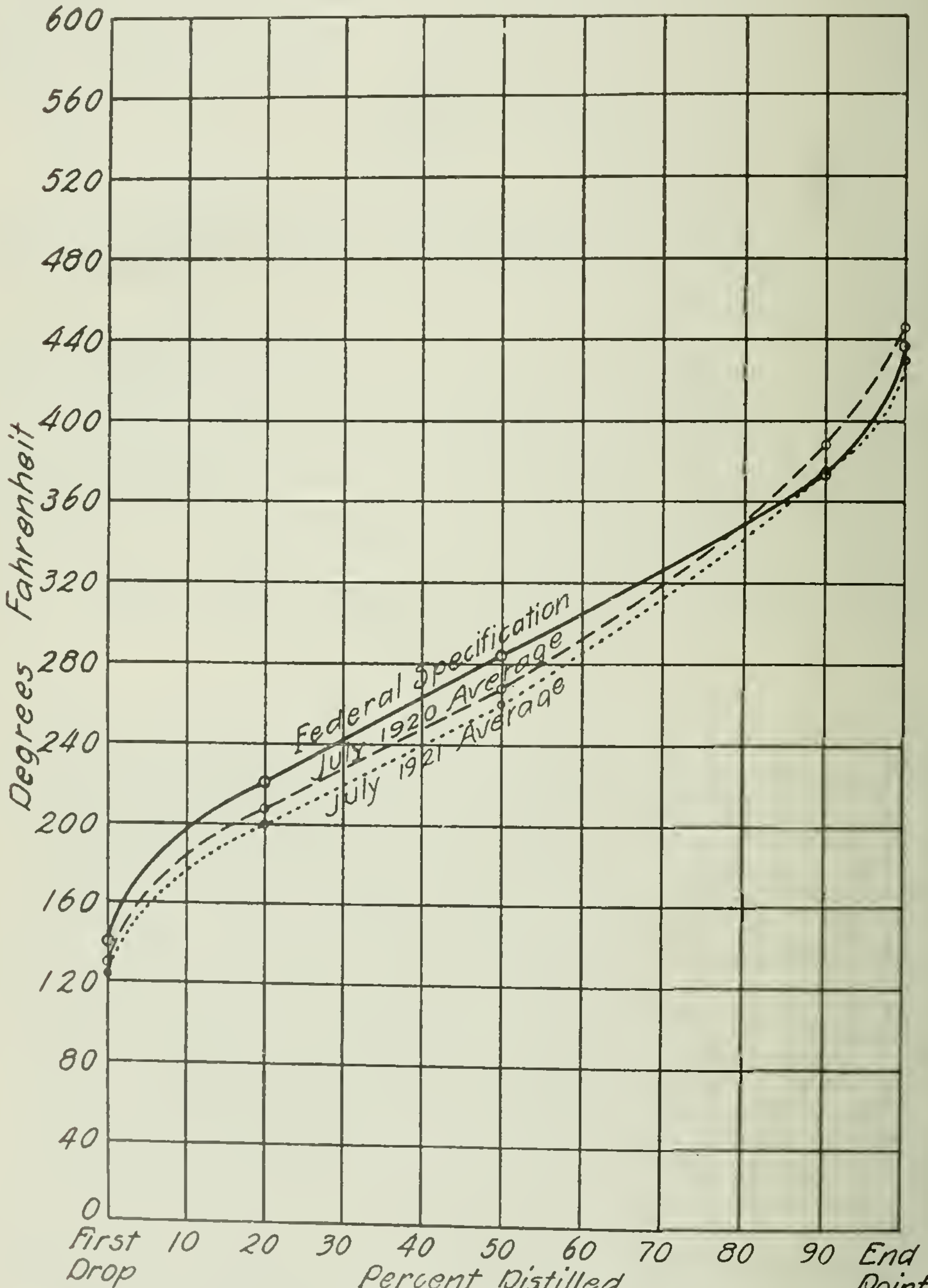


Fig. 49—Distillation Curves of Gasoline Sold in 1921 (U. S. B. M.)

THE COMBUSTION OF GASOLINE.

Average Results of Tests on Eleven 5-passenger Cars.
(See J. I. and E. Chem. Jan. 1921, Page 51.)

CONDITION OF TEST	Miles per Gallon	Completeness of Combustion	Lbs. Air per Lb. of Gasoline	Analysis of Exhaust Gas Per Cent by Volume					
				CO_2	O_2	CO	CH_4	H_2	N_2
Engine racing	....	70	12.2	9.1	1.5	6.9	0.8	3.0	78.8
Engine idling	....	69	11.8	8.9	1.4	7.6	0.6	3.7	77.8
Three per cent grade (up)									
15 miles per hour	13.2	75	12.6	10.2	1.1	5.7	0.6	2.6	79.8
10 miles per hour	12.7	75	13.0	9.9	1.5	5.7	0.5	2.5	79.8
3 miles per hour	6.2	72	12.2	9.8	0.9	6.5	0.6	3.0	79.2
Down 3% grade—									
15 miles per hour	24.5	70	12.3	9.5	1.4	6.5	0.9	2.9	78.8
10 miles per hour	22.8	70	12.3	8.6	1.4	7.0	0.7	3.1	79.2
3 miles per hour	9.9	72	12.9	9.5	1.5	6.0	0.7	2.7	79.6
Level grade—									
15 miles per hour	16.9	76	14.4	9.3	2.2	5.6	0.8	2.8	79.3
10 miles per hour	16.9	72	12.7	9.3	1.9	6.3	0.6	3.1	78.8
3 miles per hour	7.5	72	12.6	9.1	1.6	6.7	0.6	3.0	79.0

EFFECT OF CARBURETOR ADJUSTMENT ON GASOLINE CONSUMPTION AND EXHAUST GAS COMPOSITION.

Four-cylinder roadster, engine 4⅛ in. bore x 4½ in. stroke; Johnson carburetor; intake air and manifold heated; using gasoline 66.4°Be' distillation 10%, 127°F; 50%, 225°F, dry 441°F; average 239°F. Tests at 15 miles per hour ascending a 3% grade of asphalt in good condition.

Gasoline consumption, miles per gallon	14.9	13.9	10.6	8.8
Exhaust gas analyses, per cent—				
CO_2	13.4	12.0	10.2	6.5
O_2	1.7	1.4	0 3	1.2
CO	1.2	2.0	6.4	11.6
CH_4	0.2	1.1	0.8	1.0
H_2	0.0	0.0	2 4	6.4
N_2	83.5	83.5	79.9	73.3
Carburetor Adjustment, lbs. air per lb. gasoline	14.5	14.2	11.8	9.9
Per cent completeness of combustion	95	85	74	56
Condition of exhaust	clear	clear	slightly smoky	smoky
Operation	irregular	smooth	excellent	poor power

TABLES FOR COMPUTING AUTOMOBILE HORSE POWER.

(S. A. E. Horse Power Table.)

Four cycle
Limit of error, .005

$$HP = \frac{D^2N}{2.5}$$

Two cycle
Limit of error, .005

$$HP = \frac{D^2N}{1.5151}$$

D = diameter or bore of cylinder in inches.
N = number of cylinders.

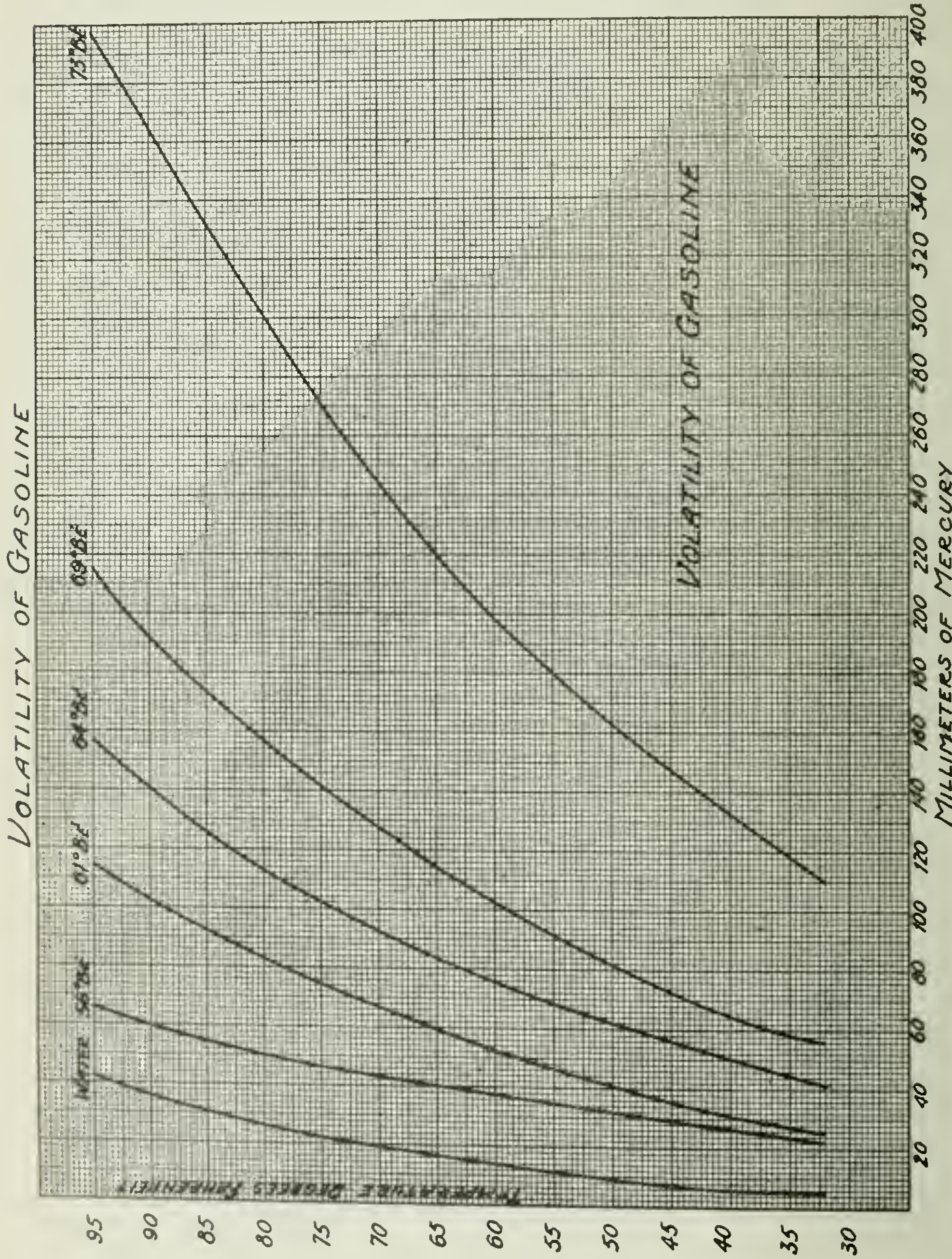


Fig. 50—The Volatility of Gasoline.

AVERAGE COMPOSITION BY VOLUME OF EXHAUST GAS FROM TESTS OF 23 CARS AT 15 MILES PER HOUR.

	Level grade	Ascending 3% grade
Carbon dioxide	8.9%	9.6%
Oxygen	2.3	1.3
Carbon monoxide	6.3	6 4
Methane	0.9	0.6
Hydrogen	3.0	2 9
Nitrogen	78.6	79 2
Total	100.0%	100.0%

Exhaust gas at 65°F and 29.92 in Hg., level grade = 988 cu. ft. per gallon of gasoline.

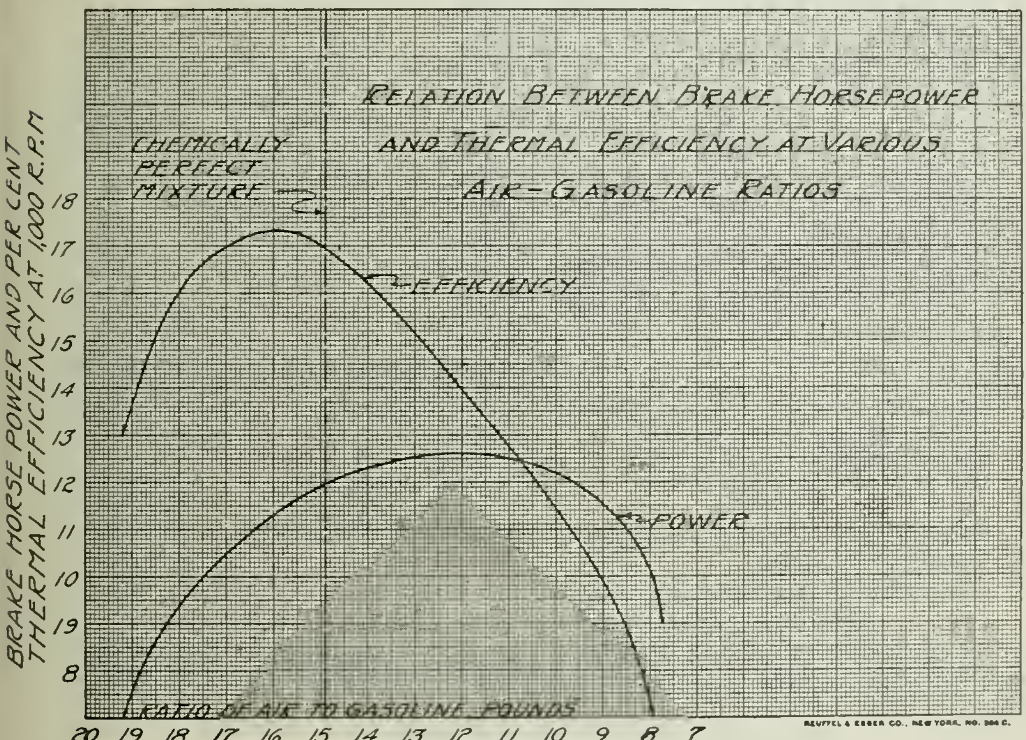


Fig. 51—Relation of Power and Combustion Efficiency in Gasoline Engines.

ULTIMATE COMPOSITION OF GASOLINE.

Specific gravity	0.713
Carbon	84 3%
Hydrogen	15.7%

Calorific value, 21,300 B.T.U. per lb.=130,000 B.T.U. per gal.

EXHAUST GAS FROM 1 GAL. GASOLINE ON LEVEL GRADE TESTS CONTAINS:

988x6 3=62.2 cu. ft. CO
988x0.9= 9.1 cu. ft. CH_4
988x3.0= 2.9 cu. ft. H_2

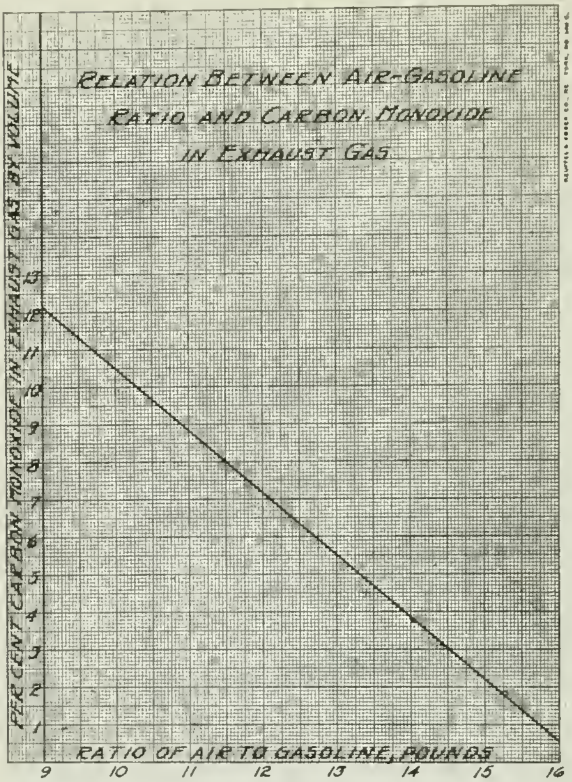


Fig. 52—Relation of Carbon Monoxide to the Gasoline Mixture in Gasoline Engines.

TOTAL HEAT IN UNBURNED GASES PER GALLON GASOLINE.

$$62.2 \times 320 = 19{,}900 \text{ B.T.U.}$$
$$9.1 \times 1000 = 9{,}100 \text{ B.T.U.}$$
$$29.6 \times 332 = 9{,}500 \text{ B.T.U.}$$
$$\overline{38{,}500}$$

Gross B. T. U. per cu. ft. at 65° F. and 29.92 in Hg.

$$\frac{38{,}500}{130{,}000} = 29.6\%$$

29.6% of the total heat of the gasoline goes out in the exhaust in the form of combustible gases.

EFFICIENCY OF AUTOMOBILES MOVING ON LEVEL GROUND AT 35 MILES PER HR.

Water radiator and engine radiation		40%
Exhaust gas heat and pipe resistance of pipe		36%
Engine friction		6%
Engine power—transmitted		18%
Transmission friction	3.5%	
Rear tire friction	5.0%	
Front tires and wheels	2.5%	
Air resistance	7.0%	
Total	18.0%	

The apparent flexibility of the engine is governed largely by reducing the last four items. This is largely accomplished by lubrication and tire inflation.

U. S. Specifications for Gasoline.

(Technical Paper 298 Bureau of Mines.)

AVIATION GASOLINE, FIGHTING GRADE.

General:

1. This specification covers the grade of gasoline used by the United States Government and its agencies as a fuel for fighting planes where the highest efficiency is required.

2. The gasoline shall be free from undissolved water and suspended matter.

Properties and Tests:

3. Color: The color shall be not darker than 25 Saybolt.
4. Doctor test: The doctor test shall be negative.
5. Corrosion test: One hundred cc of the gasoline shall cause no gray or black corrosion and no weighable amount of deposit when evaporated in a polished copper dish.
6. Unsaturated hydrocarbons: Not more than 1.0% of the gasoline shall be soluble in concentrated sulphuric acid.
7. Distillation range:

When 5% of the sample has been recovered in the graduated receiver, the thermometer shall not read more than 65°C (149°F) or less than 50° C. (122° F.).

When 50% has been recovered in the receiver, the thermometer shall not read more than 95°C (203°F).

When 90% has been recovered, in the receiver, the thermometer shall not read more than 125°C (257°F).

When 96 % has been recovered in the receiver, the thermometer shall not read more than 150°C (302°F). The end point shall not be higher than 165° C. (329° F.).

At least 96% shall be recovered as distillate in the receiver from the distillation.

The distillation loss shall not exceed 2% when the residue in the flask is cooled and added to the distillate in the receiver.

8. Acidity: The residue remaining in the flask after the distillation is completed shall not show an acid reaction.
9. The United States War Department requires the fighting grade to be colored red after inspection and acceptance.

All tests shall be made according to the methods for testing gasoline adopted by the Interdepartmental Petroleum Specifications Committee.

AVIATION GASOLINE, DOMESTIC GRADE.

General:

1. This specification covers the grade of gasoline used by the United States Government and its agencies for aviation fuel where the fighting grade is not required.
2. The gasoline shall be free from undissolved water and suspended matter.

Properties and Tests:

3. Color: The color shall be not darker than 25 Saybolt.
4. Doctor test: The doctor test shall be negative.

5. Corrosion test: One hundred cc of the gasoline shall cause no gray black corrosion and not weighable amount of deposit when evaporated in a polished copper dish.

6. Unsaturated hydrocarbons: Not more than 2.0% of the gasoline shall be soluble in concentrated sulphuric acid.

7. Distillation range:

When 5% of the sample has been recovered in the graduated receiver, the thermometer shall not read more than 75°C (167°F) or less than 50°C (122°F).

When 50% has been recovered in the receiver, the thermometer shall not read more than 105°C (221°F).

When 90% has been recovered in the receiver, the thermometer shall not read more than 155°C (311°F).

When 96% has been recovered in the receiver, the thermometer shall not read more than 175°C (347°F).

The end point shall not be higher than 190° C. (374° F.).

At least 96% shall be recovered as distillate in the receiver from distillation.

The distillation loss shall not exceed 2% when the residue in the flask is cooled and added to the distillate in the heceiver.

8. Acidity: The residue remaining in the flask after the distillation is completed shall not show an acid reaction.

All tests shall be made according to the methods for testing gasoline adopted by the Interdepartmental Petroleum Specifications Committee.

MOTOR GASOLINE ("NEW NAVY").

General:

1. This specification covers the grade of gasoline used by the United States Government and its agencies as a fuel for automobiles, motor boats and similar engines.

2. The color shall be not darker than No. 16 Saybolt.

3. A clean copper strip shall not be discolored when submerged in gasoline for 3 hours at 122°F.

Properties and Tests:

4. Distillation range:

When the first drop has been recovered in the graduated receiver, the thermometer shall not read more than 60°C (140°F).

When 20% has been recovered in the receiver, the thermometer shall not read more than 105°C (221°F).

When 50% has been recovered in the receiver, the thermometer shall not read more than 140°C (284°F).

When 90% has been recovered in the receiver, the thermometer shall not read more than 190°C (374°F).

The end point shall not be higher than 225°C (437°F).

At least 95% shall be recovered as distillate in the receiver from the distillation.

All tests shall be made according to the methods for testing gasoline adopted by the Interdepartmental Petroleum Specifications Committee.

TURPENTINE SUBSTITUTE.

General:

1. This specification covers the grade of mineral spirits used by the United States Government and its agencies for thinning paints and varnishes and as a substitute for turpentine.

2. This material shall be free from undissolved water and suspended matter.

Properties and Tests:

3. Color: The color shall be water white.

4. Spot test: It shall evaporate completely from filter paper in 30 minutes.

5. Flash point: The flash point shall not be lower than 30°C (86° F.). (Tag. Closed Tester.)

6. Sulphur: The sulphur test shall be negative.

7. Distillation range: Not over 5% shall distill below 130°C (266°F).

Not less than 97% shall distill below 230°C (446°F).

8. Acidity: The residue remaining in the flask after the distillation is completed shall not show an acid reaction.

All tests shall be made in accordance with the methods for testing gasoline adopted by the Committee on Standardization of Petroleum Specifications.

Specifications for Natural Gasoline.

(Adopted by Association of Natural Gasoline Manufacturers.)

	GRADE "A".	GRADE "B".
Gravity	Not below 72° Be′	Not below 76° Be′
	Not above 76° Be′	Not above 80° Be′
End point	Not over 375° F.	Not over 375° F.
Color	Water white	Water white
Recovery	Not less than 90%	Not less than 85%
Vapor tension	Not over 10 pounds	Not over 10 pounds

	GRADE "C."	GRADE "D".
Gravity	Not below 80° Be′	Not below 80° Be′
	Not above 84° Be′	Not above 84° Be′
End point	Not above 375° F.	Not above 330° F.
Color	Water white	Water white
Recovery	Not less than 85%	Not less than 80%
Vapor tension	Not over 10 pounds	12 pounds maximum

	GRADE "E".	GRADE "F".
Gravity	Not below 84° Be′	Not below 87° Be′
	Not above 87° Be′	Not above 90° Be′
Initial boiling point	Not below 65° F.	Not below 60° F.
End point	Not above 330° F.	Not above 330° F.
Color	Water white	Water white
Vapor tension	15 pounds maximum	Under maximum required by Bureau of Explosives.

	GRADE "G".
Gravity	Specified by seller
Color	Water white
Recovery	Not less than 85%
Vapor tension	Specified by seller

Specifications for Motor Natural Gasoline.

(Adopted by Association of Natural Gasoline Manufacturers.)

GRADE "1".

Gravity	Not below 60° Be′ Not above 62° Be′
Initial boiling point	Not less than 87° F.
End point	Not over 450° F.
Color	Water white
Recovery	Not less than 90%
Vapor tension	Not over 6 pounds

GRADE "2".

Gravity	Not below 62° Be′ Not above 66° Be′
Initial boiling point	Not less than 80° F.
End point	Not over 450° F.
Color	Water white
Recovery	Not less than 86%
Vapor tension	Not over 8 pounds

GRADE "3".

Gravity	Not below 66° Be′ Not above 70° Be′
Initial boiling point	Not less than 70° F.
End point	Not over 450° F.
Color	Water white
Recovery	Not less than 83%
Vapor tension	Not over 10 pounds

GRADE "4".

Gravity	Specified by seller
Initial boiling point	Not less than 85° F.
End point	Not over 465° F.
Color	Water white
Recovery	Not less than 86%
Vapor tension	Not over 8 pounds

NOTE.—All tests to be determined by methods of A. S. T. M. with additional provisions, condenser water temperature 32-34° F.

Summary of Refined Oil Inspection Laws and Taxes.

ALABAMA.

Gasoline—The distillation test shall show an initial boiling point of 140°F, 18% over at 250°F or below and an end point below 437° F. Tax on gasoline is 1/20c per gallon.

Kerosene—Shall have a fire test of 120° F. or over. Tax on kerosene is ½c per gallon.

ARIZONA.

Has no requirements for quality of gasoline or kerosene, but levies a road tax of 1c per gallon on gasoline.

ARKANSAS.

Gasoline—The gravity shall be taken at 60° F. and marked on the container. The tax on gasoline is 1c per gallon, to be applied on road improvements. Inspection tax of ⅛c per gallon.

Kerosene—Shall have a fire test of 150° F. by Tagliabue open cup. Tax on kerosene, ⅛c per gallon.

CALIFORNIA.

Has no laws in regard to quality of gasoline or kerosene. Levies no general tax.

COLORADO.

Gasoline—Gravity shall be taken. Gasoline shall contain not more than 5% of solid matter. Road tax of 1c per gallon.

Kerosene—Shall have a flash point of not less than 90° F. by Foster cup.

CONNECTICUT.

Has no gasoline laws. Levies a road tax of 1c per gallon on gasoline.

Kerosene—Shall have a flash point of 110° F., fire test, 140° F. by Tag. open tester.

DELAWARE.

Has no gasoline laws. Levies no tax on gasoline.

Kerosene—Shall have burning point of 115° F. by Tag. open tester.

FLORIDA.

Gasoline—Gravity shall be placed on the label. Road tax of 1c per gallon is levied on gasoline and an inspection tax of ⅛c per gallon on all petroleum products.

Kerosene—Shall be free from glue, water and suspended matter. The color shall be at least 21 Saybolt, flash point over 100° F., end point shall be below 600° F.

GEORGIA.

Gasoline—Container shall be properly labeled with the gravity and name of the product. Road tax of 1c per gallon is levied. General tax of ½c per gallon for oil inspection.

Kerosene—Shall have flash point of over 100° F. by Elliott closed tester.

IDAHO.

Gasoline—Shall be of the quality standardized by the U. S. Bureau of Mines and shall be labeled and sold as to true name and grade. No tax levied.

Kerosene—Shall have fire test of over 120° F. by Tag. open tester.

ILLINOIS.

Gasoline—Must be branded "Condemned for illuminating purposes." No other requirements. No tax levied.

Kerosene—Shall have fire test of over 150° F. by Tag. open cup.

INDIANA.

Gasoline—Gravity shall not be less than 56° Be'.

Kerosene—Shall have flash point of over 120° F. by Foster cup.

IOWA.

Gasoline—Gravity shall be between 70° Be' and 80° Be' and shall distill from 150° F. to 210° F. All other products shall be branded "substitute for gasoline." Shall show percentage boiling below 135° F., from 135° F. to 210° F., from 210° F. to 302° F., percentage above 302° F. No tax levied.

Kerosene—Shall flash above 100° F. by Elliott closed tester. tester.

KANSAS.

Gasoline—Shall be water white, contain no acid, shall be sweet by the doctor test, have an end point of 450° F. or below, 20% shall be distilled at 230° F., 50% at 325° F. Gravity test is required.

Kerosene—Shall flash at a temperature above 110° F. by Foster cup. Tax levied on both gasoline and kerosene.

KENTUCKY.

Gasoline—No gasoline laws. Road tax of 1c per gallon is levied on gasoline.

Kerosene—Shall have fire test of over 130° F. by Tag. open cup. An inspection tax of 1/20c per gallon is levied on all oil.

LOUISIANA.

Gasoline—No gasoline law except that 1c per gallon is levied for roads.

Kerosene—Shall have flash point above 125° F. Any oil flashing below this temperature shall be labeled "dangerous and explosive."

MAINE.

Gasoline—Must be labeled "unsafe for illuminating purposes."

Kerosene—Must have a fire test above 120° F. by Tag. open cup. No provision is made for state inspection of oil, this being in charge of local government.

MARYLAND.

Has no laws governing quality of petroleum products.

MASSACHUSETTS.

Kerosene—Flash point of 100° F., fire test, 110° F. or more by Tag. open cup. No other petroleum requirements.

MICHIGAN.

Gasoline—Must be correctly labeled.

Kerosene—Flash point 120° F. by Foster cup. Local laws in Detroit and other cities are such as to accept Navy specification gasoline.

MINNESOTA.

Gasoline—Shall have initial boiling point of 140° F., 20% over at 221° F., 50% at 315° F., 90% at 420° F., end point not over 450° F., residue not over 3%, 86% shall be recovered. Shall be marked "unsafe for illuminating purposes." Test shall be placed on label. Gasoline marked "high test" shall be a superior product.

Kerosene—Shall be water white, contain no glue, suspended matter or water, residue at 600° F. shall not be over 5%. Flash point 100° F., fire test 120° F. by Tag. open cup. Certificate as to quality shall be on package. Inspection tax of 5c per barrel is levied on all refined petroleum.

MISSISSIPPI.

Has no laws governing quality of refined petroleum.

MISSOURI.

Gasoline—Gravity over 58° Be′ is to be sold as gasoline Gravity of 50° Be′ to 58° Be′ is to be sold as mixed gasoline or naphtha.

Kerosene—Shall be water white containing no water or tar. Flash point over 120° F. by Tag. open cup. Gravity not less than 40° Be′. Not more than 4% residue at 570° F.

MONTANA.

Gasoline—Shall be free from water and other foreign matter and shall be deodorized and contain no acid. Have initial boiling point below 140° F., 20% between 158 and 221° F., 50% below 275° F., 90% below 390° F., end point below 460° F. Gasoline acceptable if sum of 20% and 90% temperatures is below 611.

Kerosene—Flash point over 110° F. by Tag. open cup. Shall contain no water or foreign matter. No fee for inspection and no tax.

NEBRASKA.

Gasoline—Shall be water white and contain no water or impurities. Other requirements are new Navy specifications.

Kerosene—Shall be water white, free from water or tar. On distillation shall have residue not over 7% at 570° F. Flash point over 112° F. by Foster cup. Gravity over 40° Be′. Inspection fee 6c per barrel.

NEVADA.

No inspection laws.

NEW HAMPSHIRE.

Gasoline—No law.

Kerosene—Flash point 100° F., fire test 120° F. by open cup. This law more specifically for liquid polishes.

NEW JERSEY.

Gasoline—Shall be properly labeled.

Kerosene—Flash point on the label which shall be more than 100° F.

NEW MEXICO.

Gasoline—Gravity of over 46° Be'. Road tax of 1c per gallon.

Kerosene—Flash point of over 120° F.

NEW YORK.

Kerosene—Flash point of 110° F. by Tag. open cup. No other laws.

NORTH CAROLINA.

Gasoline—Shall have initial boiling point of 140° F., 20% over at 221° F., 50% over at 284° F., 90% over at 374° F. end point below 437° F., loss not over 5%. Manufacturer must send notice of shipment with full information to Commissioner of Agriculture, Raleigh, N. C. Road tax, 1c per gallon, and inspection tax of ¼c per gallon.

Kerosene—Flash point of not over 100° F. by Elliott cup. Not over 6% residue on distilling at 572° F.

NORTH DAKOTA.

Gasoline—Class I or household gasoline on distillation shall yield less than 3% at 158° F. and not over 6% residue at 284° F. Class I is not subject to tax. Class II gasoline on distillation shall yield from 3% to 15% at 158° F. 96% shall distill over. End point shall be below 428° F. Shall not be over 36% residue at 284° F. Class II is taxed at ¼c per gallon. Class III comprises all other gasoline and is taxed at 1c per gallon.

Kerosene—Flash point 100° F., fire test 125° F. by Elliott closed cup. Shall be water white. Not over 6% shall be distilled at 310° F. and residue shall not be over 4% at 570° F.

OHIO.

Gasoline—Shall be labeled "dangerous."

Kerosene—Flash point over 120° F. by Foster cup.

OKLAHOMA.

Gasoline—High grade or aero gasoline shall be water white, free from acid, 5% distilled at 122° F., 97% at 350° F. Other gasoline shall be labeled with the quality and brand "Motor fuel oil."

Kerosene—First grade shall have gravity of 40 to 48° Be' flash point above 120° F. A. S. T. M. tester. Second grade kerosene, flash point above 110° F. A. S. T. M. tester.

OREGON.

Gasoline—Gravity shall be over 56° Be'. Road tax of 2c per gallon on gasoline. No law on refined oil.

PENNSYLVANIA.

Gasoline—Road tax of 1c per gallon.

Kerosene—Fire test 110° F. by Tag. open cup.

RHODE ISLAND.

Kerosene—Flash point 110° F. by Tag. open cup.

SOUTH CAROLINA.

Gasoline—New Navy gasoline with an end point 225° C. Inspection tax ⅛c per gallon.

Kerosene—Flash point 100° F. with Elliott tester. Residue on distilling at 570° F. shall be less than 6%.

SOUTH DAKOTA.

Gasoline—Gravity shall be recorded.

Kerosene—Shall be water white and contain no tar. Shall distill not over 10% at 300° F., residue not over 4% at 570°. Flash point above 105°F. with New York closed tester. Gravity shall be over 41° Be'. Road tax of 1c per gallon on gasoline. Inspection tax of 5c per barrel.

TENNESSEE.

Gasoline—Shall be labeled "unsafe for illuminating purposes."

Kerosene—Flash point shall be over 120° F. Tag. open cup. Inspection fee on gasoline, 20c per barrel; 25c per barrel on kerosene.

TEXAS.

Gasoline—Initial boiling point shall be 140° F., 20% at 221° F., 45% at 275° F., 90% at 356° F., end point 428° F., 95% shall be recovered on distillation. Vapor tension shall be below 10 pounds at 100° F.

Kerosene—No kerosene law.

UTAH.

Kerosene—No state laws. Salt Lake City requires that kerosene be water white, free from water or tar, flash point 110° F. by Foster or Tag. cup.

Gasoline—Gasoline in Salt Lake City shall be the quality set forth by specifications of Bureau of Mines. Products shall be properly labeled.

VERMONT.

Kerosene—Fire test 110° F. by Tag. open cup.

VIRGINIA.

No law on petroleum products.

WASHINGTON.

Gasoline—Containers shall be branded with gravity. Road tax, 1c per gallon.

Kerosene—Fire test 120° F. with Tag. open cup.

WEST VIRGINIA.

No law.

WISCONSIN.

Gasoline—Containers shall be marked with gravity. Inspection tax, 5c per barrel.

Kerosene—Flash point 105° F., fire test 120° F. with Tag. open cup.

WYOMING.

Gasoline—New navy gasoline containing not over 2% of unsaturated hydrocarbons. End point 437° F.

Kerosene—Shall be water white, containing no water or tar. Flash point 110° F. with Foster closed cup. On distillation shall have a residue of not over 5% at 572° F.

Possible Savings in Use of Gasoline.

The Bureau of Mines estimates that the following savings can be effected daily:

	Gallons
Tank wagon losses	7,200
Leaky carburetors, average 1/17 of a pint per car	31,400
Poorly adjusted carburetors, ½ pint per car	240,000
Motors running idle, ¼ pint per car	150,000
Wasted in garages, 10 pints per day	67,000
Saved by using kerosene in garages	108,000
Needless use of passenger cars, 1¾ pints per car	897,400

This makes a total of 1,500,000 gallons a day, or 561,000,000 gallons a year, whereas our war needs were 350,000,000 gallons a year, or less than two-thirds of what may be considered as wasted at the present time.

SUGGESTIONS TO GASOLINE USERS.

The following important suggestions for avoiding waste will not only save gasoline, but users of motor vehicles will be benefitted personally and individually through more efficient and more economical operation of cars:

1. Store gasoline in underground steel tanks. Use wheeled steel tanks with measuring pump and hose. They prevent loss by fire, evaporation and spilling.
2. Don't spill or expose gasoline to air—it evaporates rapidly and is dangerous.
3. Don't use gasoline for cleaning and washing—use kerosene or other materials to cut grease.
4. Stop all gasoline leakages. Form habit of shutting off gas at tank or feed pipe.
5. Adjust brake bands so they do not drag. See that all bearings run freely.
6. Don't let engine run when car is standing. It is good for starter battery to be used frequently.
7. Have carburetors adjusted at service stations of carburetor or automobile companies—they will make adjustments without charge.
8. Keep needle valve clean and adjust carburetor (while engine is hot) to use as lean mixture as possible. A rich mixture fouls the engine and is wasteful.
9. Pre-heat air entering carburetor and keep radiator covered in cold weather—this will insure better vaporization.
10. See that spark is timed correctly with engine and drive with spark full advanced—a late spark increases gas consumption.
11. Have a hot spark, keep plugs clean and spark points properly adjusted.
12. Avoid high speed. The average car is most economical at 15 to 25 miles an hour.
13. Don't accelerate and stop quickly—it wastes gas and wears out tires. Stop engine and coast long hills.
14. Cut down aimless and needless use of cars. Do a number of errands in one trip.
15. Know your mileage per gallon. Fill tank full and divide odometer mileage by gallons consumed.

Benzinum Purificatum (U. S. Pharmacopoeia).

Purified Petroleum Benzin.

Benzin. Purif.—Petroleum Ether.

A purified distillate from American petroleum consisting of hydrocarbons, chiefly of the marsh-gas series. Preserve it carefully in well-closed containers, in a cool place, remote from fire.

Purified Petroleum Benzin is a clear, colorless, non-fluorescent, volatile liquid, of an ethereal, or faint, petroleum-like odor, and having a neutral reaction. It is highly inflammable and its vapor, when mixed with air and ignited, explodes violently.

It is practically insoluble in water, freely soluble in alcohol, and miscible with ether, chloroform, benzene, volatile oils and fixed oils, with the exception of castor oil.

Specific gravity: 0.638 to 0.660 at 25°C.

It distills completely between 40°C and 80°C (104°F to 176°F).

Evaporate 10 mils of Purified Petroleum Benzin from a piece of clean filter paper; no greasy stain remains, and the odor is not disagreeable or notably sulphuretted. Not more than 0.0015 Gm. of residue remains on evaporating 50 mils of Purified Petroleum Benzin at a temperature not exceeding 40°C.

Boil 10 mils of Purified Petroleum Benzin for a few minutes with one-fourth its volume of an alcoholic solution of ammonia (1 in 10) and a few drops of silver nitrate T. S ; the liquid does not turn brown (pyrogenous products and sulphur compounds).

Add 5 drops of Purified Petroleum Benzin to a mixture of 40 drops of sulphuric acid and 10 drops of nitric acid in a test tube, warm the liquid for about ten minutes, set it aside for half an hour, and dilute it in a shallow dish with water; no odor of nitrobenzene is evolved.

Comparison of Gasoline and Benzol as Motor Fuel.

Heat of combustion:	Benzol	Gasoline
B. T. U. per gallon	132330	129060
B. T. U. per pound	18054	20750
Freezing temperature	41°F	50°F below Zero
Boiling temperature	170-180	130-400°F
Rate of evaporation	Slower	Faster
Mileage per gallon (comparative)	110.	100.
Ignition temperature	Higher	Low
Pre-ignition from carbon	Less trouble	More trouble
Carbon formed	More	Less
Relative volume of air required per gallon	1.04	1.00
Relative volume of explosive gases produced per gallon	.92	1.00
Temperature of explosion	Higher	Lower
Rapidity of explosive force	Less sudden	More sudden

Benzol is most satisfactory if used mixed with gasoline or alcohol, preferably the latter.

Kerosene, Coal Oil, Illuminating Oil, Burning Oil.

Kerosene in a general way may be defined as that fraction of crude petroleum or oil made by the pyrogenic decomposition of shales or coal which distills at a temperature of from 302°F to 572°F, (150-300°C) and contains no gasoline or residuum. Its flash point is always greater than 100°F and usually greater than 120°F. Its color may be standard white, prime white, superfine white or water white. Its gravity ranges from 31 to 48°Be'. Typical kerosene has a gravity of 41 to 42°Be'. Sulphur is usually almost completely absent from kerosene, being less than 0.03%. It consists chiefly of the paraffin series, particularly when the gravity is greater than 38. The principal constituents are nonane, decane, undecane, duodecane, tridecane, tetradecane, pentadecane, hexadecane and heptadecane. With lower gravities it contains naphthenes and aromatic compounds. This is particularly true of Louisiana oils and California oils.

The quality of good kerosene has been found to be within the following limits:

1. Specific gravity is between 0.760-0.860 (54.2-32.8°Be').
2. Flash point is over 100°F by closed tester.
3. Color is water white with no turbidity.
4. Cold test is below 10°F.
5. End point is below 600°F.
6. Sulphur is below 0.05%.
7. Acid is absent.
8. It does not lose more than 1% on treatment with 66° sulphuric acid.
9. It burns without incrustation or smoking in an ordinary kerosene lamp.

The grades of burning oils are shown in the following table with the relative value of each grade in cents per gallon at refinery.

North Texas.	
40@42 prime white distillate	2½c
40@43 prime white kerosene	2½c
42@43 prime white kerosene	3 c
Oklahoma.	
41@43	3½c
42@43	4 c
44@46	5 c
42@43 distillate	3½c
Pennsylvania.	
45 prime white	6 c
45 water white	6½c
46 water white	7 c
47 water white	8 c
48 water white	9 c
30 mineral seal	6¼c
West Virginia.	
45 water white	6 c
47 water white	8 c

Kerosene is produced in amounts that greatly exceed the market demand so that the surplus is used for house heating and mixed with gas oil for cracking stock. It is specially adapted for high pressure (600 lbs.) cracking.

U. S. Specifications for Burning Oil (1921).

WATER WHITE KEROSENE.

General:

1. This specification covers the grade of kerosene used by the United States Government and its agencies as an illuminating oil. This oil may be used as fuel and for cleaning in case of necessity.
2. The oil shall be free from water, glue and suspended matter.

Properties and Tests:

3. Color: The color shall not be darker than No. 21 Saybolt.
4. Flash point: The flash point shall not be lower than 115°F (closed tester-tag).
5. Sulphur: The sulphur shall not be more than 0.06%.
6. Floc: The floc test shall be negative.
7. Distillation: The end point shall not be higher than 600°F.
8. Cloud test: The oil shall not show a cloud at 0°F.
9. Doctor test: The doctor test shall be negative.
10. Burning test: The oil shall burn freely and steadily for 18 hours.

All tests shall be made according to the methods for testing burning oils adopted by the Committee on Standardization of Petroleum Specifications.

SPECIAL NOTE COVERING KEROSENE FOR U. S. NAVY.

When specifically provided for, a representative sample of the oil delivered will be tested photometrically after burning for one hour in a lamp fitted with a No. 1 sun hinge burner. Five hours later, another photometric test will be made to determine any change in intensity of the light; the maximum allowable loss shall be 5%. The flame shall show at least 6 candlepower when compared photometrically with an incandescent lamp which has been standardized by the Bureau of Standards.

Otherwise specifications enumerated above apply for United States Navy Kerosene.

PRIME WHITE KEROSENE.

General:

1. This specification covers the grade of kerosene used by the United States Government and its agencies where kerosene is required primarily as a fuel and for cleaning purposes. This oil can be used as an illuminant in case of necessity.
2. The oil shall be free from water, glue and suspended matter.

Properties and Tests:

3. Color: The color shall not be darker than No. 16 Saybolt.
4. Flash point: The flash point shall not be lower than 115°F (tag closed tester).
5. Sulphur: The sulphur shall not be more than 0.09%.
6. Floc: The floc test shall be negative.
7. Distillation: The end point shall not be higher than 625°F.
8. Cloud test: The oil shall not show a cloud at 5°F.
9. Burning test: The oil shall burn freely and steadily for 8 hours.

All tests shall be made according to the methods for testing burning oils adopted by the Committee on Standardization of Petroleum Specifications.

LONG TIME BURNING OIL.

General:

1. This specification covers the grade of burning oil used by the United States Government and its agencies where a long time burning oil is required.

2. The oil must be free from water, glue and suspended matter.

Properties and Tests:

3. Color: The color shall not be darker than No. 21 Saybolt.

4. Flash point: The flash point shall not be lower than 115°F (tag closed tester).

5. Floc: The floc test shall be negative.

6. Cloud test: The oil shall not show a cloud at 0°F.

Note: Temperature of 0°F can be varied either up or down to suit the climatic conditions in the territory in which the oil is to be used.

7. Burning test: The oil must burn freely and steadily for 120 hours or until the oil is consumed.

All tests shall be made according to the methods for testing burning oils adopted by the Committee on Standardization of Petroleum Specifications.

Oil for use by the Bureau of Lighthouses shall be as described by the Department of Commerce, which specifications, etc., at the present time are as follows:

1. The kerosene must have a flash point of not less than 140°F and fire point of not less than 160°F (tag closed tester).

2. The kerosene must contain no free acids or mineral salts. Litmus paper immersed in it for five hours must remain unchanged.

3. One hundred grams of kerosene shaken with 40 grams of sulphuric acid (sp. gr. 1.73) must show little or no coloration.

4. When distilled from a still so jacketed as not to allow of local heating at a rate of not over 10% in ten minutes, the kerosene shall not distill below 350°F and 98% shall distill under 515°F, the temperature taken being that of the condensing vapor.

5. When burned for 120 hours in a lens lantern supplied with a fifth order oil lamp, the kerosene must burn steadily and clearly without smoking, with minimum incrustation of wick, slight discoloration of chimney and less than 10% loss of candlepower. A lamp of this description will be loaned to successful bidder.

300 DEGREE MINERAL SEAL OIL.

General:

1. This specification covers the grade of oil used by the United States Government and its agencies for lamps in passenger coaches and for illuminating railroad equipment, and where a high flash illuminant is required.

2. The oil must be free from water, glue and suspended matter.

Properties and Tests:

3. Color: The color must not be darker than No. 16 Saybolt.

4. Flash point: The flash point shall not be lower than 250°F (Cleveland open cup).

5. Fire point: The fire point shall not be lower than 300°F (Cleveland open cup).

6. Floc test: The floc test shall be negative.

7. Cloud test: The oil shall not show a cloud at 32°F.

8. Reaction: The oil shall be neutral.

9. Burning test: The lamp shall give a symmetrical flame, free from smoke, when burned continuously without readjustment until all of the oil is consumed.

All tests shall be made according to the methods for testing burning oils adopted by the Committee on Standardization of Petroleum Specifications.

SIGNAL OIL.

General:

1. This specification covers the grade of oil used by the United States Government and its agencies for railroad signal lamps.

2. The oil shall be free from water, glue and suspended matter.

3. The oil shall be compounded from 300 degree mineral seal oil, as adopted by the Committee on Standardization of Petroleum Specifications with pure prime winter strained lard oil or sperm oil, or with a mixture of pure prime winter strained lard oil and sperm oil.

Grade A shall not contain less than 30% of fatty oil by volume.

Grade B shall not contain less than 22% of fatty oil by volume.

Grade A shall always be furnished unless Grade B is specifically ordered.

Properties and Tests:

4. Flash point: The flash point shall not be lower than 250°F (Cleveland open cup).

5. Fire point: The fire point shall not be lower than 300° F (Cleveland open cup).

6. Cloud test: The oil shall not show a cloud at 32°F.

7. Free fatty acids: Grade A shall not contain over 0.60% of free fatty acid calculated as oleic acid. Grade B shall not contain over 0.45% free fatty acid calculated as oleic acid.

8. Burning test: The oil shall burn 24 hours without trimming or adjusting the wick.

All tests shall be made according to the methods for testing burning oils adopted by the Committee on Standardization of Petroleum Specifications.

GAS OIL.

Gas oil is that fraction of petroleum distillation coming off after the kerosene or other illuminating oil. It is usually a destructive distillation resulting in a distilled product carrying a considerable amount of olefins and a residue having a lower viscosity than would be the case without a partially destructive distillation. When it is desired to avoid a destructive distillation, steam may be used, giving an oil suitable for absorption purposes sometimes known as straw oil.

Gas oil is used for making gas and for carbureting coal gas or water gas. It is also used to make Blaugas, which is a product liquified under a pressure of about 1,500 pounds. It is also used for Pintsch gas. A typical gas oil has the following properties:

Specific gravity	0.843=36.1°Be'
Flash point	90°C
Burning test	116°C

Distillation test:

0°C-150°C	0 0%
150°C-300°C	44.0%
300°C up	55.3%
Coke	0.7%

GAS OIL FOR DIESEL ENGINES (U. S. NAVY).

1. Flash point not lower than 150°F (Abel or Pennsky-Marten's closed cup).

2. Water and sediment—trace only.

3. Asphaltum—none.

STRAW OIL (U. S. BUREAU OF STANDARDS).

The characteristics of a straw oil for absorption of light oils from gas as recommended by some operators and which are concurred in by the committee of coal-tar products are substantially as follows:

1. Specific gravity not less than 0.860 (34°Be') at 15.5°C (60°F).

2. Flash point in open cup tester not less than 135°C (275°F).

3. Viscosity in Saybolt viscosimeter at 37.7°C (100°F) not more than 70 seconds.

4. The pour test shall not be over 1.1°C (30°F).

5. When 500 cc of the oil are distilled with steam at atmospheric pressure collecting 500 cc of condensed water, not over 5 cc of oil shall have distilled over.

6. The oil remaining after the steam distillation shall be poured into a 500 cc cylinder and shall show no permanent emulsion.

7. The oil shall not lose more than 10% by volume in washing with 2½ times its volume of 100% sulphuric acid when vigorously agitated with acid for five minutes and allowed to stand for two hours.

An additional set of specifications for wash oil which is used by one Government department is as follows:

Specific gravity shall not be greater than thirty-five and nine-tenths degrees (35.9°) Baume' at 60°F, equivalent to specific gravity 0.844.

Viscosity shall not be more than 56 seconds in a Saybolt viscosimeter at 100° Fahrenheit.

The oil shall not thicken or cloud at 25°F in the cold test.

At least 95% of the oil shall separate as a clear layer within 10 minutes after 100 cubic centimeters of oil and 100 cubic centimeters of water have been shaken together vigorously for 20 seconds at a temperature of 70°F.

There shall not be more than 14% of loss in volume of oil when 1 volume of oil and 2½ volumes of 100% sulphuric acid are vigorously agitated for 5 minutes and allowed to settle for 2 hours.

The oil shall not begin to distill below 240°C.

Quality of Absorption Oil for Extracting Gasoline from Natural Gas (Westcott "Casinghead Gasoline").

Gravity	35.6°
Initial boiling point	536 °F
End point	698 °F
Fire test	312.8°F
Saybolt viscosity@100°F	40.5

Distillation.

Initial	273 °C
5%	295 °C
10%	300 °C
20%	305 °C
30%	308.6°C
40%	311 °C
50%	316 °C
60%	322 °C
70%	329 °C
80%	336.5°C
90%	360 °C

LUBRICATING OILS.

The principal source of lubricating oil is petroleum from which the lighter components, naphtha, kerosene, solar oil and gas oil have been removed by distillation, the residue thus obtained being used directly as a lubricant or separated by distillation into various fractions. By removing some of the fractions, as well as by mixing others, a variety of products may be obtained with special properties (viscosity, flash point, cold test and specific gravity).

This is the principle on which the industry is based. The separate fractions are further refined to remove odor, resinous materials, etc., as well as to attain the desired lightness of color. This is accomplished by means of sulphuric acid, agitating with a stream of air, the acid being later removed by washing with alkali or water; the purification may also be brought about by filtration through fuller's earth (see chapter on refining).

The oil may be distilled with superheated steam or with partial vacuum, excessive direct firing being avoided to prevent decomposition. The temperature of the superheated steam is kept somewhat higher than that of the still. Commercially, the distillates are cooled and separated according to specific gravity, flash point and viscosity.

Direct firing is much used in separating the crude oil fractions, thus increasing the yield of illuminating oils and producing a raw wax distillate. The refining, however, is carried on with superheated steam.

ECONOMY OF LUBRICATION.

The economical transmission of power is largely dependent upon the maximum reduction of friction.

The purpose of lubrication is to overcome friction in so far as possible and to prevent wear and deterioration of adjacent moving parts.

It is claimed that from 40% to 80% of all power produced by machinery is lost in friction, and a very considerable part of this is lost in avoidable friction due to improper lubrication.

THEORY OF LUBRICATION.

A lubricant should prevent direct contact between the bearings and the moving parts of machinery, thus substituting for metallic friction and wear the much smaller internal friction of the lubricant. The more completely this result is attained under the conditions of temperature, speed and pressure, the more valuable the lubricant from a mechanical point of view. Whether the mechanically most efficient lubricant is the most economical depends somewhat on the ratio of efficiency, the amount used and the price of the material. Greases have a low mechanical efficiency compared with liquid oils, but from the point of economy and cleanliness they are far superior.

Only liquids with great tendency to adhere are suited for lubrication, since only these have the property to penetrate by capillarity where journal and bearings are the closest and where the danger of contact and wear is the greatest. The lubricating oils prevent direct contact of the metal surfaces because of their adhesion to these surfaces and because their viscosity keeps them from being squeezed out by the pressure on the bearing.

Experience has shown that the power to adhere to metals increases with the viscosity of the oil. Since the danger that an oil will be pressed out increases with the pressure on the bearings, it is advisable for high pressures to use oils of considerable viscosity.

With low pressure and high speed there should be used a very mobile oil, with higher pressure and low velocity more viscous oils. If, for example, a spindle rotating with practically no pressure but very rapidly were lubricated with a very viscous oil, it would mean a lavish waste of power. But to lubricate a transmission gear with a mobile oil would be a waste of lubricant, while the use of a heavy grease would be entirely suitable. In fact, the use of a solid lubricant, graphite, with heavy oils as a vehicle, has proven most desirable in the case of very heavy bearings and transmission gears with enormous pressures.

The oil should not lose its power of reducing friction by evaporation, gumming or by acting chemically on the metal of the bearings or journal.

The oil or grease should not solidify or greatly change its viscosity under conditions of use.

The qualities of various types of lubricating oils are as follows:

Viscosity at—	Spindle	Light M'ch'n'y	Heavy M'ch'n'y	Auto-mobile	Engine	Steam Cylinder	Large Cylinder
70° F.	75–500	375–750	1750–875	470–1100	300–400	....	2800–400
100° F.	......	180–220	....	160–400	130–150	....	....
122° F.	75– 90	......	110– 280	....	....	1100	300– 560
210° F.	.....	40– 50	45– 60	40– 55	44– 47	120–150	....
Flash point, °F Min.	140	160	390	350	430	525	450
Cold test, ° F.	10	5	10– 40	10	25	45	40
Gravity, Be'.	......	....	....	19 32	23– 30	24– 30	....

Flash and burning points of lubricants are the respective temperatures at which the vapors arise in sufficient amount to ignite and to burn continuously. They should be high enough to prevent any danger of fire in using the oil and to be assured that a light oil has not been added to a heavy oil to regulate viscosity. With the same viscosity asphaltic base oils (Texas, California and Mexico) has a lower flash point and a higher specific gravity than paraffin base oils (Pennsylvania and West Virginia).

Specific gravity is the relation of the weight of a given volume of oil to the weight of the same volume of water. The oil trade usually uses the Baume' scale of gravity, which is entirely arbitrary. The paraffin oils with the same viscosity are lighter (have a higher gravity-Baume') than the asphaltic or semi-asphaltic oil. Gravity is not a measure of the quality of a lubricating oil.

Viscosity is a most important property for lubrication. The viscosity is expressed in the terms of the Saybolt Universal Viscosimeter in this country, the Engler in Germany and the Redwood in England. Paraffin oils are said to lose their viscosity most readily in use in an explosion cylinder by reason of the greater ease in decomposing to lighter products than do asphaltic oils. They tend to be as viscous at higher temperatures as asphalt base oils though less viscous at atmospheric temperature.

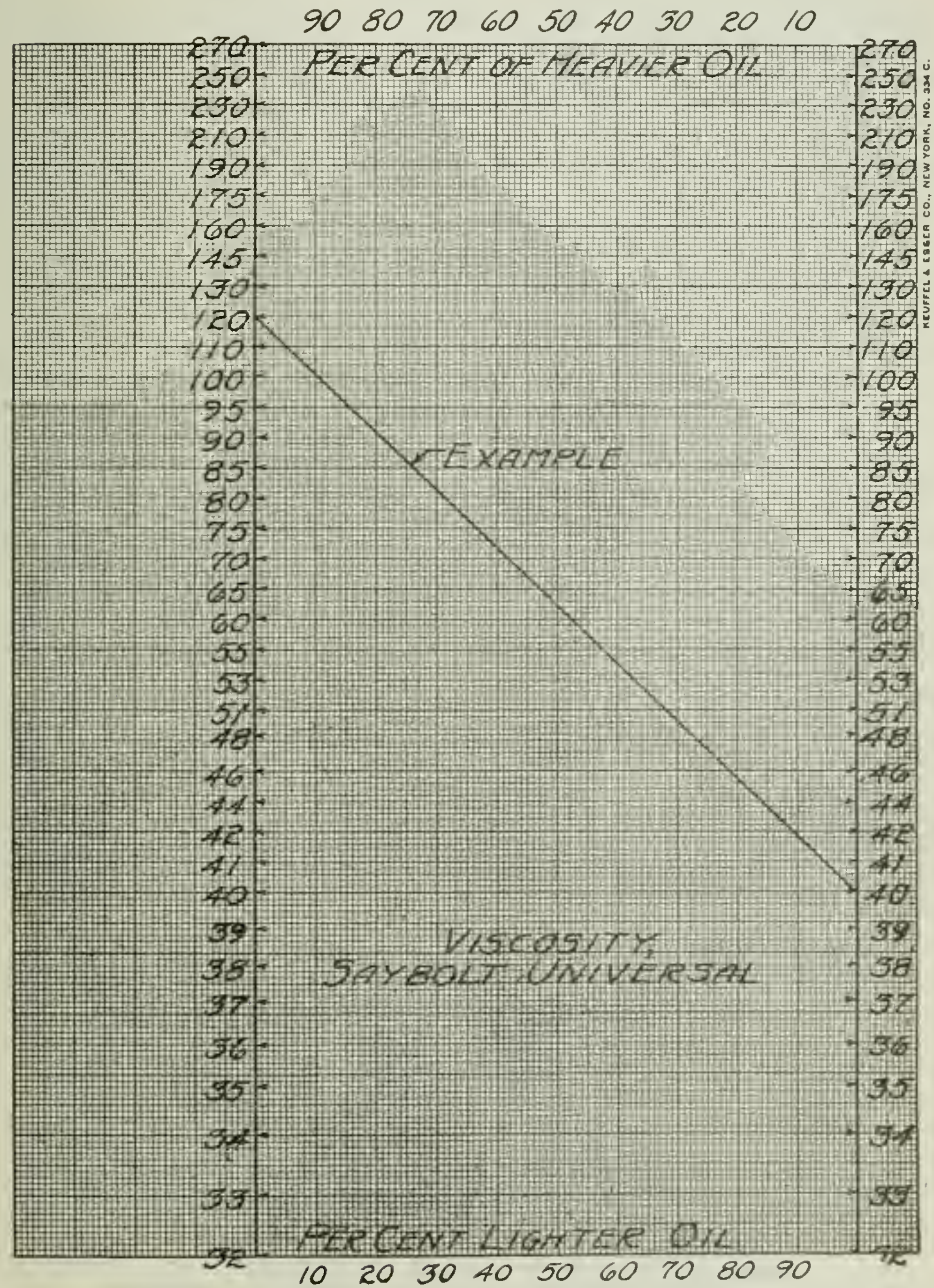


Fig. 54—Viscosity Blending Chart for Lubricating Oils.

The residual carbon is a most harmful property in lubricants for explosion motors, such as automobiles. High residual carbon is found in poorly refined and blended oils. It is usually found in oils that are not entirely made from overhead or distilled stock but partly from cylinder or residual stocks or fatty oils.

Cold test determines the lowest temperature at which the oil will flow. A low cold test is desirable for ease in circulating and handling in cold weather. A low cold test for motor oils indicates the absence of heavy ends that produce excessive carbon in the cylinder.

Color is not an index of the value of a lubricating oil. The lighter the color, other things being equal, the purer the oil.

Free acid should be, and usually is, absent. It is an indication of mineral acid that has not been neutralized and washed out in refining or of the presence of naphthenic acids, or of the use of animal or vegetable oils.

A lubricating oil for use in internal combustion engines should have a good viscosity at all temperatures under which the engine will operate. This means that the oil should remain fluid in the coldest weather and should have some degree of viscosity up to 250°F. The piston walls of the engine attain temperatures as high as 400°F. At this high temperature, however, practically all oils have the same viscosity. However, it is quite important that the oils also have a good viscosity at the lower temperatures. An engine motor oil should be a completely distilled oil and should contain no residual or fatty matter. On evaporation in air at 500°F it should yield a minimum amount of pitch and by the Conradson carbon test should have the minimum amount of carbon. The flash point is mainly of importance in that it indicates that the oil contains no light oils. So far as operating conditions are concerned, it is of little importance for the reason that a motor oil in a short time after being used, has a very low flash point. After the oil has served its purpose and gotten by the piston rings, then it should readily evaporate and leave a minimum amount of carbonaceous matter. A motor oil containing vegetable or animal oil produces acid on being subjected to heat and pressure.

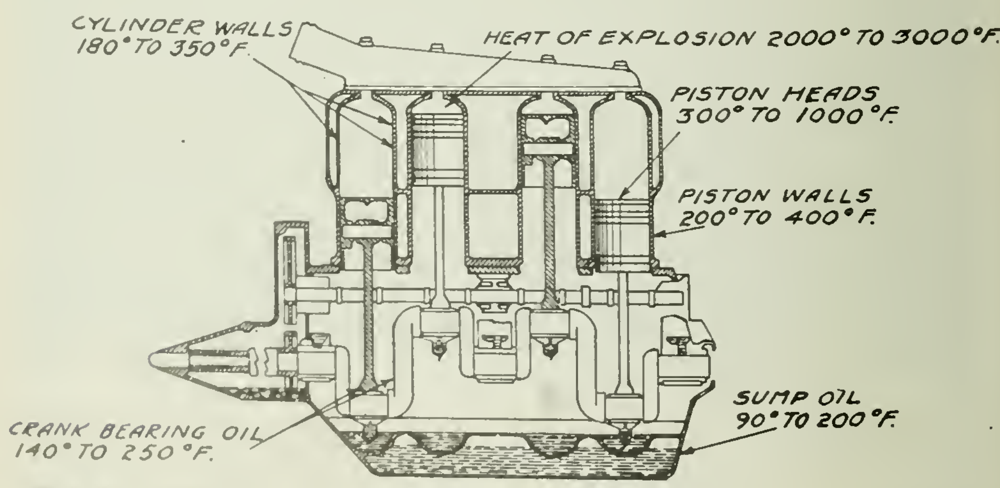


Fig. 55—Operating Temperatures of Various Parts of a Gasoline Engine.

Summary of Tests of Motor Lubricants of Standard Quality as Purchased on the Kansas City Market in January 1922*.

1. Key Number........	1	2	3	4	5	6	7	8	9
3. Retail price.........	$1.20	$1.20	$1.20	$1.20	$1.00	$1.00	$1.20	$1.20	$1.00
4. Specific gravity......	.9325	.908	.912	.917	.896	.874	.920	.938	.903
5. Baume' Gravity.....	20.2°	24.3°	23.6°	22.8°	26.4°	30.4°	22.3°	19.3°	25.1°
6. Color—N. P. A......	Q	E	M	M	N 4½	O P 5½	P S 6¼	E+	N 4½
7. Color—Iodimetric....	351	1480	52	51	70	247	219	2048	88
8. Flow test	15° F	47° F	+5° F	+3° F	+4° F	35° F	28° F	27° F	+10° F
9. Flash point—open...	355° F	430° F	360° F	365° F	250° F	300° F	365° F	325° F	350° F
10. Fire test............	430° F	496° F	415° F	420° F	375° F	465° F	425° F	410° F	405° F
11. Viscosity—Saybolt—									
Stand'd Univ. 70° F	2400	4410	710	810	336	720	1035	4775	505
100° F	650	1300	250	285	155	300	327	992	198
150° F	150	305	85	91	65	105	99	203	75
210° F	61	97	49	52	44	56	52	71	46
12. Carbon (ASTM).....	0.48%	1.43%	0.08%	0.08%	0.09%	0.39%	0.18%	1.05%	.085%
13. Gumming and Coking									
(Pitch)...........	18.4%	45.6%	10.8%	11.6%	14.0%	29.2%	12.8%	30.0%	12.8%
14. Heat-pressure tests—									
Pressure—maximum .	21.5a	28.9	23.5	32.3	24.5	22.5	28.9	36.0	29.2
Gravity increase Be' .	4.6	6.3	4.3	6.4	4.1	6.9	5.3	5.1	4.5
Gasoline produced %	19.0	23.0	20.0	24.0	21.0	24.0	23.0	18.0	21.0
Gasoline gravity Be	56.7	60.0	57.2	58.5	56.8	60.5	58.2	57.2	59.1
Kerosene produced %	16.0	16.0	16.0	16.0	20.0	17.0	16.0	16.0	17.0
Kerosene gravity Be'	29.8	38.0	33.6	34.0	36.2	40.6	33.8	32.9	35.4
Residue %..........	65.0	61.0	64.0	60.0	59.0	59.0	61.0	66.0	62.0
Gravity residue Be'	17.0	19.2	22.6	17.1	20.9	27.0	16.7	16.1	19.5
Pitch in residue %	26.5	45.9	11.6	20.0	14.9	26.4	32.1	29.7	19.4
Acidity N/10%......	8.0	3.5	7.0	4.5	4.5	4.5	4.0	9.0	4.0

*The tests include Mobiloil, Monogram, Polarine, Texaco, Enarco, Vedol, Havoline and Sinclair brands.

Summary of Tests of Motor Lubricants of Standard Quality as Purchased on the Kansas City Market in January, 1922—Continued.

1.....	10	11	12	13	14	15	16	17	18	19	20
3.....	$1.00	$1.00	$1.00	$0.90	$0.90	$1.00	$1.00	$1.00	$1.20	$1.05	$1.50
4.....	.915	.915	.927	.897	.913	.8685	.869	.922	.927	.902	.963
5.....	23.1°	23.1°	21.1°	26.2°	23.5°	31.4°	31.4°	22.0°	21.1°	25.4°	15.4°
6.....	O-5	D	I J 2¼	I J 2¼	E	M-4	M-4	N 4½	O P 5½	P-6	G
7.....	152	719	15	13	1100	44	154	79	190	155	2
8.....	29° F	41° F	—21° F	+24° F	43° F	+23° F	34° F	+5° F	5° F	40° F	—14° F
9.....	370° F	390° F	360° F	380° F	410° F	380° F	390° F	330° F	355° F	395° F	530° F
10.....	420° F	475° F	420° F	435° F	470° F	460° F	475° F	395° F	420° F	460° F	590° F
11.....											
	856	1800	1835	556	2776	441	732	884	2345	655	5350
	315	570	510	214	660	187	297	295	666	248	1365
	105	157	127	79	173	76	106	91	159	86	320
	52	65	62	17	68	47	56	50	63	48	104
12.....	0.11%	0.72%	0.04%	0.06%	0.98%	.044%	0.25%	0.12%	0.26%	0.08%	0.195%
13.....	12.0%	25.6%	10.4%	7.6%	30.4%	11.2%	20.0%	10.4%	21.2%	11.6%	67.0%
11.....											
	24.5	30.6	21.5	22.0	27.2	25.0	32.3	23.0	28.9	28.9	80.0
	4.1		5.0	4.8	5.6	5.9	5.9	5.1	5.8	4.8	11.4
	18.0	22.0	20.0	20.0	21.0	25.0	26.0	19.0	20.0	21.0	25.0
	57.9	58.9	57.9	60.7	59.8	61.1	61.9	59.1	59.4	60.1	56.7
	15.0	17.0	16.0	15.0	16.0	18.0	18.0	18.0	17.0	16.0	20.0
	34.6	36.1	41.5	37.2	38.8	40.4	40.2	33.0	33.8	37.8	31.5
	66.0	61.0	64.0	65.0	63.0	57.0	56.0	63.0	63.0	63.0	55.0
	19.0	18.2	17.9	22.0	19.3	27.3	25.5	18.1	16.8	19.7	16.7
	20.0	32.1	11.9	10.0	20.4	10.0	17.6	12.0	17.6	17.6	42.4
	5.0	3.5	1.0	3.0	4.0	2.5	2.5	4.5	4.0	5.0	766.0

Sample No. 20 is castor oil.

Properties of Various Lubricants.

PARTLY FROM "PETROLEUM."

Trade Name or Classification	Machines and Conditions	Compound Per Cent	Baume Gravity Degrees	Saybolt Viscosity	Flash Point, F°	Fire Test, F°	Cold Test, F°
Cylinder oil	Steam engine; medium pressure; no superheater	Five per cent	24.5–27	250 @ 212° F	620	690	44
Cylinder oil	Steam engine; high pressure; superheater	Straight mineral	24.5	375 @ 212° F	630	700	.....
Cylinder oil	Steam engine; low pressure; no superheater	Five per cent	25–26.0	130-150 @ 212° F	550	600	.....
Engine oil (heavy)	Heavy, hot bearings (extreme)	Straight mineral	24.0	300–325 @ 100° F	450	500	40
Engine oil (heavy)	Heavy bearings; lower duty than above	Straight mineral	24.5–25	250–280 @ 100° F	400	450	35
Engine oil (heavy compound)	Heavy bearings	5% compound	24–25	190–240 @ 100° F	400	450	34–36
Engine oil (medium)	Medium bearings; splash feed; pump circulation	Five per cent	28–30	190–210 @ 100° F	400	450	32
Crankcase oil (heavy)	Steam engine; crankcase splash	Straight mineral	26.5	150 @ 100° F	440	490	30
Crankcase oil (medium)	Steam engine; crankcase splash	Straight mineral	28.0	120 @ 100° F	400	450	28
Crankcase oil (light)	Steam engine	Straight mineral	32.0	75 @ 100° F	395	445	26
Turbine oil (heavy)	Steam turbine; large sizes	Straight mineral	30.5	200 @ 100° F	420	470	20
Turbine oil (light)	Steam turbine; small sizes	Straight mineral	32.0	150 @ 100° F	395	445	.....
Compressor oil (heavy)	Air compressor; single stage	Straight mineral	26.5	115 @ 212° F	500	550	55
Compressor oil (light)	Air compressor; two-stage	Straight mineral	30.0	200–380 @ 100° F	420	470	20–25
Ice machine	Ammonia compressor; two-stage	Straight mineral	26–27	100 @ 70° F	350–360	420	0–4
Dynamo oil (heavy)	Large dynamos and motors; ring oil bearings	Straight mineral	30.5	200 @ 100° F	420	470	20
Dynamo oil (medium)	Medium dynamos and motors; ring oil bearings	Straight mineral	32.0	150 @ 100° F	395	445	.....
Dynamo oil	Small motors, 1/32 to 5 HP; small ring oil bearings	Straight mineral	27.5	90 @ 100° F	345	400	18
Black machine	Rough, slow speed bearings, lineshafts, crushers, etc.; cheap work	Straight mineral	29.0	100 @ 70° F	325	380	5–15

Properties of Various Lubricants—Continued.

Trade Name or Classification	Machines and Conditions	Compound Per Cent	Baume' Grqvity Degrees	Saybolt Viscosity	Flash Point, F°	Fire Test, F°	Cold Test F°
General machine (heavy)	Hoists, elevators and general machinery, cool running	Straight mineral	24.0	300 @ 100° F	410	460	40
General machine (medium)	Machine tools, print presses, large lathes, etc	Straight mineral	26.0	150 @ 100° F	380	430	30
Spindle oil	Light machines for spinning, automatics, etc	Straight mineral	30–35	60–150 @ 70° F	340	390	.....
Loom oil	Weaving machines; highspeed medium weight machines	Straight mineral	28.0	203 @ 100° F	360	400	.....
Gas engine oil	Gas engine cylinders and general splash and force feed lubrication of gasoline automobile and tractor engines	Straight mineral	24.0	300–400 @ 212° F	210–420	250–470	.....
Motor (light)	Pa. Petroleum	0.0012% C. Carbon	30.5	185 @ 100° F	415	475	20° F
Motor (medium)	Pa. Petroleum	0.0031% C. Carbon	30.0	285 @ 100° F	435	500	25
Motor (heavy)	Pa. Petroleum	0.0060% C. Carbon	29.5	475 @ 100° F	440	500	35
Cylinder oil	Ranger, Texas	1.976 % C. Carbon	22.6	135 @ 212° F	485	550	50
Motor oil	Texaco	0.045 % C. Carbon	20.0	652 @ 100° F	380	450	10° F

EFFECT OF AIR-COOLED MOTOR (FRANKLIN) ON LUBRICATING OIL

	No. 1	No. 2
Crude from which manufactured	South Texas	Pennsylvania
Gravity before using	.934=20.0° Be'	.875=30.2° Be'
Gravity after using	.920=22.3° Be'	.860=33.0° Be'
Viscosity at 100° before use	652	251
Viscosity at 100° after use	229	140
Free carbon before use	0.00	0.00%
Free carbon after use	0.08%	90%
Conradson carbon before use	0.045%	0.050
Miles car run in use	1000	600
Lubricating oil consumed	8%	40%

NATURAL HYDROCARBONS—VACUUM DISTILLED.

Table showing the properties of vacuum distilled hydrocarbons and atmospheric pressure forced fire distilled hydrocarbons of a heavy residuum from Mid-Continent oil.

Fraction	Gravity	Viscosity	Sulphur
0—10%	0.868 31.3°Be′	46	0.39%
10—20%	0.877 29.6°Be′	60	0.35%
20—30%	0.895 26.4°Be′	143	0.43%
30—40%	0.909 24.0°Be′	293	0.53%
40—50%	0.920 22.1°Be′	740	0.76%
50—60%	0.920 22.1°Be′	745	0.68%
60—70%	0.920 22.1°Be′	1058	0.70%
70—80%	0.920 22.1°Be′	2600	0.56%

HYDROCARBONS FROM FORCED FIRE DISTILLATION OF SAME OIL.

Fraction	Gravity	Viscosity
0—10%	0.864 32.1°Be′	51
10—20%	0.877 29.6°Be′	69
20—30%	0.888 27.6°Be′	109
30—40%	0 893 26.7°Be′	141
40—50%	0.894 26.6°Be′	141
50—60%	0.887 27.0°Be′	106
60—70%	0.878 29.4°Be′	75
70—80%	0.877 29.6°Be′	69

EFFECT OF TEMPERATURE ON VISCOSITY OF NATURAL MID-CONTINENT HEAVY OILS.

		Av'ge Mid-Continent Fuel Oil 26.8°Be′	Heavy Kansas Crude 19.6°Be′
60°F	=	294.	....
70°F	=	190.	3360.
100°F	=	94.	1250.
120°F	=	70.	680.
120°F	=	55.	328.
212°F	=	41.	105.

(Viscosity is expressed in terms of the Saybolt Universal)

EFFECT OF CRACKING ON THE LUBRICATING QUALITIES OF OIL.

In the cracking of petroleum by heat the paraffin hydrocarbons are most readily decomposed into lighter hydrocarbons. The lubricating hydrocarbons remaining in cracked oil are therefore not paraffin but consist chiefly of naphthenes and aromatics. In other words, cracking reduces the viscosity of heavy hydrocarbon oils based on the same gravity. This fact is set forth in the patent to Burton (U. S. No. 1,167,884, Jan. 11, 1916) as follows:

Lubricating fractions made from Mid-Continent Crude Petroleum:

Baume′ Gravity	Viscosity at 100° (Saybolt Viscosimeter)
25.0	235
26.0	190
26.0	165
26.5	145
27.5	100

Lubricating fractions made from California Crude Petroleum:

Baume′ Gravity	Viscosity at 100°
18.8	449
20.4	235
20.6	339
21.6	146
21.8	167
22.5	139

Lubricating fractions made from Cracked Petroleum Residua:

Baume′ Gravity	Viscosity	Gravity	Viscosity
28.9	36	15.2	88
26.5	38	15.0	89
23.8	42	14.7	97
21.5	45	14.1	105
21.1	51	13.2	110
20.2	52	13.0	116
18.7	58	12.0	158
17.8	62	10.8	198
17.2	65		
16.7	66		
15.8	76		

U. S. Specifications for Lubricating Oils.

CLASS "A".

General:

1. This specification covers the grades of petroleum oil used by the United States Government and its agencies for the general lubrication of engines and machinery where a highly refined oil is not required. This oil is not to be used for steam cylinder lubrication.

2. Only refined petroleum oils without the admixture of fatty oils, resins, soap or other compounds not derived from crude petroleum will be considered.

3. These oils shall be supplied in five grades, known as extra light, light, medium, heavy and extra heavy.

Properties and Tests:

4. Flash and Fire Points: The flash and fire points of the five grades shall not be lower than the following:

	Flash Deg. F	Fire Deg. F
Extra light	315	355
Light	325	365
Medium	335	380
Heavy	345	390
Extra heavy	355	400

5. Viscosity: The viscosity of the five grades of oil at 100°F shall be within the following limits:

Extra light	140-160 seconds
Light	175-210 seconds
Medium	275-310 seconds
Heavy	370-410 seconds
Extra heavy	470-520 seconds

6. Color: The color of the extra heavy grade shall not be darker than No. 6 National Petroleum Association Standard, or its equivalent. The color of the other grades shall not be darker than No. 5 National Petroleum Association Standard, or its equivalent.

7. Pour Test: The pour test shall not be above the following temperatures:

Extra light	35°F
Light	35°F
Medium	40°F
Heavy	45°F
Extra heavy	50°F

8. Acidity: Not more than 0.10 milligram of potassium hydroxide shall be required to neutralize 1 gram of the oil.

9. Corrosion: A clean copper plate shall not be discolored when submerged in the oil for 24 hours at room temperature.

10. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

U. S. Specifications for Lubricating Oils.

CLASS "B"

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication of turbines, dynamos, high speed engines and other classes of machinery where an oil better than Class A is required. The oil shall be satisfactory for use in circulating and forced feed systems.

2. Only refined petroleum oils without the admixture of fatty oils, resins, soaps or other compounds not derived from crude petroleums will be considered.

3. These oils shall be supplied in five grades known as extra light, light, medium, heavy and extra heavy.

4. Flash and Fire Points: The flash and fire points of the five grades shall not be lower than the following:

	Flash Deg.F	Fire Deg.F
Extra light	315	355
Light	325	365
Medium	335	380
Heavy	345	390
Extra heavy	355	400

5. Viscosity: The viscosity of the five grades at 100°F shall be within the following limits:

Extra light	140-160 seconds
Light	175-210 seconds
Medium	275-310 seconds
Heavy	370-410 seconds
Extra heavy	470-520 seconds

6. Color: The color of the extra heavy grade shall not be darker than No. 6 National Petroleum Association Standard or its equivalent. The color of the other grades shall not be darker than No. 5 National Petroleum Association Standard or its equivalent.

7. Pour Test: The pour test shall not be above the following temperatures:

Extra light	35°F
Light	35°F
Medium	40°F
Heavy	45°F
Extra heavy	50°F

8. Acidity: Not more than 0.07 milligram of potassium hydroxide shall be required to neutralize 1 gram of oil.

9. Corrosion: A clean copper plate shall not be discolored when submerged in the oil for 24 hours at room temperature.

10. Emulsifying properties: The oil shall separate (see note) in 30 minutes from an emulsion with 1—Distilled water, 2—1% salt solution, 3—Normal caustic soda solution.

Note:—This means that there shall be only a slight cuff between the water and the oil.

The demulsibility shall not be less than 300.

11. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

Specifications for Lubricating Oils.

CLASS "C"

GENERAL:

1. This specification covers the grades of petroleum oil used by the United States Government and its agencies for lubrication of air compressors and international combustion engines, except aircraft, motorcycle and Diesel engines; also for the lubrication of turbines and other machinery where an oil better than Class B is required. This oil shall be satisfactory for use in circulation and forced feed systems.

2. Only refined petroleum oils without the admixture of fatty oils, resins, soaps or other compounds not derived from crude petroleum will be considered.

3. These oils shall be supplied in five grades, known as extra light, light, medium, heavy and extra heavy.

PROPERTIES AND TESTS:

4. Flash and fire points: The flash and fire points of the five grades shall not be lower than the following:

	Flash Deg.F.	Fire Deg.F
Extra light	315	355
Light	325	365
Medium	335	380
Heavy	345	390
Extra heavy	355	400

Oil for use in oil compressors where the air leaving any stage or cylinder has a temperature above 212°F shall have a flash point not lower than 400°F.

5. Viscosity: The viscosity of the five grades at 100°F shall be within the following limits:

Extra light	140-160 seconds
Light	175-210 seconds
Medium	275-310 seconds
Heavy	370-410 seconds
Extra heavy	470-520 seconds

6. Color: The color of the extra heavy grade shall not be darker than No. 6 National Petroleum Association Standard or its equivalent. The color of the other grades shall not be darker than No. 5 National Petroleum Association Standard or its equivalent.

7. Pour test: The pour test shall not be above the following temperatures:

Extra light	35°F
Light	35°F
Medium	40°F
Heavy	45°F
Extra heavy	50°F

8. Acidity: Not more than 0.05 milligrams of potassium hydroxide shall be required to neutralize one gram of the oil.

CLASS C—LUBRICATING OILS—Continued.

9. Corrosion: A clean copper plate shall not be discolored when submerged in the oil for 24 hours at room temperature.

10. Emulsifying Properties: The oil shall separate (see note) in 30 minutes from an emulsion with:
1—Distilled water. 2—1% salt solution. 3—Normal caustic solution.

Note:—This means that there shall be only a slight cuff between the water and the oil.

The demulsibility shall not be less than 300.

11. Carbon Residue: The carbon residue shall not exceed the following:

Extra light	0.10%
Light	0.20%
Medium	0.30%
Heavy	0.40%
Extra heavy	0.60%

12. Further tests on oils of Class C may be required at the option of the Department of the Government using the oils.

13. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

AIRCRAFT MACHINE GUN OIL.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication of machine guns on aircraft, for the c.c. interrupter gears and for gun oil for cleaning and oiling machine guns and small arms.

2. The oil shall be a highly refined, filtered, straight-run petroleum oil, suitable in every way for the uses specified in Paragraph 1. It shall be a pure petroleum product, without the addition of vegetable or animal oils or fats of any kind. It shall not contain any material which might gum or corrode metals under any conditions.

PROPERTIES AND TESTS:

3. Flash point: The flash point shall not be less than 200°F.

4. Viscosity: The viscosity at 100°F shall be within the following limits: 80 to 115 seconds.

5. Pour test: The pour test shall be 45 degrees or more below zero Fahr.

6. Acidity: Not more than 0.03 milligrams of potassium hydroxide shall be required to neutralize 1 gram of oil.

7. Carbon residue: The carbon residue shall not be more than 0.03%.

8. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

BUFFER OIL FOR RECOIL AND RECUPERATOR CYLINDERS OF ALL BRITISH TYPES OF HOWITZERS AND GUN CARRIAGES.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for filling the recoil and recuperator cylinders of all British type howitzers and gun carriages.

2. The oil shall be a pure refined petroleum oil.

PROPERTIES AND TESTS:

3. The flash point shall not be lower than 265°F.

4. Viscosity: The viscosity at 100°F shall be within the following limits: 65 to 75 seconds.

5. Pour Test: The pour test shall not be above 0°F.

6. Acidity: Not more than 0.05 milligrams of potassium hydroxide shall be required to neutralize 1 gram of the oil.

7. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization for Petroleum Specifications.

CUP GREASE.

GENERAL:

1. This specification covers the grades of cup grease used by the United States Government and its agencies for the lubrication of such parts of motor equipment and other machinery as are lubricated by means of compression cups; # ½ and #1 to be used in spindle cups or transmissions.

2. The grease shall be a well manufactured product, composed of a calcium soap made from high grade animal or vegetable oils or fatty acids, and a highly refined mineral oil.

3. The mineral oil used in reducing the soaps shall be a straight well refined mineral oil with a viscosity at 100°F of not less than 100 seconds.

PROPERTIES AND TESTS:

4. Soap Content:

(a) # ½ cup grease shall contain approximately 13% calcium soap
(b) # 1 cup grease shall contain approximately 14% calcium soap
(c) # 3 cup grease shall contain approximately 18% calcium soap
(d) # 5 cup grease shall contain approximately 24% calcium soap

5. Consistency: These greases shall be similar in consistency to the approved trade standards for # ½, # 1, # 3 and # 5 grease.

6. Moisture: The grease shall be a boiled grease, containing not less than one or more than three per cent of water when finished.

7. Corrosion: A clean copper plate shall not be discolored when submerged in the grease for 24 hours at room temperature.

8. Ash:

½ grease. The ash shall not be greater than 1.7%
1 grease. The ash shall not be greater than 1.8%
3 grease. The ash shall not be greater than 2.3%
5 grease. The ash shall not be greater than 3.5%

9. Fillers: The grease shall contain no fillers such as resins, resinous oils, soapstone, wax, talc, powdered mica or graphite, sulphur, clay, asbestos or any other filler.

10. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

TRANSMISSION LUBRICANT.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication of transmission gears and bearings, differential gears, worm drives, winch drives and roller and ball bearings used in connection with such parts of the equipment of motor vehicles.

2. The lubricant shall be a refined petroleum product, without the addition of any vegetable or animal oils or products derived from them and be entirely free from fillers.

PROPERTIES AND TESTS:

3. Flash point: The flash point shall not be lower than 460°F.

4. Viscosity: The viscosity at 210°F shall be within the following limits: 175 to 220 seconds.

5. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

MARINE ENGINE OIL.

GENERAL:

1. This specification covers the grade of oil used by the United States Government and its agencies for the lubrication of reciprocating steam engines in marine service where a compound engine oil is required.

This oil must not be used in circulating or forced feed systems.

PROPERTIES AND TESTS:

2. The oil shall be a compounded oil made from refined petroleum oil and 10% to 20% of blown refined rapeseed or blown refined peanut oil; so compounded that it will not separate or break down in any way either before or while in service.

3. Viscosity: The viscosity shall be:

65 to 75 seconds at 210°F.
Not over 700 seconds at 100°F.

4. Pour Test: The pour test shall not be above 32°F.

5. Acidity: The oil shall not contain more than 1.50% of acid calculated as oleic acid (equivalent to 3.0 mg K.O.H. per gram of oil).

6. Corrosion: A clean copper plate shall not be discolored when submerged in oil for 24 hours at room temperature.

7. Emulsifying Properties: The oil shall remain completely emulsified for an hour from an emulsion with:

1. Distilled water. 2. 1% salt solution.

8. Wick Feed: The oil shall show a flow at the end of 14 days of at least 30% of its flow at the end of the first 24 hour period.

9. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

MINERAL STEAM CYLINDER OIL FOR NON-CONDENSING ENGINES.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for non-condensing steam engine cylinder lubrication where a mineral oil is required; also as a stock oil for compounding.

PROPERTIES AND TESTS:

2. The oil shall be a well refined petroleum oil without compounding of any nature.

3. Flash point: The flash point shall not be lower than 475°F.

4. Viscosity: The viscosity at 210°F shall be within the following limits: 135 to 165 seconds.

5. Cold test: The cold test shall not be above 45°F.

6. Precipitation test: When 5 cc of the oil is mixed with 95 cc of petroleum ether and allowed to stand 24 hours, it shall not show a precipitate or sediment of more than 0.25 cc (5% by volume of the original oil).

7. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

COMPOUNDED STEAM CYLINDER OIL FOR NON-CONDENSING ENGINES.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication of steam cylinders of non-condensing engines and pumps where a compounded oil is required.

PROPERTIES AND TESTS:

2. The oil shall be a well refined petroleum oil, compounded with not less than 5 nor more than 7% of acidless tallow oil or lard oil.

3. Flash point: The flash point shall not be lower than 475°F.

Viscosity: The viscosity at 210°F shall be within the following limits: 120 to 150 seconds.

5. Cold test: The cold test shall not be above 45°F.

6. Precipitation test: When 5 cc of the oil is mixed with 95 cc of petroleum ether and allowed to stand 24 hours, it shall not show a precipitate or sediment of more than 0.25 cc (5% by volume of the original oil.)

7. Acidity: The oil shall not contain more than 0.40% of acid calculated as oleic acid (equivalent to 0.80 mg. KOH per gm. of oil).

8. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

FLOOR OIL.

GENERAL:

1. This specification covers the grade of oil used by the United States Government and its agencies for polishing and preserving wooden floors.

2. The oil shall be a well refined straight petroleum oil.

PROPERTIES AND TESTS:

3. Flash point: The flash point shall not be lower than 300°F.

4. Viscosity: The viscosity at 100°F shall be within the following limits: 60 to 100 seconds.

5. Color: The oil shall be pale or red in color. Black oil will not be accepted.

6. Pour test: The pour test shall not be above 35°F.

7. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

GEAR CHAIN AND WIRE ROPE LUBRICANT.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication and protection of chains, wire ropes and gears of cranes, dredges, steam shovels and all other heavy equipment, for the lubrication and protection of the gears and ropes of balloon hoists; and for swabbing the wires and cables of aircraft.

2. The oil shall be a petroleum product only, free from vegetable or animal oils or products derived from them. It shall be entirely free from fillers, such as talc, resin, and all materials of every nature not related to the original product.

PROPERTIES AND TESTS:

3. Viscosity: The viscosity at 210°F shall be within the following limits: 900 to 1,100 seconds.

4. Protection: When applied to a plate of polished steel the lubricant shall protect the steel for a period of thirty days when immersed in a 10% salt solution.

5. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

GUN AND ICE MACHINE OIL.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for cleaning and oiling guns and small arms where Aircraft Machine Gun Oil is not required; also for lubrication of the cylinders of Ice Machines; for lubrication of pneumatic tools and for hydraulic systems.

2. The oil shall be a straight-run, highly refined petroleum oil, free from vegetable or animal oils or products derived from them; shall be suitable in every way for the uses listed in Paragraph 1; and shall not gum or corrode metals under any conditions.

3. These oils shall be supplied in two grades known as # 100 and # 125.

PROPERTIES AND TESTS:

4. Flash point: The flash point shall not be lower than 290°F.

5. Viscosity: The viscosity at 100°F shall be within the following limits:

100 oil 95 to 110 seconds
125 oil 120 to 135 seconds

6. Pour test: The pour test shall not be above 5°F.

7. Acidity: Not more than 0.03 milligram of potassium hydroxide shall be required to neutralize 1 gram of the oil.

8. Emulsifying properties: The oil shall separate completely in 30 minutes from an emulsion with:

1. Distilled water.
2. 1% salt solution.
9. Normal caustic soda solution.

The demulsibility shall not be less than 300.

9. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

RECOIL OIL.

GENERAL:

1. This specification covers the grades of petroleum oil used by the United States Government and its agencies to fill the recoil cylinders of gun carriages.

2. Only refined petroleum oils without the admixture of fatty oils, resins, soap or other compounds not derived from crude petroleum will be considered.

3. These oils shall be supplied in three grades, known as light, medium and heavy.

PROPERTIES AND TESTS:

4. Flash and fire points: The flash and fire points of the three grades will not be lower than the following:

	Flash Deg.F	Fire Deg.F
Light	225	250
Medium	315	355
Heavy	345	390

5. Viscosity: The viscosity of the three grades of oil at 100°F shall be within the following limits:

Light	40- 45 seconds
Medium	140-160 seconds
Heavy	385-430 seconds

6. Color: The oil shall be pale or red in color. Black oil will not be accepted.

7. Pour test: The pour test shall be 5 or more degrees below zero F.

8. Acidity: Not more than 0.05 milligram of potassium hydroxide shall be required to neutralize 1 gram of the oil.

9. Corrosion: A clean copper plate shall not be discolored when submerged in the oil for 24 hours at room temperature.

10. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

LIBERTY AERO AND MOTOR CYCLE OIL.

GENERAL:

1. This specification covers the grade of oil used by the United States Government and its agencies for the lubrication of stationary cylinder air-craft engines and motor cycles.

2. The oil shall be made from pure, highly refined petroleum products and must be suitable in every way for the entire lubrication of stationary cylinder air-craft engines and motorcycle engines operating under all conditions. The oil shall not contain moisture, sulphonates, soap, resin, or tarry constituents which would indicate adulteration or lack of proper refining.

3. These oils shall be supplied in two grades, to be known as Grade 1 and Grade 2.

PROPERTIES AND TESTS:

4. Flash point: The flash point of the two grades shall not be lower than the following:

Grade 1—400°F. Grade 2—500°F.

5. Viscosity: The viscosity of the two grades at 210°F shall be within the following limits:

Grade 1	(Summer)	90-100 seconds
	(Winter)	75- 85 seconds
Grade 2		125-135 seconds

6. Pour Test: The pour test of Grade 1 shall not be above the following limits:

Summer 45°F. Winter 15°F.

7. Cold Test: The cold test of Grade 2 shall not be above 35°F.

8. Acidity: Not more than 0.10 mg. of potassium hydroxide shall be required to neutralize one gram of Grade 1 oil.

9. Emulsifying Properties: The oil shall separate completely in one hour from an emulsion from distilled water at a temperature of 180°F.

10. Carbon Residue: The carbon residue on Grade 1 shall not be over 1.5%; on Grade 2, not over 2.00%.

11. Precipitation test: When 5 cc of the oil is mixed with 95 cc of petroleum ether and allowed to stand 24 hours, it shall not show a precipitate or sediment of more than 0.25 cc (5% by volume of the original oil).

12. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

OIL AND GREASE USED IN RECOIL MECHANISM OF 75 AND 155 MM GUN CARRIAGE (French).

GENERAL:

1. This specification covers the grade of petroleum oil and grease used by the United States Government and its agencies for the recoil mechanism of 75 and 155 mm French gun carriages.

RECUPERATOR OIL:

2. Recoil oil (heavy) shall be used.

RECUPERATOR GREASE:

3. The grease shall be a well manufactured product composed of a calcium soap made from high grade animal or vegetable oils or fatty acids and a highly refined mineral oil.

4. The mineral oil used in reducing the soap shall have a viscosity at 100°F of not less than 180 seconds.

PROPERTIES AND TESTS:

5. Soap Content: The grease shall contain approximately 18% of a calcium soap.

6. Consistency: This grease shall be similar in consistency to the approved trade standard for No. 3 grease.

7. Moisture: The grease shall be a boiled grease containing not less than 1 nor more than 3% of water when finished.

8. Corrosion: A clean copper plate shall not be discolored when submerged in the grease for 24 hours at room temperature.

9. Ash: The ash shall not be greater than 2.3%.

10. Fillers: The grease shall contain no fillers, such as rosin, resinous oils, soapstone, wax, talc, powdered mica or graphite, sulphur, clay, asbestos or any other filler.

11. All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

PARAFFIN WAX.

GENERAL:

1. This specification covers the grades of paraffin wax used by the United States Government and its agencies.

2. This wax shall be a highly refined petroleum product, free from animal or vegetable wax or other adulterants.

3. This wax shall be supplied in three grades known as 130-132, 124-127, and 117-120.

PROPERTIES AND TESTS:

4. Color: The color shall be water-white.

5. Melting point: The melting points shall be as indicated:

Grade	°F Melting point	°C
130-132	130-132	approx. 55
124-127	124-127	approx. 52
117-120	117-120	approx. 48

All tests shall be made according to the methods for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

TRANSFORMER OIL.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for oil switches, oil circuit breakers and transformers.

2. The oil shall be made from pure, highly refined petroleum products, free from animal or vegetable oils or fats of any kind and shall be suitable in every way for the purpose listed in paragraph one.

PROPERTIES AND TESTS:

3. Flash point: The flash point shall not be lower than 290°F.

4. Viscosity: The viscosity at 100°F shall be within the following limits: 95-110 seconds.

5. Pour test: The pour test shall not be above 20°F.

6. Acidity: Not more than 0.03 mg. of potassium hydroxide shall be required to neutralize one gram of the oil.

7. Heat Test: The oil shall not show a deposit or any change other than a darkening of color when heated to 450°F.

8. Corrosion test: A clean copper plate shall not be discolored when submerged in the oil for 24 hours at room temperature.

9. Break down test: The break down value shall not be less than 23,000 volts.

10. Unsaturation test: The oil shall not contain more than 4.0% of hydrocarbons soluble in concentrated sulphuric acid.

All tests shall be made according to the methods of testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

CAR OIL.

GENERAL:

1. This specification covers the grade of oil used by the United States Government and its agencies as a lubricant on journals of all cars, passenger coaches, steam and electric locomotives.

2. Only refined petroleum oils, without the admixture of fatty oils or other compounds not derived from crude petroleum will be considered.

PROPERTIES AND TESTS:

3. Flash point: The flash point of this oil shall not be lower than 300°F.

4. Viscosity: The viscosity at 210°F shall be within the following limits: 65-75 seconds.

5. Cold test: The cold test shall not be above 32°F.

6. Precipitation test: When 5 cc of the oil is mixed with 95 cc of petroleum ether and allowed to stand 24 hours, it shall not show a precipitate or sediment of more than 0.25 cc (5% by volume of the original oil).

7. All tests shall be made according to the method for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

LOCOMOTIVE ENGINE OIL.

GENERAL:

1. This specification covers the grade of oil used by the United States Government and its agencies as a lubricant (by the Panama Canal) for all locomotives, running gears of all locomotive cranes, deck machinery of dredges (except engines) and for cold-saws in machine shops.

2. Only refined petroleum oils, without the admixture of fatty oils or other compounds not derived from crude petroleum, will be considered.

PROPERTIES AND TESTS:

3. These specifications are identical with those of Car Oil (Panama Canal).

4. Flash point: The flash point of this oil shall not be lower than 300°F.

5. Viscosity: The viscosity at 210°F shall be within the following limits: 65 to 75 seconds.

6. Cold Test: The cold test shall not be above 32°F.

7. Precipitation test: When 5 cc of the oil is mixed with 95 cc of petroleum ether and allowed to stand 24 hours, it shall not show a precipitate or sediment of more than 0.25 cc (5% by volume of the original oil).

8. All tests shall be made according to the method for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

CRANK PIN GREASE, DRIVING JOURNAL COMPOUND, ROD CUP GREASE.

GENERAL:

1. This specification covers the grade of grease used by the United States Government and its agencies for the lubrication of driving journal on locomotives (provided with grease cellars) and for the lubrication of cranks and rods on locomotives (provided with grease cups).

2. The grease must be a well manufactured product, suitable in every way for the purpose listed in paragraph No. 1. It shall be composed of a soda soap (made from tallow) combined with a well refined cylinder stock petroleum oil.

PROPERTIES AND TESTS:

3. It shall be smooth, uniform and must not crumble under pressure.

4. Color: Driving Journal Compound shall be green or greenish in color. Rod Cup Grease and Crank Pin Grease shall be slightly yellowish, in color.

5. Soap Content: The soap content shall not be less than the following:

Driving Journal Compound........................45%
Rod Cup Grease..40%

6. Free Alkali: Neither grade shall contain less than 0.50% nor more than 2.5% of free alkali, calculated as NaOH.

7. The total water, glycerin and impurities present shall not exceed one-third of the total dry soap content.

8. All tests shall be made according to the method for testing lubricants adopted by the Committee on Standardization of Petroleum Specifications.

PETROLEUM GREASE.

Petroleum grease is a sort of amorphous wax. It is obtained as follows:

When refining to cylinder stock, the residue in the still, which is a cylinder stock, is mixed with naphtha. This mixture is then allowed to settle, while being kept at a low temperature. The mixture separates into two parts, the lower being the petroleum grease and the upper part is drawn off. This upper part is then heated to drive off the naphtha which can be used again and the remaining residue is a low cold-test stock.

The petroleum grease may be filtered to produce the different colored petrolatums. With some crudes, it is possible to obtain the petrolatum stock by straight refinement; that is, it remains as a residue in the still, after the lighter parts of the crude have been distilled off. These crudes are very few, however, and come from certain sections of Pennsylvania.

PETROLATUM.

Petrolatum consists of the higher members of the Paraffin series, which settle from certain kinds of petroleum mixed and inseparable from some of the oily constituents of the oil. Its uses for the light-colored or filtered material are medicinal and for the toilet, or as dark-colored material, it is used by makers of oiled paper and for the purposes as outlined elsewhere.

Bacon & Hamor, "American Petroleum Industry" classify the commercial varieties of petrolatum under two heads:

1. Those which are obtained as a ready-formed mixture of hydrocarbons of gelatinous consistency.

2. Those made by directly mixing solid paraffins of low melting-point with heavy lubricating oils. The latter varieties are less homogeneous and are liable to deposit granules of paraffin on keeping, and they are therefore not suited for the preparation of ointments as is the true American petrolatum.

The viscosity of natural American petrolatum is given as:

	45°C	50°C	80°C	100°C
Engler Visc.	4.8	3.7	2.1	1.6

Petrolatum is also called petroleum jelly, petrolatum ointment, petrolatum album and white petrolatum jelly, according to its degree of refinement by the medical profession.

It is insoluble in water and easily soluble in ether, chloroform, oil of turpentine, benzine, carbon bisulphide, petroleum benzine and also most of the fixed or volatile oils.

The specific gravity ranges from about .820 to .865 at 60°F.

It does not oxidize on exposure to the air and is not readily acted upon by chemical reagents.

Some of the main types of greases and their uses are as follows:

(a)	Axle Grease	Carriage and wagon axles.
(b)	Cup Greases	Used in compression cups, funnel cups, or in the bearing by packing.
(c)	Gear Greases	Tacky, waterproof grease for gears, racks, etc.
(d)	Curve or Track Greases	Applied with brush or dauber to railway track curves.
(e)	Launching Grease	Used on shipways.
(f)	Tunnel-bearing Grease	Made in small blocks, about 56 lbs. Used in standard grease boxes to lubricate shaft bearings of steam ships.
(g)	Semi-fluid Grease	Used in textile mills, high-speed machinery, etc., also in mine cars.
(h)	Steel-mill Greases	Cold-neck grease. Usually a cold-set resin grease. For toll necks running at ordinary temperatures. Hot neck grease: An adhesive, high-melting-point grease, waterproof.
(i)	Elevator Greases	Plunger grease: Waterproof, acid-less grease. Must not injure rod packings. Slide grease: Used on elevator slides. Usually No. 3 consistency graphited.
(j)	Gear-shield Grease or Pinion Glaze	Usually made in 3 consistencies of different melting points. Used on steel mills, etc., where gears are exposed to intense heat. The grease in cooling forms a cushion which adheres to the gear. Usually the heavy grade requires melting before application to the gear.
(k)	Railroad Grease	Rod grease. Usually hard. Used in driving rod cups. Driving-journal compound: hard. Made to fit the grease boxes. Wool-mixed grease: Made of long-fibre woolen yarn and a small percentage of cotton waste, impregnated with a high-melting-point grease. Used for journal lubrication, instead of usual oil and waste. Air-brake grease: Usually a graphited waterproof grease.
(l)	Paper-mill Greases	Usually fiber type. High melting point. Bearings are very hot, due to steam passing through them. Wool-mixed grease often used, or box is packed with wool, and from time to time fresh grease is added.

Properties of Various Greases.

	1	2	3	4	5	6	7	8
Moisture	0.13%	11.89%	1.67%	0.72%	0.41%	1.7%	4.4%	3.6%
Ash	0.14	11.90	1.42	3.47	0.52	2.2	3.0	6.5
Insoluble in 86° petroleum ether	13.42	30.45	8.86	31.27	2.44	...	...	...
Float test 100° C	30	Over 1200	34	121	75	...	...	...
Melting point	70° F	Over 200° F	80° F	168° F	68° F	103° F	190° F	210° F
Condition of grease at 0° F	rigid hard	rigid waxy	90° pen. stiff	100° pen. stiff	60° pen. stiff	... ...	... ...	... ...

Approximate Composition.

	1	2	3	4	5	6	7	8
Mineral oil	86.6%	69.0%	91.1	68.7%	97.6%	88.3%	84.5%	67.3%
Soaps, Resin, Filler, etc	13.3	19.1	7.2	30.6	2.0	10.0	11.1	29.1
Water	0.1	11.9	1.7	0.7	0.4	1.7	4.4	3.6
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

1 = Crater.
2 = Friction proof.
3 = Spicer.
4 = Non-fluid.

5 = Green seal.
6 = Brand not known.
7 = Brand not known.
8 = Brand not known.

PETROLEUM LIQUIDUM, U. S. P.

Liquid Petrolatum.

Petrolat. Liq.—Liquid Paraffin, Mineral Oil.

A mixture of liquid hydrocarbons obtained from petroleum. Preserve it in well closed containers, protected from light.

Heavy Liquid Petrolatum.—Heavy Liquid Petrolatum has a viscosity of not less than 3.1 when determined by the test given below.

Light Liquid Petrolatum.—Light Liquid Petrolatum has a viscosity of not more than 3 when determined by the test given below and vaporizes freely.

Each variety conforms to the following description and tests:

Specific gravity for Liquid Petrolatum, 0 828 to 0.905 at 25°C.

A colorless, transparent, oil liquid, free or nearly free from fluorescence, odorless and tasteless when cold and possessing not more than a faint petroleum odor when heated.

When cooled to 10°C Liquid Petrolatum does not become more than opalescent (solid paraffins).

Insoluble in water or alcohol; soluble in ether, chloroform, petroleum benzin or in fixed or volatile oils. Camphor, menthol, thymol and many similar substances are dissolved by Liquid Petrolatum.

Boil 10 mils. of Liquid Petrolatum with an equal volume of alcohol, the alcoholic liquid is not acid to litmus (acids).

Introduce into a glass-stoppered cylinder which has been previously rinsed with sulphuric acid 5 mils. of Liquid Petrolatum and 5 mils. of colorless sulphuric acid, heat in a water bath during 10 minutes, shaking well at intervals of 30 seconds; the oil remains unchanged in color and the acid does not become darker than pale amber (carbonized impurities).

Prepare a clear, colorless saturated solution of lead oxide in an aqueous solution of sodium hydroxide (1 in 5) and mix 2 drops of this solution with 4 mils. of Liquid Petrolatum and 2 mils. of dehydrated alcohol; the mixture does not darken after heating for 10 minutes at 70°C and cooling (sulphur compounds).

Viscosity.—Make a permanent mark about 2 cm. below the bulb of a 50 mil. pipet of the usual type and note the time in seconds required at 25°C for the level of distilled water to fall from the upper to the lower mark as the liquid flows from the pipet. The time should not be less than 25 seconds nor more than 30 seconds for the pipet selected.

Draw the Liquid Petrolatum to be tested into this pipet, which should be clean and dry, and note the time in seconds required at 25°C for its level to fall from the same upper to the lower mark as above determined. The quotient indicates the viscosity. Distilled water at 25°C is taken as 1.

Average Dose.—Metric, 15 mils.; apothecaries, 4 fluidrachms.

PETROLATUM, U. S. P.

Petrolat.—Petrolatum Ointment, Petroleum Jelly.

A purified mixture of semi-solid hydrocarbons obtained from petroleum.

Petrolatum is an unctuous mass, varying in color from yellowish to light amber, having not more than a slight fluorescence even after being melted. It is transparent in thin layers, completely amorphous, free or nearly free from odor or taste.

Petrolatum is insoluble in water, almost insoluble in cold or hot alcohol or in cold dehydrated alcohol, freely soluble in ether, chloroform, carbon bisulphide, oil of turpentine, petroleum benzin, benzene or in most fixed or volatile oils.

Specific gravity, 0.820 to 0.865 at 60°C.

It melts between 38° and 54°C.

Heat about 2 gms. of Petrolatum in an open porcelain or platinum dish over a Bunsen burner flame. It volatilizes without emitting an acrid odor and on incineration not more than 0.05% of ash remains.

Shake melted Petrolatum with an equal volume of hot distilled water; the latter remains neutral to litmus (acid or alkalies).

Digest 10 grams of Petrolatum at 100°C for half an hour with 10 grms. of sodium hydroxide and 50 mils. of distilled water, then separate the aqueous layer and supersaturate it with sulphuric acid; no oils or solid substance separates (fixed oils, fats or rosin).

PETROLATUM ALBUM, U. S. P.

White Petrolatum.

Petrolat. Alb.—White Petroleum Jelly.

Petrolatum wholly or nearly decolorized.

White Petrolatum is a white or faintly yellowish unctuous mass, transparent in thin layers even after cooling to 0°C, completely amorphous.

In other respects White Petrolatum has the characteristics of and responds to the tests for identity and purity under Petrolatum.

Paraffin Wax.

After the gasoline, kerosene, naphtha and gas oil have been removed from crude petroleum by distillation, the residue is run into a special still. This may be the ordinary cylindrical horizontal still or the tower still. In the horizontal still, the entire distillate is generally collected for the wax distillate. In the tower still, the distillate is usually taken off in three portions, a light distillate, an intermediate distillate and a heavy distillate, coke only remaining in the still.

The heavy distillate contains the wax and is generally known as "wax distillate," and contains from 5% to 12% of wax and has a gravity of about 30 to 35°Be'. The amount of paraffin wax in the usual crude petroleum varies from nothing up to 2%. In rare instances, petroleum has been found containing as much as 10% of wax. In the crude petroleum, the wax exists in the amorphous form known as protoparaffin which is converted into pyroparaffin or crystalline wax by the action of high temperature.

Distillate carrying the crystalline wax is pumped to the chilling machine in which it is passed through cylinders, inside of which are inner cylinders containing brine at a very low temperature. These inner brine cylinders are revolved to get good distribution of the heat. On the outside of the revolving cylinders are scrapers which prevent the oil flow from becoming sluggish, due to the solidification of the wax. The chilled wax distillate is pumped from the chilling machines to the wax press. In the wax press the cylinders and the plunger push the plates against each other and the iron rings around the outer edge of the plates form a tight leak proof joint. The pump pressure on the oil forces it through a canvas sheet on which the wax collects. The oil drips down into a trough where it is collected and pumped into the lubricating stock. The wax collected on the canvas plates is removed with chipping chisels or "spuds" and falls into a conveyor which carries it to the slack wax tank. This slack wax is about 50% pure wax and 50% oil. The slack wax is now melted and pumped into a sweating pan. Each pan is equipped with a coil of pipe near the bottom. The melted wax is run into the pans and is chilled by water running through the pipe coils until it is solid. The temperature of the solid mass is now slowly raised and under these conditions the oil is gradually squeezed from the wax and flows away. Most of the color in the slack wax is carried away with the oil in sweating. The wax that is obtained from the first process of sweating is commonly spoken of as paraffin scale. The wax that is re-sweated is spoken of as sweated wax. The yellow sweated wax is now melted and filtered through bone meal or fuller's earth. The product ordinarily is colorless, odorless and tasteless. The fuller's earth absorbs all tarry and asphaltic compounds and is used in the proportion of about one ton of fuller's earth to five tons of wax. The filtration and decolorization of the wax is usually carried on by gravity in large upright cylinders. The fuller's earth may be used over and over again if burned out to remove coloring matter and residual waxy and oily material. The oil taken from the slack wax in sweating is commonly spoken of as foot's oil. (See also p. 197.)

Paraffin wax is usually sold according to melting point. Different methods of determining melting point are used. Paraffin wax is marketed according to the melting point which varies from 105°F for what is known as match wax to 140°F which is the highest grade wax such as is used for wax paper for packing edible articles. Most of the high melting point wax is imported and comes from East Indian crude petroleum.

Chemically, paraffin wax consists of paraffin hydrocarbons having a general formula of C_nH_{2n+2} and ranging from $C_{23}H_{48}$ to $C_{35}H_{72}$.

Uses of Paraffin Wax.—"Crude Wax": This product is sold to match factories as "Match Wax" for use on the heads of matches. It is also used in leather tanneries as a stuffing or loading for the leather. It is sometimes used for burning in special lamps used by miners and for marine bunker lights. It is useful also for waxing yarn in the textile industry, to act as a softener and lubricant for the yarn during winding. The customary melting ranges for the two regular grades of wax are 117°F—119°F and 124°F—126°F. Crude wax may be used for any purpose where a petroleum taste and odor are not objectionable. It is shipped either in slabs or sold in barrels. The slabs are packed in cases of about 250 pounds, or in jute bags of about 225 pounds.

"Refined Wax." This product should be free from taste and odor. It is used for such purposes as a coating for cheese, electrical insulation, coating for beer vats, artificial flower manufacture, coating vinegar and cider barrels, lining butter tubs, coating butter cartons, coating paper milk bottle tops, coating paper drinking cups and milk bottles, sealing preserves and jams, coating the necks of drug bottles, etching, also for coating meats, sausages and any product which must be prevented from drying out and losing weight. Some other uses are: Coatings for whisky, alcohol, molasses and sour kraut barrels, polishing wooden handles, spokes and wooden ware, saturating paper used in waterproof signs, oyster and ice cream pails.

It is usually shipped in 20-pound slabs and packed either in jute bags or wooden cases. A brief description of the method of using wax to coat cheese is as follows: The wax is used to improve the appearance of the cheese and to prevent the accumulation of the green mold which may appear on cheese that is not frequently handled. It also prevents shrinkage and evaporation of the cheese. The wax is melted in a large vat, which is heated by steam pipes or hot water baths. A direct flame cannot be used, because of the danger of charring the wax. The cheese is immersed in the melted wax for a few seconds and it is then placed on a rack for cooling. Usually the cheese is waxed when it is received at the storage warehouse and when it is from one to two weeks old. This coating for cheese boxes and butter tubs permits them to be shipped dry, improving their appearance and preventing burst hoops from waterstocked staves. (J. R. Battle.)

Paraffin wax is valued by the color, melting point and the specific gravity. The price of the crude wax having a melting point of from 120°F to 126°F is about 2c per pound, while the highly refined wax having a melting point of up to 140°F is worth about 7c per pound. (1922.)

Paraffin wax is ordinarily obtained from petroleum; also from shale oil and ozocerite. Paraffin exists in crude petroleum in the form of protoparaffin, in which condition it does not crystallize out and cannot be expressed from oil at low temperatures. In order to obtain it in condition for refrigeration and filtration, the heavy oil is subjected to a destructive distillation, thereby producing the crystalline pyroparaffin.

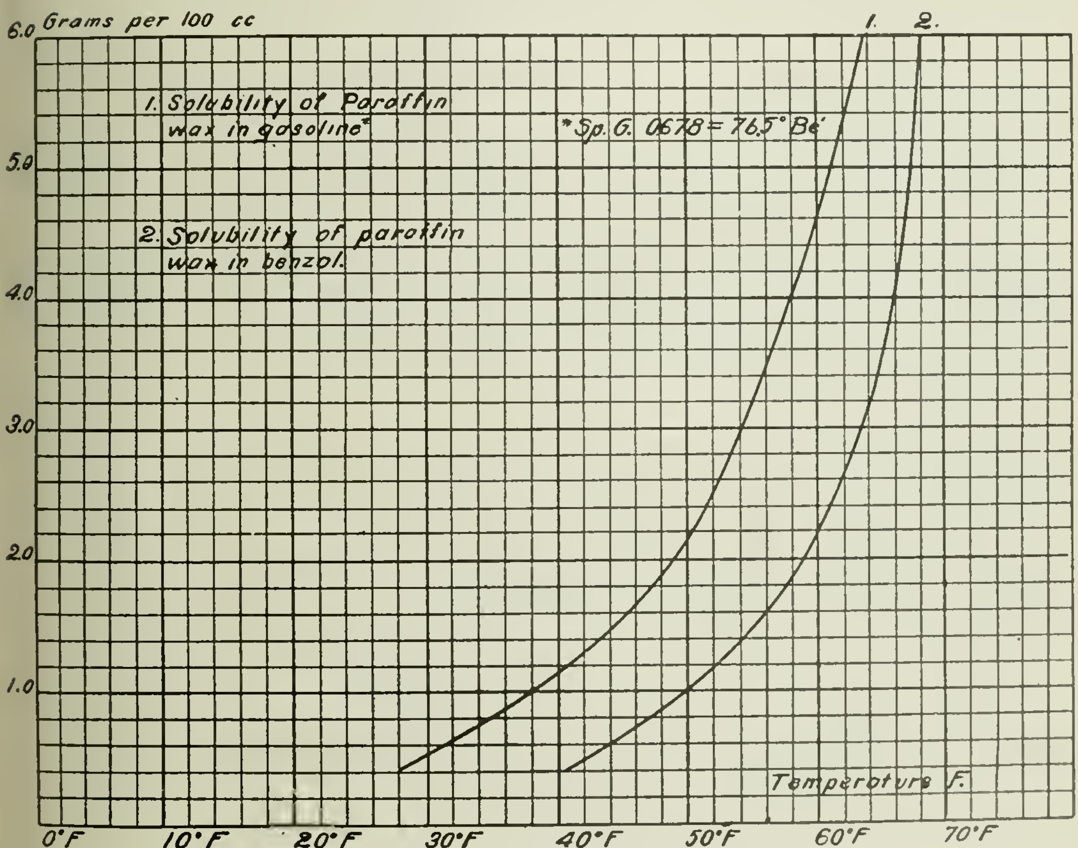


Fig. 56—Solubility of Wax.

Pennsylvania petroleum furnishes from 1½% to 2% paraffin wax, some petroleum such as one in Roumania giving as much as 10%.

The wax distillate from which paraffin is obtained contains ordinarily about 10% of wax. This distillate has a gravity of from 33°Be′ to 35°Be′ and distills over at a temperature of 500°F to 700°F. The paraffin is freed from oil by the sweating process after filtration.

PARAFFINUM, U. S. P.

Paraffin.

A purified mixture of solid hydrocarbons usually obtained from petroleum.

Paraffin is a colorless or white more or less translucent mass, crystalline when separating from solution, without odor or taste and slightly greasy to the touch.

It is insoluble in water or alcohol, slightly soluble in dehydrated alcohol, freely soluble in ether, petroleum benzine, benzene, carbon disulphide, volatile oils or in most warm fixed oils.

Specific gravity, about 0.900 at 25°C.

It melts between 50° and 57°C.

When strongly heated it ignites, burns with a luminous flame and deposits carbon.

Heat about 0.5 gm. of paraffin in a dry test tube with an equal weight of sulphur; the mixture becomes black from separated carbon and hydrogen sulphide gas is evolved.

Paraffin is not acted upon or colored by concentrated sulphuric or nitric acid in the cold.

Shake melted paraffin with an equal volume of hot alcohol; the separated alcohol does not redden moistened blue litmus paper (acids).

Miscellaneous Oils and Their Uses.

Recoil Cylinder Oil or Hydroline Oil is used to fill the recoil cylinders of gun carriages. It should have a viscosity (S. U.) of less than 145 at 32°F and over 43 at 100°F with a cold test below 0°F. Loss at 212°F for 2 hours, under 5%.

Recuperator Oil is used for the recoil mechanism of 75 and 155 mm French gun carriages. Free from saponifiable matter, flash point over 345°F, viscosity 100°F, 385 to 430. Pour test, below —5°F.

Recuperator Grease consists of 18% of lime soap; of tallow oil, neatsfoot oil, lard oil or equivalent, and 82% mineral oil of 180 viscosity at 100°F; maximum water content, 3%; ash, below 2.3%.

Air Compressor Oil quality varies according to the character of the compressor. In single stage compressors the maximum temperature developed per stroke without cooling by air or water varies from 145°F for 10 pounds to 750°F for 250 pounds pressure. For a compressor operating at 125 pounds pressure, the lubricating oil for air cylinders should have the following properties: Viscosity at 100°F, 270-350; flash point over 375°F. For higher pressure, a high viscosity oil is required. Oils should be distilled or of paraffin base.

Oxygen Gas Compressors. Oil cannot be used for this purpose. Water solutions of soft soap (potassium linolate) or glycerin is used.

Carbon Dioxide Compressors. Glycerin is commonly used, but same oils as for air compressors are satisfactory but must not give a flavor to the carbon dioxide.

Ammonia Compressors. A pure mineral oil, cold test —5°F, flash 365°F, viscosity 100 at 100°F.

Airplane Oil (see special specifications). Castor Oil was originally used and first grade had following properties: Pale yellow, clear, specific gravity .964, flash point 550°F, fire test, 618°F, cold test —10°F, Saybolt Universal Viscosity 100°F=1440, 150°F=308, 200°F=117, 210°F=95, 250°F=64. Acid value 1, free acid 0.5, iodine value 88.3.

Brick Oil, Repress Oil or Brockie is oil used on the die through which the plastic clay is pressed for forming the brick. The oil covers the clay column when it leaves the die and prevents sticking to the steel plate over which it travels. The column is again oiled before entering the cutting machine to prevent sticking to the cutting wires and again to the wire cut sides. About 90% of 27°Be′ distillate with 10% of De Gras oil is commonly used for this purpose.

Car Oil, Axle Oil, Summer Black Oil are used for saturating waste for packing the journal boxes of car axles. It should be sufficiently viscous not to readily drip from the waste. A flash test of 380°F and cold test of 5°F is usually required.

Thread Cutting Oil, Bolt Oil is a compounded product used as a combination of a lubricant and cooling agent. It is usually composed of a water insoluble metallic soap such as calcium stearate, copper oleate, zinc oleate which acts as an emulsifying agent, and a viscous neutral oil about 200 viscosity. A small amount of ammonia or alkali greatly aids the emulsion. Instead of the metallic soap, sulphonated oils, naphthenic acids and agitator sludge oils may be used to produce the emulsions.

Quenching Oils are used for slower cooling of steel than is accomplished with water. It must be a pure mineral oil with a high flash point.

Condenser, Compounded and Blown Oils are mixtures of mineral lubricating oils with seed oil, the seed oil usually being blown to increase the viscosity.

Cylinder Oil or Cylinder Stock is the residue obtained from distilling special grades of light crude oils with a very large amount of steam, avoiding cracking as much as possible and from which the wax distillate has been removed. Cylinder oils vary in gravity from 20° to 27°Be′, flash point from 475°F to 650°F, viscosity at 210°F Saybolt, 100 to 350, cold test 30 to 60°F. They usually are not filtered but may be refined by filtering through Fuller's earth or bone black.

Core Oil is 36° gravity mineral oil compounded with boiled linseed oil or china wood oil.

Cream Separator Oils are nonviscous oils of about 30° to 34°Be′ gravity, 70 to 200 viscosity at 70°F.

Cup Greases are mixtures of petroleum oil and lime soap with or without rosin oil.

Floor Oil is a light non-viscous neutral oil.

Gear Case Oil or Transmission Oil is a steam refined cylinder oil with a gravity of about 25°Be′, flash point 600°F, cold test of 30°F, Saybolt viscosity at 210°F of 240.

Harness Oil is a compounded oil or a mineral oil of 175 viscosity at 100°F and about 25°Be′ to 30°Be′ gravity containing petrolatum, leather oil and wax and some fatty oils.

Ichthyol is an artificial preparation obtained by the distillation of certain bituminous shales and subsequent sulphonation and neutralization with ammonia or soda. It comes on the market under the official name of Ammonii Icythyo-sulphonas or Ammonium Sulpho-ichthyolate. The specific gravity of the preparation is approximately 1.0, and it has a viscosity of 17.7 (Engler). A typical preparation contains 15% to 16% of sulphur, and it is to the sulphur that the value of the preparation is largely due. On account of the difficulty in duplicating exactly the original product and the scarcity of the original product, it has now attained a very high price.

Knitting Machine Oil is a spindle oil of 70-200 viscosity@70°F.

Leather Oil is a non-viscous neutral oil of low viscosity.

Motor-Cycle Oil is a high viscosity lubricating oil similar to aeroplane oil.

Neutral Oils are oils obtained from pressed distillate.

Non Viscous Neutral Oil is neutral oil having a viscosity below 135 Saybolt at 100°F.

Viscous Neutral Oil is neutral oil having a viscosity above 135 at 100°F.

Mazout is the term applied to residual fuel oil in Russia.

Mineral Seal Oil is heavy burning oil obtained in the distillation for cylinder stock.

Oildag is a compound of deflocculated graphite suspended in petroleum lubricating oil covered by U. S. Patent No. 911,358 by Acheson.

Paraffin Oil is the wax-free oil obtained by pressing wax distillate.

Petrolatum is a semi-solid paraffin oil or wax composed of sufficient varieties of petroleum hydrocarbons to give an indistinct melting point. It has a flow point of about 105°F (see Petrolatum Mollum).

Petroleum Coke is the residue in coking or tar stills and usually constitutes about 5% of the crude oil. Mid-Continent crude leaves a residue ordinarily about 6 inches thick in the still and Mexican crude petroleum leaves a residue about 30 inches thick in the bottom of the still. One ton of Panuco (Mexico) crude oil gives 365 pounds of coke.

Roll Oil for tin, copper and brass rolls has the same qualities as engine oil.

Sewing Machine Oil is light neutral oil with a viscosity of 75 at 70°F, cold test 20°F or below, fire test 400°F, flash point 340°F and gravity of 34.5°Be′.

Spindle Oil is the lighter lubricating oil usually of a gravity of 25-35°Be′, flash point 300-450°F, viscosity 40-400 at 70°F, cold test at 0°F-40°F, colorless to dark red.

Stitching Oil is a light non-viscous neutral oil used in stitching shoes.

Summer Black Oil is a black lubricating oil of about 500-600 fire test and is used for tempering and for concrete waterproofing.

Tempering Oil is a viscous neutral oil frequently the same as hammer oil and summer black oil.

Thickened Oil is a mineral oil in which the viscosity is increased by the addition of unvulcanized rubber, aluminum soap or blown vegetable oil.

Turbine Oil is a non-emulsifying oil of about 150 viscosity at 70°F and a flash point of about 420°F.

Watch Oil is usually a non-petroleum oil and is ordinarily Dolphin oil. Good watch oil is, however, made from petroleum and is a close distillation cut just above kerosene with a very low cold test.

Wool Oil is a sun bleached neutral oil sometimes compounded with lard oil and with a viscosity of 140-160· Saybolt, gravity of about 32°Be′ and flash point of 375°F. It is used to aid in carding the wool fibers.

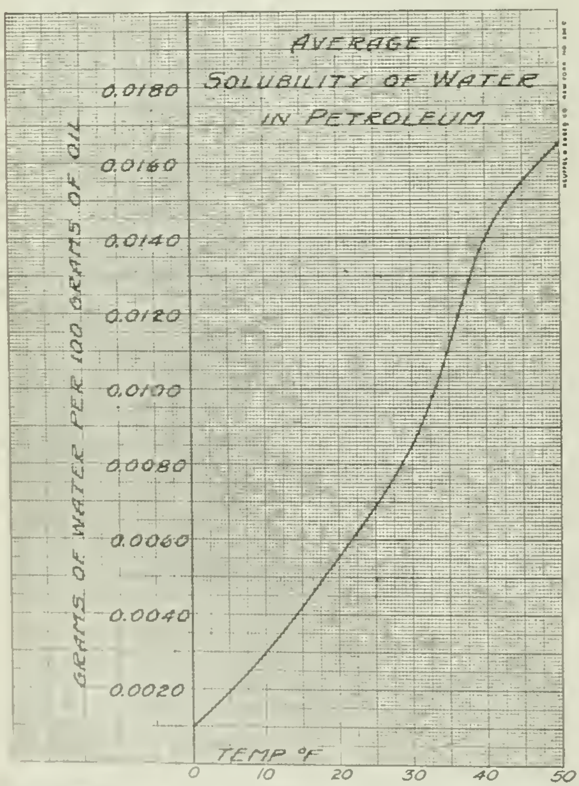


Fig. 57—Solubility of Water in Petroleum.

Transformer Oils are used for cooling transformer coils used for changing the voltage of electric currents. Oil serves in distributing the heat and conducting it to the radiating surfaces. It prevents oxidation and hardening of the wire insulation. Transformer oil must be a poor conductor of electricity (a high dielectric strength) for which reason, it must contain no moisture, acid, soaps, suspended matter, dissolved salts or saponifiable matter. The effect of moisture on the dielectric strength is shown in Fig. 59. Coils of copper are most satisfactory for circulating water to cool transformer oil. Lead coils have been known to react with pure mineral oil to form lead soap. Presumably sufficient oxygen dissolves in the oil to allow this reaction to take place.

The following method is used to test the dielectric strength (for other tests see general methods of testing lubricants).

Method of Testing the Dielectric Strength of Transformer Oils.

The apparatus used for this test is shown in Figure 58, and is manufactured by the Westinghouse Electric and Manufacturing Company for this purpose. It consists of a graduated glass cylinder in which is placed two testing terminals, each a brass sphere ½ in. in diameter. The lower sphere is fixed and the upper sphere is adjustable in its distance from the lower sphere. In making the test, the cylinder is filled with the oil and the gap between the two terminals is adjusted. The oil is allowed to stand for 10 minutes so that any air bubbles may escape. The testing voltage is now applied, beginning low and gradually increasing and without opening the circuit until the breakdown occurs. The oil is then shaken up and the test is repeated until at least five breakdowns have occurred. The average of these breakdowns is taken as the dielectric strength.

Instead of having a fixed distance between the terminals a constant voltage may be used and the grap decreased by adjusting the upper terminal with a slow motion screw until the breakdown occurs.

As a general thing, the dielectric strength is proportional to the amount of moisture in the oil. It is also effected by the presence of saponifiable oil.

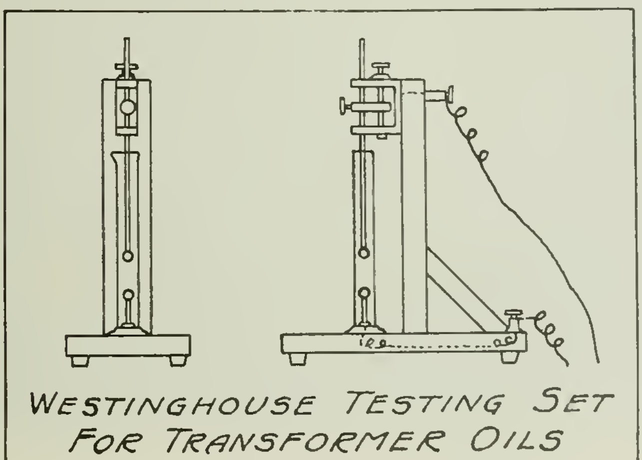


Fig. 58—Apparatus for Testing Dielectric Strength.

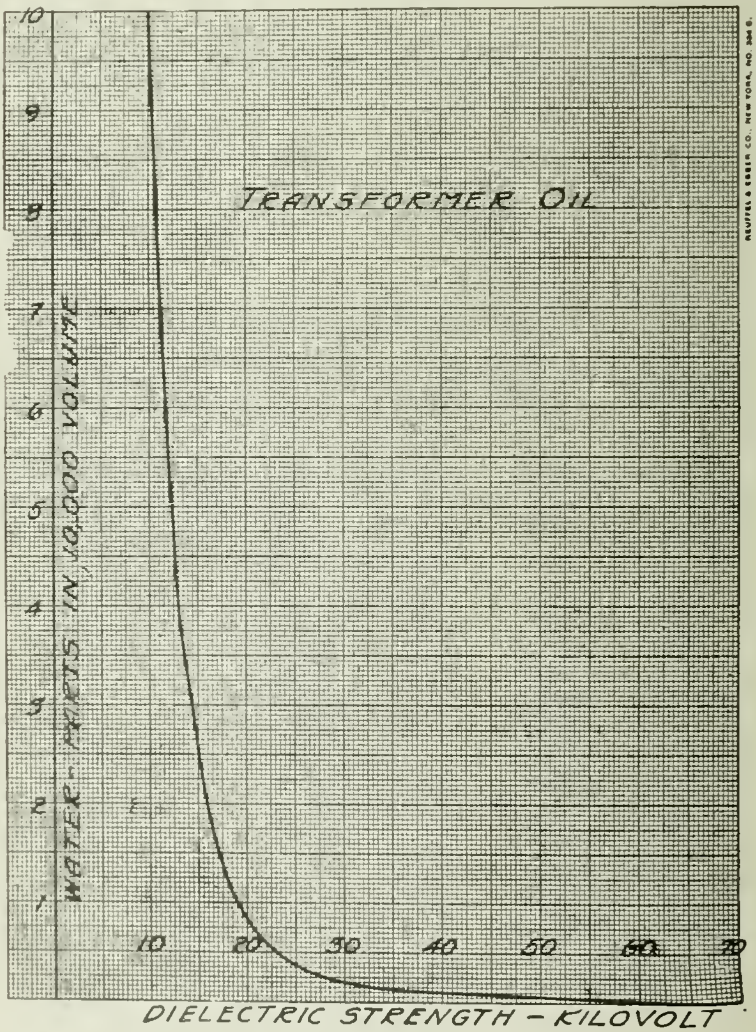


Fig. 59—Relation of Water Content to Dielectric Stength of Transformer Oils.

Fuel Oil.

Liquid fuel is chiefly crude petroleum and its residues. Shale oil, coal tars, wood tars and vegetable and animal oils are also used as fuel to a very limited extent. Petroleum as a fuel for use in steam or power plants has considerable variations. Its most distinctive chemical features are the practical absence of mineral matter, water and light gasoline and the presence of a large amount of hydrogen. Ordinarily when fuel oil is mentioned, reference is made to the residue from petroleum distillation, the gasoline and kerosene having first been removed.

The chief properties making fuel oil available for use are the ease with which it flows, the low cost of handling and the absence of residue. Fuel oil has a remarkably constant heat of combustion. The heat of combustion in terms of B. T. U. per pound of oil is higher with lighter oils but is lower in B. T. U. per gallon with lighter oils, therefore it is obvious that the heavier oils are cheaper for fuel at the same price per gallon, which is the unit of measurement. Ordinarily, fuel oil obtained from petroleum when dry and free from sediment has a very definite heating value in relation to gravity as is shown by the accompanying tables on page 318.

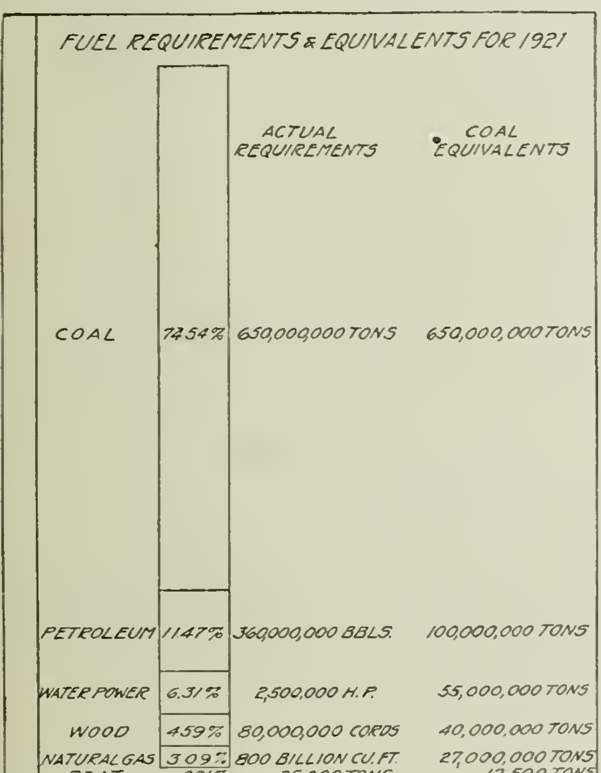


Fig. 60—Fuel Requirements of the United States.

The chief impurities found in fuel oil are water or brine and asphaltic sediment. The asphaltic sediment or tarry matter has almost as great heating value as the dry oil itself but the brine or water very greatly diminishes the heating value as well as interferes with the mechanical use of the oil. Fuel oil is ordinarily only used under conditions of its greater convenience than coal. In so far as the cost of heat obtained from fuel oil is concerned it is in most localities much higher than coal. The price of coal is the governing feature in the price of fuel oil. In general practice, three barrels of fuel oil are equivalent to one ton of coal screenings.

The gravity varies according to the character of the oil and the amount of light constituents that have been distilled out of it. The following table shows typical gravities of fuel oil from different sources:

	Gravity
Mexican fuel oil	12.6°Be′
Paraffin base fuel oil	27.5°Be′
California fuel oil	15.5°Be′
Towanda fuel oil	26.0°Be′
Mid-Continent heavy fuel oil	23.5°Be′
Typical Mid-Continent oil	26.5°Be′
Garber, Oklahoma fuel oil	31.3°Be′

The viscosity of fuel oil is not proportional to the gravity as is indicated by the following tables:

Viscosity and Gravity of Fuel Oils. (See Pages 313-4.)

	Gravity	Viscosity at 70°F
California Crude	16.9°Be′	5400
Residuum from same after cracking	15.5	414
Heavy Kansas Crude	19.7	3360
Residuum from same after cracking	21.2	178
Heavy Mid-Continent fuel oil	23.5	810
Residuum from same after cracking	21 2	135
Garber, Okla., fuel oil	31.3	183
Residuum from same after cracking	28.0	70
Heavy Mexican flux oil	10 8	14500
Residuum from same after cracking	12 6	530
Average Mid-Continent fuel oil	27.5	272
Residuum from same after cracking	23.7	88

As compared with other sources of heat, the theoretical amount of heat obtainable from petroleum or fuel oil as determined when the combustion is complete and the absorption of heat is complete is as follows:

1,000,000 B. T. U. of Petroleum at $1.00 per bbl. costs	$0.165
1,000,000 B. T. U. of good slack coal at $3.00 per ton	0.136
1,000,000 B. T. U. of natural gas at $0.30 per 1,000 cu. ft	0.33
1,000,000 B. T. U. of coal gas at $0.50 per 1,000 cu. ft	0.79
1,000,000 B. T. U. of electricity at 1c per k. w. hour	2 93

The above is based upon the following: Fuel oil of specific gravity 0.900=25.7°Be′, weight per gallon 7.5 lbs., weight per barrel 315 lbs. B. T. U. per lb.=19,225, per ton=38,450,000, per gallon=144,200, cubic foot=1,078,500, per barrel=6,056,000.

Slack coal=11,000 B. T. U. per pound.

Natural gas=900 B. T. U. per cubic foot.

Theoretical Equivalents.

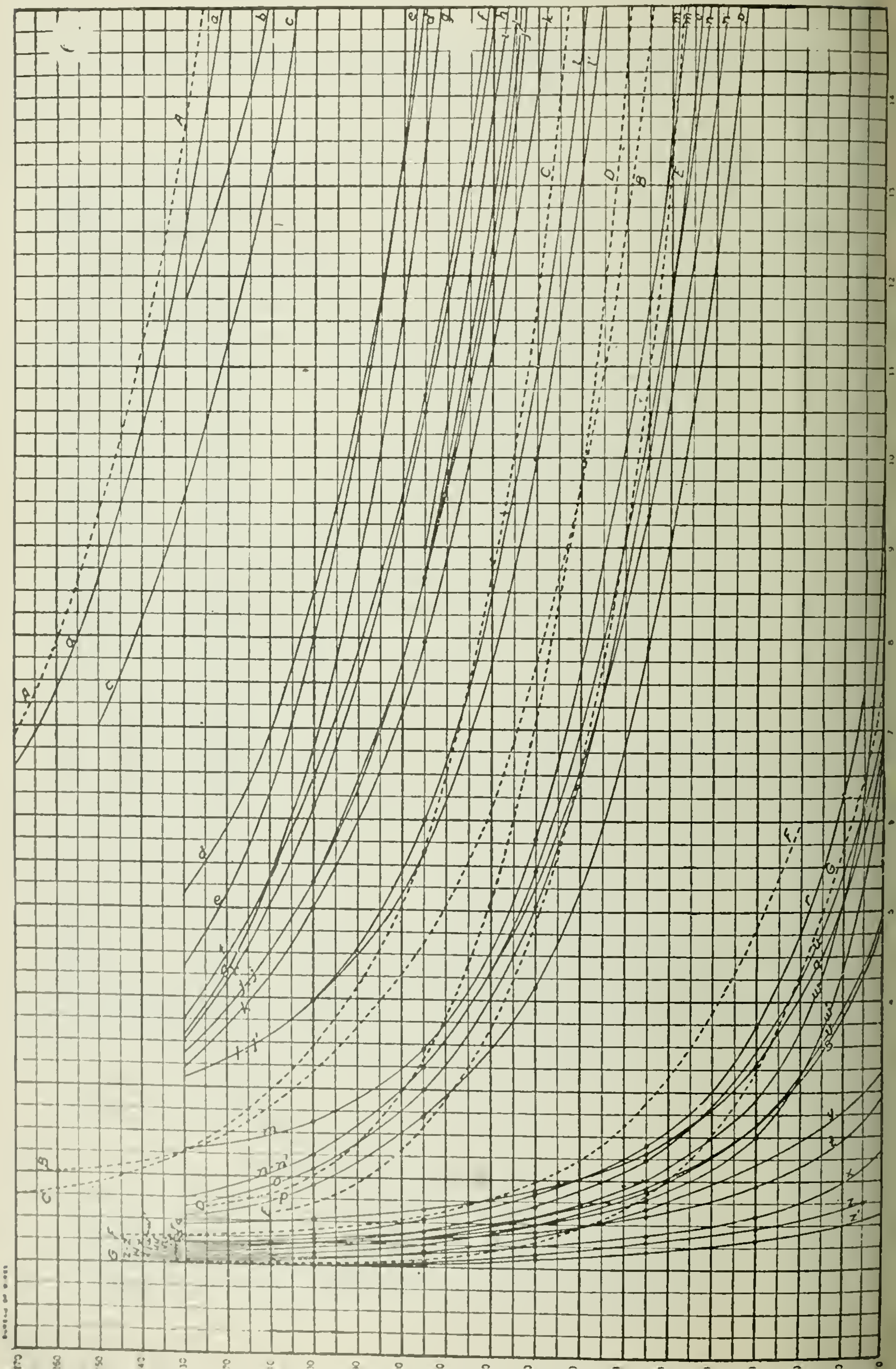
1 ton of coal=36 bbls. oil=24,500 cu. ft. of natural gas.
1 gallon of oil=13.1 lbs. coal=160 cu. ft. of natural gas.
1 barrel oil=0 278 ton coal=680 6 cu. ft. of natural gas.
1 pound oil=1.75 lbs. coal=21.3 cu. ft. of natural gas.
1 pound coal=0.763 gallon oil=12.2 cu. ft. of natural gas.

As to the actual heating value of fuel oils from various sources the table on page 315 is representative:

KEY TO FIGURE 61.

Curve No.	TYPE OF OIL	GRAVITY		Flash Point, °F
		Specific	° Be'	
	SOLID CURVES			
a	Mexican residue	1.000	10.0	374
b	"Toltec fuel oil," Inter-Ocean Oil Co., N. Y.	.988	11.7	220
c	"Toltec or Panuco oil," Inter-Ocean Oil Co.	.986	12.0	124
d	"No. 102," Union Oil Co., Bakersfield, Cal.	.980	12.9	280
e	"No. 18," Union Oil Co., Bakersfield, Cal.	.980	12.9	285
f	"Standard" Mexican crude (lot 2)	.964	13.4	202
g	"No. 25," Union Oil Co., Bakersfield, Cal.	.978	13.2	262
h	Mexican crude, Texas Co.	.952	17.3	126
i	Sample No. 3, Angol-Mex. Pet. Products Co.	.952	17.3	164
j	"Gaviota Refinery," Associated Oil Co., Cal.	.953	17.1	230
j'	Mexican oil, Atlantic torpedo flotilla, March, 1914	.947	18.1	182
k	Standard Mexican crude (lot 1)	.954	17.0	145
l	Mexican oil, U. S. S. Arethusa	.950	17.6	182
l'	"Nos. 1, 2, 3," Anglo-Mexican Pet. Products Co.	.955	16.8	188
m	Producers Crude No. 1 fuel oil, Union Oil Co., California	.959	16.1	174
n	"Coalinga Field," Associated Oil Co., Monterey, Cal.	.957	16.5	186
n'	"Avon Refinery," Associated Oil Co., Avon, Cal.	.953	17.1	168
o	Richmond, California	.953	17.1	228
p	Sun Co., Louisiana	.936	19.8	275
q	"Standard," Illinois	.893	27.3	146
r	Gulf Refining Co., Navy standard oil, U. S. S. Perkins	.892	27.5	180
s	"Standard," Indiana	.880	29.6	144
t	"Standard Star," California	.912	23.9	180
u	"Standard," Illinois (lot 4)	.893	27.3	146
v	"Standard," Indiana (lot 4)	.880	29.6	144
w	Gulf Refining Co., Navy contract	.882	29.3	170
w'	"Standard," Lima, Ohio, crude	.876	30.4	149
x	Camden Chemical Co., by-product of coal tar.			
y	"Star," California	.912	23.9	180
z	Gulf Refining Co., Navy standard oil, U. S. S. Roe	.885	28.7	182
z'	Standard Mexican gas oil	.856	34.2	151
•	Indicates test results.			
	DOTTED CURVES			
A	Panuca crude, Inter-Ocean Oil Co.	.975	13.7	146
B	Mexican petroleum, Texas Co.	.938	19.5	234
C	Associated Oil Co., California	.971	14.2	257
D	Bakersfield, Cal., pipe line to Port Costa	.970	14.4	260
E	California Standard Oil Co., steamer Santa Barbara	.962	15.7	282
F	Beaumont, Tex., Gulf Refining Co.	.907	24.8	222
G	Navy standard oil, Texas Co.	.911 to .900	24 to 26	195 to 220

From "Oil Fuel Handbook."



Properties of Fuel Oils from Various Sources.

(Based on Dry Oil).

SOURCE	Specific Gravity	Baume' Gravity	Saybolt U. S. Viscosity at		Flash Point	Sulphur	B. T. U. per Lb.	B. T. U. per Gal.
			70° F	100° F				
MEXICAN RESIDUE	1.000	10.0	…	1,750	374	3.0	18,670	155,334
Mexican crude—Panuco	0.986	12.0	…	530	120	4.1	18,720	153,691
Mexican crude—Texas Co.	0.952	17.0	…	200	126	…	18,945	149,133
Mexican flux oil	0.995	10.8	14,500	2,000	350	2.9	18,690	156,773
Flux oil residue after cracking	0.975	13.6	530	…	120	…	18,755	151,103
Mexican crude—Panuco (Inter-Ocean Oil Co.)	0.975	13.6	…	2,500	140	4.0	18,800	152,656
MID-CONTINENT—								
Average of 1,200 cars	0.892	26.9	275	40	125	0.3	19,376	143,950
Heavy	0.922	21.8	…	…	132	0.7	19,170	157,220
Light	0.863	32.2	…	…	110	0.25	19,580	140,580
Towanda, Kansas	0.921	22.0	…	…	180	0.8	19,175	146,072
Allen County, Kansas	0.935	19.7	3,360	…	…	0.7	19,180	149,400
Residue same after cracking	0.926	21.2	178	…	120	…	19,150	147,646
Residuum after cracking average Mid-Continent fuel oil	0.926	21.2	88	…	125	…	19,150	147,685
OHIO, Lima, crude	0.876	29.8	290	44	149	…	19,470	141,936
CALIFORNIA—Bakersfield	0.971	14.2	1,100	50	257	0.7	18,820	152,065
Standard "Star"	0.912	23.5	125	40	180	0.7	19,210	145,803
Heavy crude	0.953	16.9	5,400	…	110	…	18,925	148,075
Residue after cracking	0.962	15.5	414	…	120	…	18,890	151,308
TEXAS—Beaumont	0.907	24.3	350	47	222	1.7	19,230	145,186
GAS OIL—Mexican	0.856	33.5	60	44	151	…	19,650	140,104
Mid-Continent	0.856	33.5	60	44	170	0.05	19,650	140,104
SHALE OIL	0.900	25.5	200	…	100	…	19,150	143,433
COAL TAR	1.25	…	90	60	200	0.60	15,700	…
WOOD TAR	…	…	…	…	…	…	…	…
COLLOIDAL LIQUID FUEL	1.25	…	…	…	120	…	16,500	…

Types of Solid and Liquid Fuels.

FUEL	PROXIMATE ANALYSIS				COMPOSITION OF COMBUSTIBLE					B. T. U.			Sp. Gr.
	H_2O	Vol.	F. C.	Ash	C	H	N	S	O	Natural	Dry	Comb.	
Anthracite Coal—Penn.	2.80	1.16	88.21	7.83	96.39	1.77	0.71	1.00	0.13	13,298	13,682	14,882	1.75
Semi-anthracite—Wash.	2.70	7.00	79.60	10.70	91.41	3.67	1.53	0.72	2.67	13,350	13,720	15,410	1.50
Semi-bituminous—W. Va.	1.72	17.85	73.56	6.87	90.48	4.64	1.46	0.74	2.68	14,571	14,827	15,941	1.40
Bituminous Coal, high moisture and high oxygen content, Colorado	19.28	34.61	41.41	4.70	76.22	5.07	1.68	0.51	16.52	9,064	12,468	13,239	1.35
Bituminous—High O_2—Ill.	11.17	39.31	39.20	10.32	77.51	5.49	1.34	5.32	10.34	11,223	12,634	14,296	1.35
Bituminous—Low O_2—Ala.	3.16	25.40	67.75	3.69	88.33	5.05	1.46	0.60	4.56	14,616	15,083	15,691	1.30
Cannel—Missouri	2.60	44.59	43.89	8.92	83.30	7.31	1.60	2.03	5.86	14,333	14,755	16,200	1.20
Lignite—North Dakota	43.78	26.07	26.33	3.82	71.09	4.40	1.24	1.09	22.27	5,972	10,624	11,398	1.15
Peat—air dried	8.68	55.77	26.04	18.19	60.00	6.00	2.00	1.08	32.00	8,237	9,020	11,264	......
Grahamite	0.00	41.00	53.30	5.70	87.20	7.50	0.20	2.00	......	......	......	......	1.172
Fuel Oil—Mexican crude	2.00	92.90	5.00	0.10	83.70	10.20	......	4.15	......	18,320	18,335	18,710	0.975
Fuel, Mid-Cont. residuum	0.00	99.80	0.10	0.10	85.62	11.98	0.50	0.35	0.60	19,358	19,358	19,376	0.892
Fuel, California	0.00	97.90	2.00	0.10	84.00	12.70	1.70	0.75	0.85	18,890	18,890	18,910	0.962
Coke Breeze	0.73	5.47	80.40	13.40	94.79	1.51	1.19	1.03	1.48	12,414	12,506	14,459	......
Oven Coke—Connellsville	0.70	0.61	89.58	9.11	90.04	0.15	......	0.81	......	13,130	13,232	14,560	......
Coke, Petroleum, Cosden	0.34	7.70	90.84	1.12	97.38	1.21	0.14	1.08	0.29	15,490	15,540	15,720	......
Wood—Scrub Oak	0.00	89.60	10.40	0.37	50.36	6.05	0.10	......	43.49	......	8,316	......	0.895
Wood—Pine	0.00	87.50	12.13	0.37	50.51	6.25	0.05	......	43.19	......	9,153	......	0.551
Charcoal	0.00	10.00	88.00	2.00	95.40	2.50	0.10	......	......	7,140	7,140	......	......
Coal Tar	......	......	......	......	89.21	4.95	1.05	0.56	0.56	......	15,708	15,708	1.25
Gas Coke—Alabama	0.00	1.59	87.01	11.40	......	......	......	0.60	......	......	12,883	......	......
Tan Bark	......	......	......	14.60	......	......	......	......	......	......	6,150	......	......
Wheat Straw	......	......	......	0.42	46.10	5.60	0.42	......	43.70	10,386	11,322	......	......
Bagasse	53.00	......	......	......	......	......	......	......	......	3,620	8,320	......	......

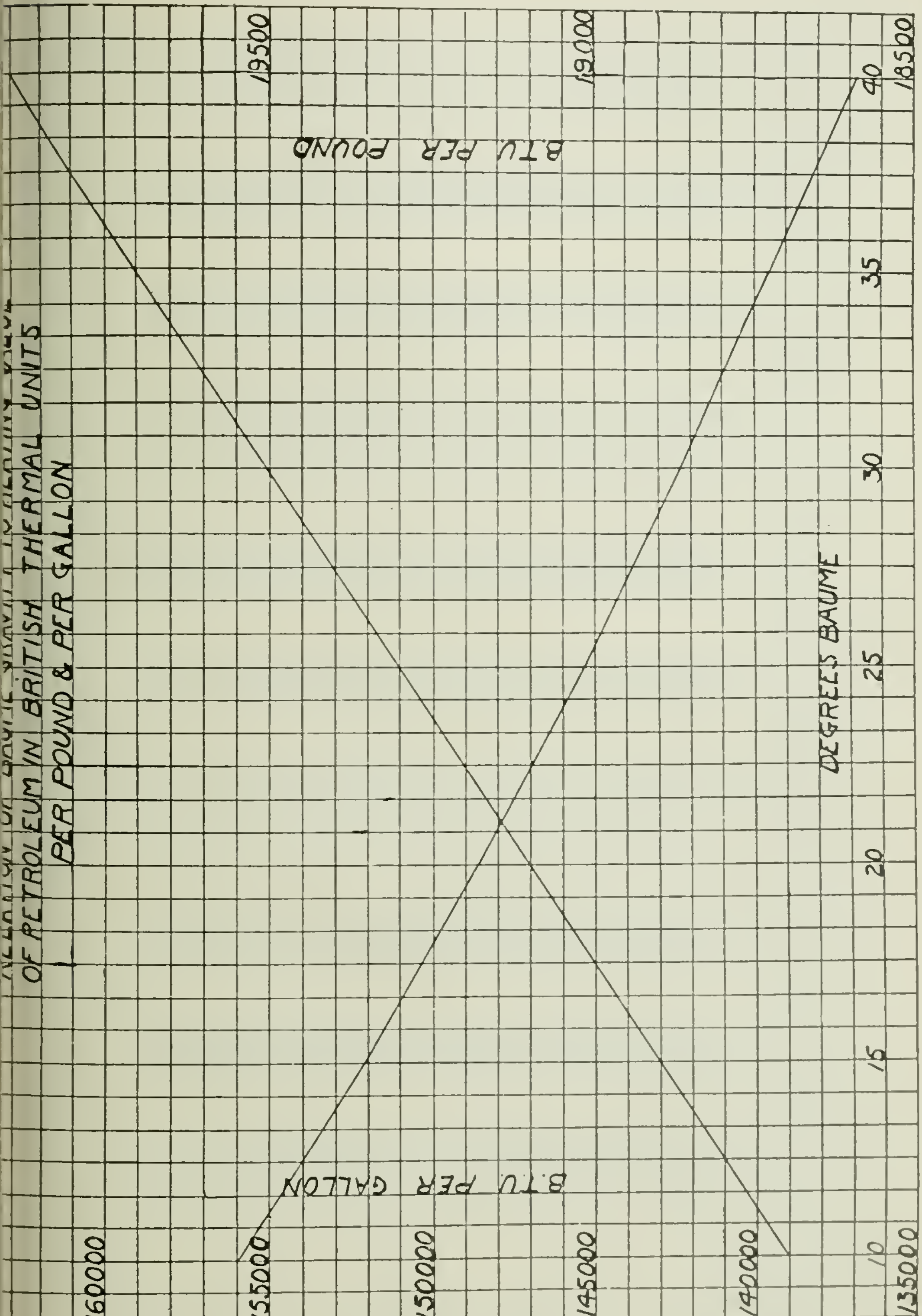


Fig. 62—Relation of Gravity to Heat of Combustion of Fuel Oils.

Relation of Gravity to Heat of Combustion of Dry Fuel Oil. (B. T. U. Per Gallon.)

Baume'	0	1	2	3	4	5	6	7	8	9
10	155,340	155,417	155,494	155,571	155,648	155,725	155,802	155,879	155,956	156,033
11	154,570	154,647	154,724	154,801	154,878	154,955	155,032	155,109	155,186	155,263
12	153,800	153,876	153,952	154,028	154,104	154,180	154,256	154,332	154,408	154,484
13	153,040	153,114	153,188	153,262	153,336	153,410	153,484	153,558	153,632	153,706
14	152,300	152,372	152,444	152,516	152,588	152,660	152,732	152,805	152,876	152,948
15	151,580	151,652	151,724	151,796	151,868	151,940	152,012	152,084	152,156	152,228
16	150,860	150,933	151,006	151,079	151,152	151,225	151,298	151,371	151,444	151,517
17	150,130	150,201	150,272	150,343	150,414	150,485	150,556	150,627	150,698	150,769
18	149,420	149,492	149,564	149,636	149,708	149,780	149,852	149,924	149,996	150,068
19	148,700	148,765	148,830	148,895	148,960	149,025	149,090	149,155	149,220	149,285
20	148,050	148,115	148,180	148,245	148,310	148,375	148,440	148,505	148,570	148,635
21	147,400	147,468	147,536	147,604	147,672	147,740	147,808	147,876	147,944	148,012
22	146,720	146,785	146,850	146,915	146,980	147,045	147,110	147,175	147,240	147,305
23	146,070	146,136	146,202	146,268	146,334	146,400	146,466	146,532	146,598	146,664
24	145,410	145,471	145,532	145,593	145,654	145,715	145,776	145,837	145,898	145,959
25	144,800	144,865	144,930	144,995	145,060	145,125	145,190	145,255	145,320	145,385
26	144,150	144,213	144,276	144,339	144,402	144,465	144,528	144,591	144,654	144,717
27	143,520	143,581	143,642	143,703	143,764	143,825	143,886	143,947	144,008	144,069
28	142,910	142,968	143,026	143,084	143,142	143,200	143,258	143,316	143,374	143,432
29	142,330	142,393	142,456	142,519	142,582	142,645	142,708	142,771	142,834	142,897
30	141,700	141,758	141,816	141,874	141,932	141,990	142,048	142,106	142,164	142,222
31	141,120	141,180	141,240	141,300	141,360	141,420	141,480	141,540	141,600	141,660
32	140,500	140,560	140,620	140,680	140,740	140,800	140,860	140,920	140,980	140,040
33	139,920	139,974	140,028	140,082	140,136	140,190	140,244	140,298	140,352	140,406
34	139,380	139,436	139,492	139,548	139,604	139,660	139,716	139,772	139,828	139,884
35	138,820	138,876	138,932	138,988	139,044	139,100	139,156	139,212	139,268	139,324
36	138,260	138,316	138,372	138,428	138,484	138,540	138,596	138,652	138,708	138,764
37	137,700	137,753	137,806	137,859	137,912	137,965	138,018	138,071	138,124	138,177
38	137,170	137,224	137,278	137,332	137,386	137,440	137,494	137,548	137,602	137,656
39	136,630	136,685	136,740	136,795	136,850	136,905	136,960	137,015	137,070	137,125
40	136,080	136,135	136,190	136,245	136,300	136,355	136,410	136,465	136,520	136,575

Relation of Gravity to Heat of Combustion of Dry Fuel Oil. (B. T. U. Per Pound).

Baume'	0	1	2	3	4	5	6	7	8	9
10	18,650	18,654	18,658	18,662	18,666	18,670	18,674	18,678	18,682	18,686
11	18,690	18,694	18,698	18,702	18,706	18,710	18,714	18,718	18,722	18,726
12	18,730	18,734	18,738	18,742	18,746	18,750	18,754	18,758	18,762	18,766
13	18,770	18,774	18,778	18,782	18,786	18,790	18,794	18,798	18,802	18,806
14	18,810	18,814	18,818	18,822	18,826	18,830	18,834	18,838	18,842	18,846
15	18,850	18,854	18,858	18,862	18,866	18,870	18,874	18,878	18,882	18,886
16	18,890	18,894	18,898	18,902	18,906	18,910	18,914	18,918	18,922	18,926
17	18,930	18,934	18,938	18,942	18,946	18,950	18,954	18,958	18,962	18,966
18	18,970	18,974	18,978	18,982	18,986	18,990	18,994	18,998	19,002	19,006
19	19,010	19,014	19,018	19,022	19,026	19,030	19,034	19,038	19,042	19,046
20	19,050	19,054	19,058	19,062	19,066	19,070	19,074	19,078	19,082	19,086
21	19,090	19,094	19,098	19,102	19,106	19,110	19,114	19,118	19,122	19,126
22	19,130	19,134	19,138	19,142	19,146	19,150	19,154	19,158	19,162	19,166
23	19,170	19,174	19,178	19,182	19,186	19,190	19,194	19,198	19,202	19,206
24	19,210	19,214	19,218	19,222	19,226	19,230	19,234	19,238	19,242	19,246
25	19,250	19,254	19,258	19,262	19,266	19,270	19,274	19,278	19,282	19,286
26	19,290	19,294	19,298	19,302	19,306	19,310	19,314	19,318	19,322	19,326
27	19,330	19,334	19,338	19,342	19,346	19,350	19,354	19,358	19,362	19,366
28	19,370	19,374	19,378	19,382	19,386	19,390	19,394	19,398	19,402	19,406
29	19,410	19,414	19,418	19,422	19,426	19,430	19,434	19,438	19,442	19,446
30	19,450	19,454	19,458	19,462	19,466	19,470	19,474	19,478	19,482	19,486
31	19,490	19,494	19,498	19,502	19,506	19,510	19,514	19,518	19,522	19,526
32	19,530	19,534	19,538	19,542	19,546	19,550	19,554	19,558	19,562	19,566
33	19,570	19,574	19,578	19,582	19,586	19,590	19,594	19,598	19,602	19,606
34	19,610	19,614	19,618	19,622	19,626	19,630	19,634	19,638	19,642	19,646
35	19,650	19,654	19,658	19,662	19,666	19,670	19,674	19,678	19,682	19,686
36	19,690	19,694	19,698	19,702	19,706	19,710	19,714	19,718	19,722	19,726
37	19,730	19,734	19,738	19,742	19,746	19,750	19,754	19,758	19,762	19,766
38	19,770	19,774	19,778	19,782	19,786	19,790	19,794	19,798	19,802	19,806
39	19,810	19,814	19,818	19,822	19,826	19,830	19,834	19,838	19,842	19,846
40	19,850	19,854	19,858	19,862	19,866	19,870	19,874	19,878	19,882	19,886

These values are based upon the average of thousands of bomb calorimeter tests for the heating value of samples of fuel oil submitted to the Kansas City Testing Laboratory from a great variety of sources.

The advantages of the use of fuel oil are as follows:

1. Handling costs are reduced; fewer firemen, coal passers, helpers, etc., are required, the reduction being approximately in the ratio of 5 to 1.

2. Ease of fire control, ignition, regulation. In an emergency such as, for instance, a failure in water supply, the oil fire can be promptly extinguished. Much time is saved in bringing up the steam pressure; 150 pounds can be secured from cold water in a half hour.

3. Since combustion is nearly perfect, much higher capacities and efficiencies obtain. Excess air is held to a minimum. The opening of furnace doors for cleaning or working of fires is dispensed with; furnace temperatures are accordingly almost constant.

4. Smaller storage space is required and this may be at a much greater distance from furnace.

5. Oil in storage does not diminish in calorific value as does coal, and there is little danger from spontaneous combustion.

6. The refuse from the combustion of fuel oil is insignificant and easy of disposal. The boiler room is free of ashes and dust. Annoyance and damage to surrounding property is minimized. Tubes do not collect ashes.

7. No banking of fire occurs with the consequent loss.

8. Smoke can be practically eliminated.

9. The heat is largely isolated to the furnace and the boiler room temperatures are much lowered.

10. Since there is less excess air, the stack area may be slightly less than that required for coal. Stacks having insufficient draft with coal may with oil, be sufficient.

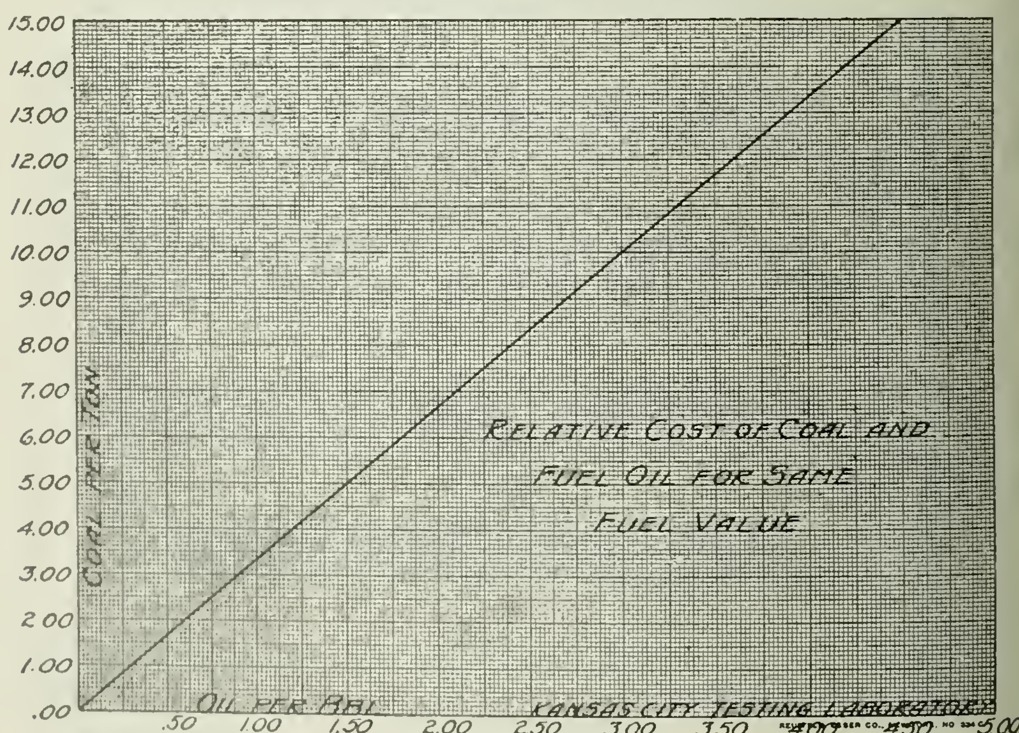


Fig. 63—Relative Cost of Coal and Fuel Oil.

11. In oil burning furnaces the heat is more uniformly distributed. There is less burning out of boiler tubes. Firing tools are unnecessary.

The disadvantages of the use of fuel oil are:

1. The fire and explosion hazard. Oil must have a flash point of 140°F or more. Some city ordinances prohibit the use of oil because of the fire risk, and require the tanks to be under ground and many feet from the nearest building.
2. Cost of oil storage.
3. A more intense temperature due to smaller excess of air with consequently increased cost of maintenance of furnace and boiler.
4. The noise in combustion and the odor is sometimes objectionable in home furnaces as well as apparent danger of fire or explosion with complicated method of burning.
5. The liability of leakage and wastage.
6. The deposition of carbon or soot on tubes and furnace walls.

REQUIREMENTS FOR BURNING FUEL OIL.

In the successful combustion of fuel oil, certain conditions must be complied with as follows:

1. A burner which gives proper atomization of the oil must be used.
2. Following atomization, the oil must be correctly mixed with air in order to give complete combustion. Air is introduced through the checker work under the burners. The quantity so admitted is varied with the amount of oil being fed; 225-250 cubic feet of air is good practice.

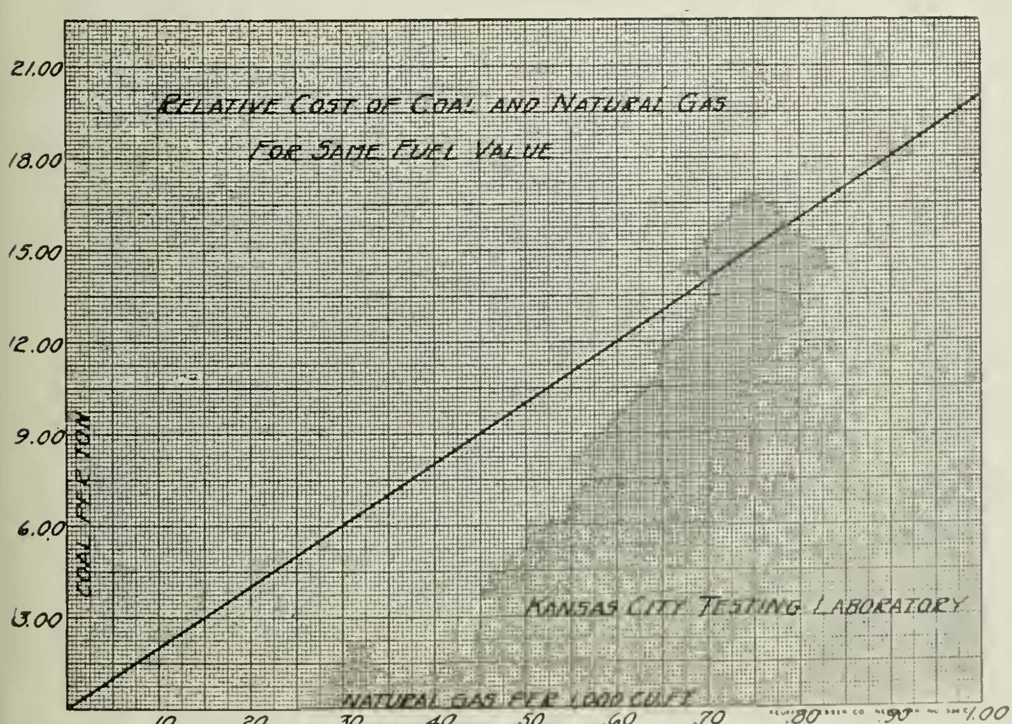


Fig. 61—Relative Cost of Coal and Natural Gas.

3. Unless the combustion is complete before the gases reach the boiler heating surfaces, it will not be completed at all until after oil and air reach the stack, when it will be wasted. To prevent this occurrence, large combustion spaces are necessary so that there is a gas travel of sufficient length.

4. Proper selection and location of burners will prevent localization of heat. Otherwise, blistering from overheating may result.

The oil burner atomizes or vaporizes the fuel so that it may be burned like a gas. There are the following types:

1. The Spray Burner. In this type the oil is atomized by compressed air or steam.

2. The Vapor Burner. In this type the oil is vaporized and passed into the furnace.

3. The Mechanical Burner. In this type, the oil is subjected to high pressure, then vaporized by forcing through a small nozzle.

The first and third types are in use in power plants, the second or carburetor type is extensively employed in Europe and in house-heaters using distillate fuel oil.

Stationary boiler plant engineers prefer spray burners over mechanical burners. Marine engineers prefer mechanical burners.

Steam spray burners are divided into two groups; outside mixers and inside mixers. Preference for the mechanical obtains where feed water is difficult or expensive to secure. The steam spray atomizer has certain advantages of flexibility, superior range of capacity and lower installation cost, notwithstanding the fact that both oil and steam lines are required, whereas the mechanical needs only the oil line. The spray burner is more easily installed in and removed

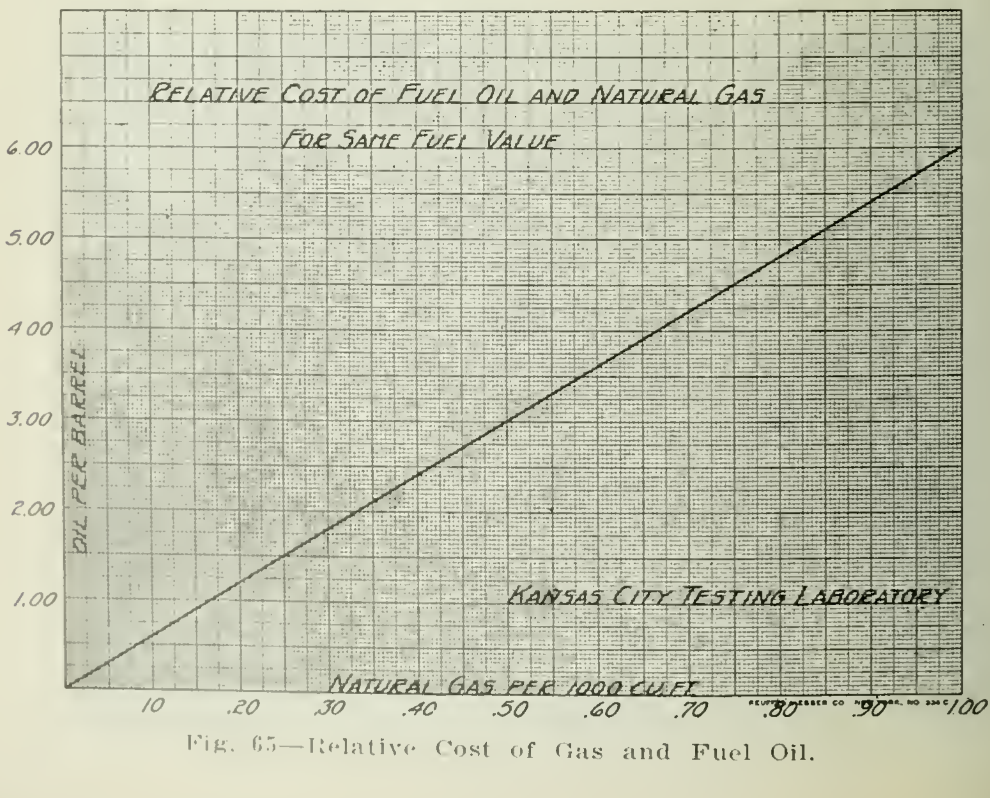


Fig. 65—Relative Cost of Gas and Fuel Oil.

from the coal-burning furnace. It requires a lower oil pressure than the mechanical. The steam required for atomization runs from 2 to 4 per cent of the boiler output. The spray burner may be operated to induce a suction on the oil supply for small installations.

OPERATION OF BURNERS.

From 25 to 50 pounds pressure is adequate where steam spray atomizers are used. The mechanical burners require pressures ranging from 50 to 250 pounds. A preferred pressure is about 200 pounds. Whatever the pressure, it must be steady with all oil burners. In the case of the mechanical, large air chambers on the oil line are a necessity if duplex reciprocating pumps furnish the pressure. There air chambers are an inconvenience in vessels where floor space is limited and the navy has overcome their need by using

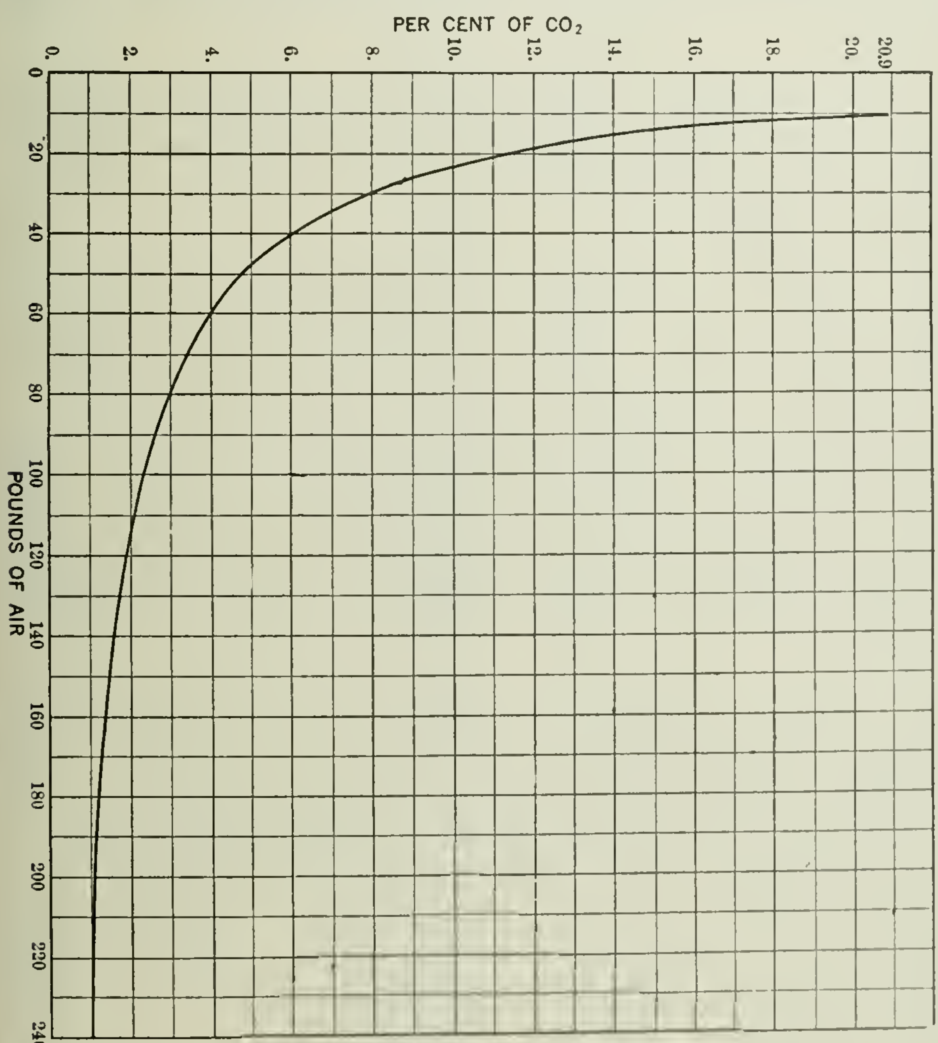


Fig. 66—Relation of Air Used to CO_2 in Stack Combustion of Fuel Oil.

rotary and screw pumps which give a steady pressure of oil with little or no air cushioning.

Fuel oil is heated to decrease the viscosity. The steam spray atomizer has the advantage over the mechanical in that it will handle oils of greater viscosity. Exhaust steam passed through coils is sufficient to raise the temperature to 125°F which is usually satisfactory. With the mechanical burner, the oil must be more mobile and a temperature of from 120 to 180°F is required. A special oil heater may be used.

In burning oil a bright, intense white flame ordinarily indicates an excess of air. The air should be regulated until the light brown haze just disappears at the top of stack.

In lighting of fires a lighted torch is placed directly under the burner pit and then the oil is turned on. This order of operation must never be reversed. If the spray is started before the torch is lighted, the oil will be injected into a dark furnace and an explosive mixture is likely to be formed by the time the torch has been lighted.

The usual feeding system consists of an installation of steam-driven pumps in duplicate. These deliver the fuel from the supply tank to the burner under pressure. Either pump may be shut down for repairs without interfering with the operation of the boiler, due to a by-passing of the piping.

In using exhaust steam to heat oil, care must be taken that the oil temperature is not raised above its flash point. A strainer should be placed on the suction line between storage tank and oil pressure pump, to keep foreign matter from stopping up the burner. A relief valve set at a maximum oil pressure should be provided between the pumps and burners to relieve excessive pressure.

A meter may be installed to record the oil consumption of each boiler. The oil piping system should be installed so that the oil can be drained back to the storage tanks when necessary. Many plants doubly insure their continuous operation by installing the equipment in duplicate sets. The supply of steam and oil may be regulated by hand to meet the requirements of the individual burner.

Standpipe pressures provide satisfactory means of operating low-pressure systems. The steam pump which runs continuously draws the oil from an underground storage tank and keeps the standpipe supplied.

The design of the oil-burning furnace is highly important. Incandescent brickwork around the flame is desirable but where this is impossible, a flat, broad flame, burning close to a white-hot checkerwork floor through which the air is continuously admitted is advisable. The flame should not impinge directly on the heating surfaces and an even heat distribution should be the aim.

The flame should never extend into the tubes. Where the furnace is located under the first pass of the boiler, the heating surfaces of the boiler easily absorb radiant energy from the incandescent firebrick. Such constructions as arches, target walls and the like are of questionable value; by localizing the heat, tubes may be burned out and the capacity of the boiler limited.

The burning of oil results in a fluffy soot deposit with a trace of oil and adheres to the tubes. If this deposit is not regularly removed, it crystallizes and carbonizes on the tubes and is difficult to scrape off. The frequent use of steam jets will result in clean tubes, the soot being easily removed in the early stages of its deposition.

Since the soot deposits which result from the combustion of oil are in the nature of pure carbon and are very adhesive their insulating effects are much increased over those from coal. With coal, the deposits settle on the top of the tube, leaving the balance of the circumference comparatively free. Oil burning causes deposits which are more evenly distributed, covering rather uniformly the entire firing areas.

Prices of Fuel Oil (U. S. G. S.)

1915—	
January	$0.40@0.50
February	.40@ .50
March	.30@ .40
April	.35@ .40
May	.35@ .40
June	.35@ .40
July	.35@ .40
August	.50@ .55
September	.50@ .55
October	.60@ .65
November	.75@ .80
December	.90@1.00
1916—	
January	1.00@1.05
February	1.05@1.10
March	1.10@1.20
April	.85@ .95
May	.60@ .80
June	.60@ .80
July	.55@ .75
August	.55@ .75
September	.55@ .75
October	.60@ .80
November	1.00@1.25
December	1.00@1.25
1917—	
January	1.00@2.00
February	1.00@2.00
March	1.00@2.00
April	1.00@2.00
May	1.00@2.00
June	1.25@1.50
July	1.25@1.50
August	1.25@1.50
September	1.25@1.50
October	1.60@2.00
November	1.25@2.25
December	1.25@2.25
1918—	
January	1.25@2.25
February	1.25@2.25
March	1.25@2.25
April	1.75@2.25
May	1.75@2.25
June	1.75@2.25
July	1.75@2.25
August	1.85@1.90
September	1.85@1.90
October	1.85@1.90
November	1.85@1.90
December	1.75@1.90
1919—	
January	1.15@2.00
February	.90@1.00
April	1.00
May	.90
June	.90
July	.80
August	.80@ .85
September	.80@ .90
October	.80@ .90
November	1.00@1.50
December	1.50@2.50
1920—	
January	2.20@2.55
February	2.15@2.20
March	2.25@2.80
April	3.00@3.25
May	3.35@3.50
June	3.15@3.50
July	3.20
August	3.25@3.35
September	3.00@3.30
October	2.50@2.85
November	2.15@2.30
December	1.70@2.05
1921—	
January	1.25@1.70
February	.55@1.00
March	.60@ .85
April	.70@ .80
May	.40@ .70
June	.40@ .50
July	.35@ .45
August	.40@ .50
September	.45@ .55
October	.75@1.10
November	.90@1.25
December	.80@1.10

The following table gives the fuel oil consumption of railroads of the United States from 1909 to 1920, figures prior to 1919 being those of the U. S. Geological Survey:

	Barrels		Barrels
1920	41,772,000	1914	31,093,266
1919	35,225,000	1913	33,004,815
1918	36,713,667	1912	33,605,598
1917	42,238,565	1911	29,748,845
1916	38,208,516	1910	23,187,346
1915	32,830,187	1909	19,905 335

Miscellaneous Facts Concerning Heating By Oil.

Good practice in the atomization of fuel oil requires an average of 0.3 pound of steam per pound of oil burned.

One pound of fuel oil requires 14 to 15 pounds or 200 cubic feet of air for complete combustion; 225 cubic feet is good practice.

The stack gases from an oil furnace for the highest efficiency should not contain less than 15% of carbon dioxide (over 13% is good).

The temperature of an oil flame with complete combustion and without an excess of air is about 3,750° F. (Natural gas flame, 3,250° F.)

One pound of oil will yield on combustion 16 to 17 pounds of gases of combustion or 400-500 cubic feet at a temperature of 400° F.

Oil is successfully used in melting iron and steel scrap. For this purpose it is much superior to coal on account of the absence of mineral matter and the very much smaller amount of sulphur.

One barrel of oil will melt one ton of steel in the reverberatory furnace, with the furnace walls already hot.

A typical malleable iron foundry by the changing of the furnaces from coal to oil fuel increased the strength of their castings 100% and increased the output 20%.

Diesel engines consume from .45 to .7 pound of heavy oil per brake H. P. per hour.

Oil requires 60% of stack area needed for coal firing.

Oil gives a fuel efficiency at least 10% greater than coal.

The advantages of oil fuel installations for locomotives and boats have been found to be as follows:

(a) Economy of space reserved for carrying fuel; 50% more fuel value per unit space.

(b) Ease in filling tanks.

(c) Rapidity of time in meeting a varying load on boiler. Fires may be instantly lighted.

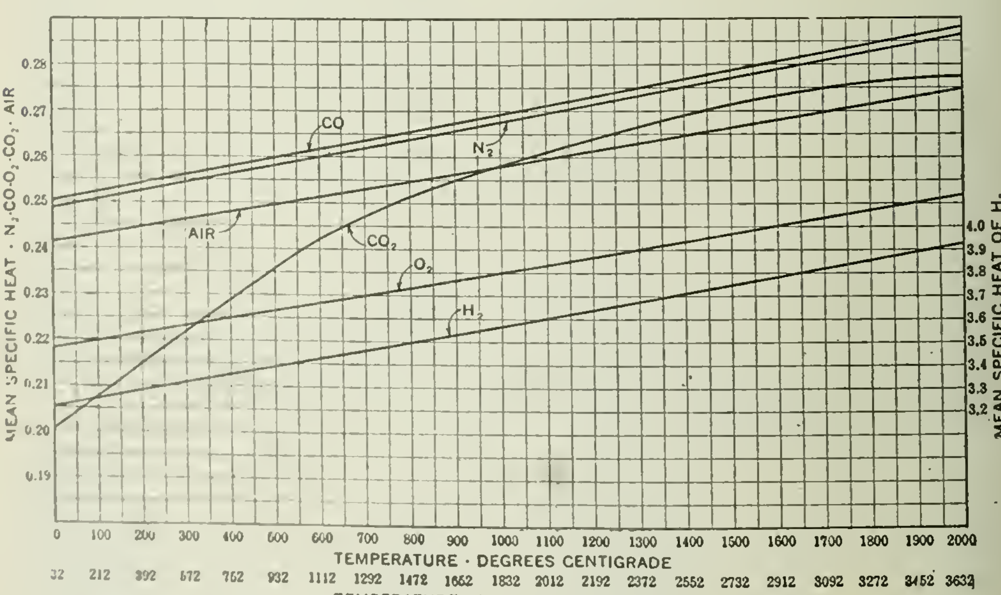
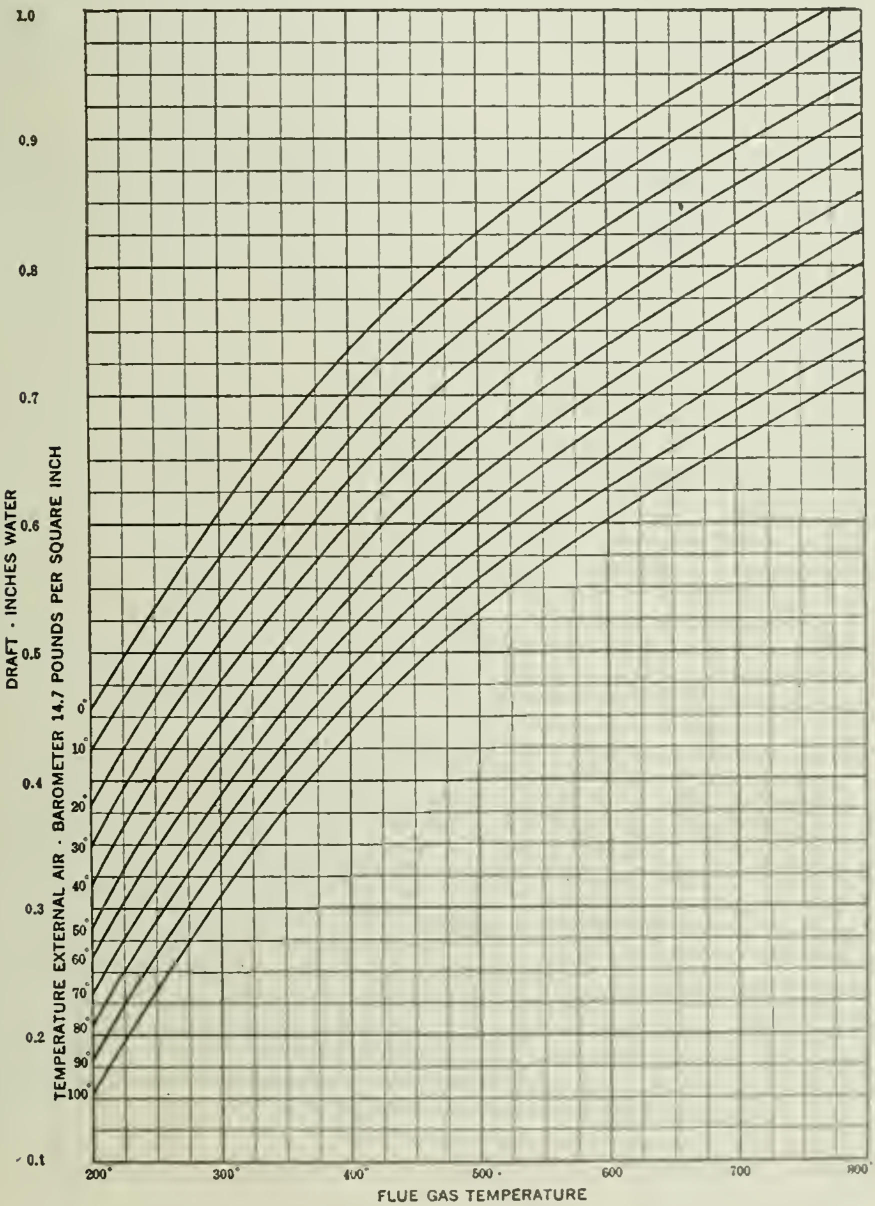


Fig. 67—The Specific Heat of Flue Gases, (G. F. Gebhardt.)

(d) Ability to force boiler to extreme duty in case of emergency.
(e) Short height of stack.
(g) Superior personnel available for the operation of the burners.
(h) Ability to secure and maintain higher speed with oil fuel than with coal. No deterioration in storage.

In the distillation of crude oil in which 50% of the crude is distilled off as benzine and kerosene, in good practice, 2.8 barrels of fuel oil are used per 100 barrels of crude oil treated.



Theoretical draft with various flue gas and air temperatures, for a chimney 100 feet high and assuming an area sufficient that friction in the chimney may be neglected. For a chimney of any other height, multiply the tabular figure by $\frac{H}{100}$, where H is the height of the chimney in feet

Fig. 68—Influence of Temperatures of Stack on Drafts in Oil Furnaces Based Upon 100-Foot Stack.

For all refining purposes in the production of gasoline, naphtha and kerosene only, from 6 to 7 barrels of fuel oil are required for each 100 barrels of crude treated, assuming that 50% of the lighter hydrocarbons are distilled from the crude.

One-fourth of a gallon of fuel oil is required to produce one gallon of 58° Baume′ gasoline by cracking according to a pressure distillation process now extensively used.

The specific heat of petroleum is about 0.5 (.49-.53), the heat of vaporization averages about 130 B. T. U. per pound and the heat of fusion 63 B. T. U. per pound (Paraffin).

For Natural Dry Petroleum of Paraffin or Semi-Paraffin Base the following relation of gravity (Baume′–U. S.) and heating value holds:

$$\text{B. T. U. per pound} = 18700 + 40\ (\text{Be}'\text{-}10).$$

Of the world's total tonnage of vessels of 100 tons and upward on Lloyd's Register, an approximate division as to the fuel motive power is as follows, according to Westgarth Brown, president of the South Wales Institute of Engineers:

	Per Cent 1919	Per Cent 1920
Using coal as fuel	76	82
Fitted to use oil as fuel for boilers	16.3	10.5
Using oil in internal combustion engines	1.7	1.5
Using sail power only	6	6

3¼ bbls. oil (42 gallons per bbl.) is the equivalent of 5,000 pounds hickory or 4,550 pounds white oak.

6 gallons oil equals 1,000 cubic feet of natural gas of calorific value of 1,000 B.T.U. per cubic foot.

3½ gallons oil equals 1,000 cubic feet of commercial or water gas of calorific value of 620 B.T.U. per cubic foot.

2¼ gallons oil equals 1,000 cubic feet by-product coke-oven gas at 440 B T.U. per cubic foot.

0.42 gallons oil equals 1,000 cubic feet blast-furnace gas at 90 B.T.U. per cubic feet.

SAMPLING FUEL OIL.

The accuracy of tests depends upon the care with which an average representative sample of fuel oil delivery has been taken and the importance of obtaining such a sample cannot be over-estimated. Top, middle and bottom samples should be taken with a standard "car thief" and these samples should be combined and thoroughly mixed to form one sample for car deliveries. Where oil is received in tanks or reservoirs the swing pipe should first be locked at a position well above the level of the water and sediment usually found in the bottom of such tanks. Tanks should be sampled every foot for the first five feet above the bottom of the swing pipe, and at five-foot intervals from there to the surface of the oil. This sampling should be done with a standard tank thief, the samples tested individually, and deductions for impurities made on the separate volumes which these samples represent. If the tank is a large one, it should be sampled through at least two hatches. In receiving large deliveries of the more viscous oils it is necessary to take many samples in order to insure fair and average impurity (M. & B. S) deductions. This is because water and sediment do not readily settle out of such oils.

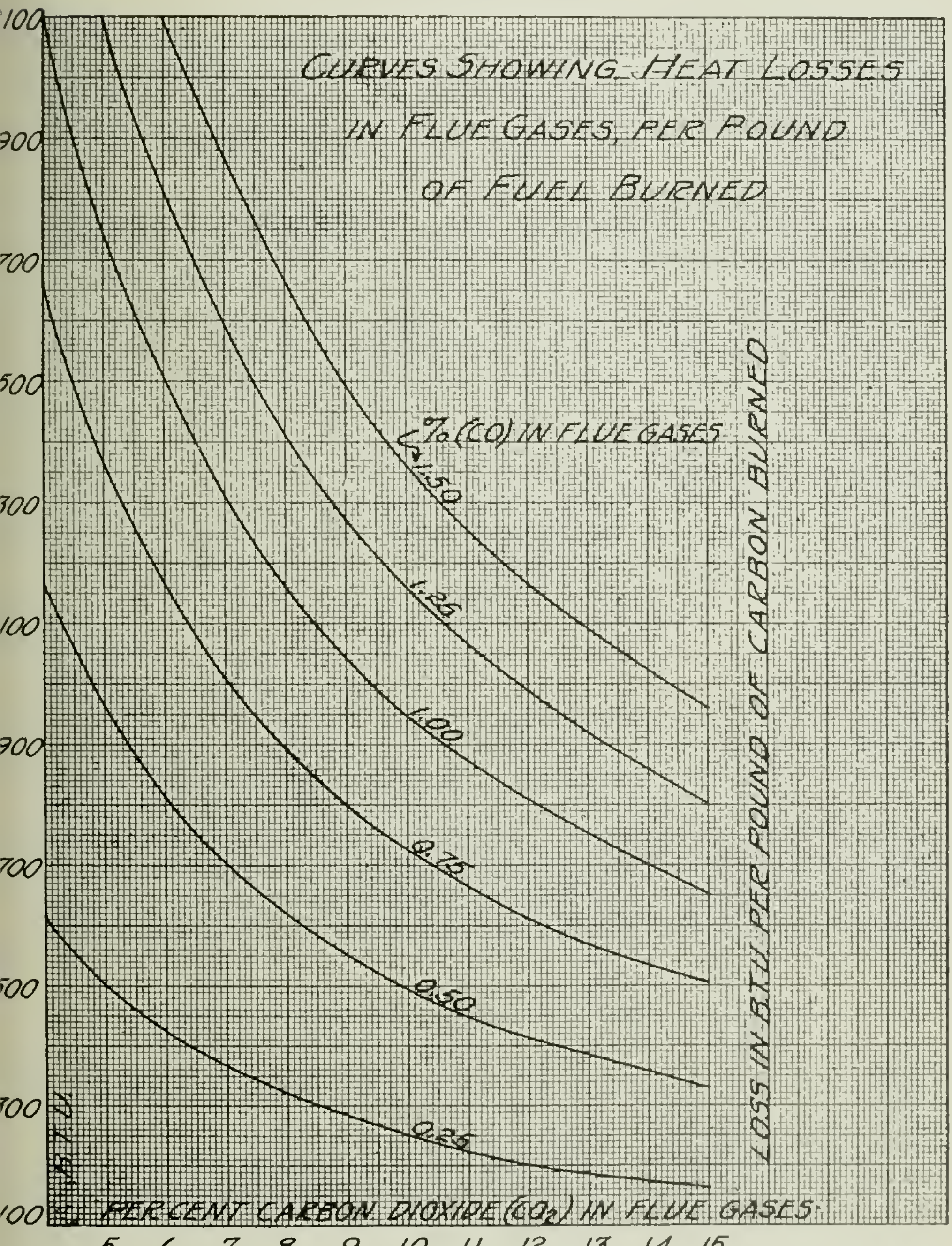


Fig. 69—Heat Losses in Flue Gases From Oil Furnaces.

Natural and Producer Gas Costs.

The following table of Producer Gas Costs includes fuel, power, repairs and maintenance, labor and supervision, interest and depreciation; in fact, every item of cost except the interest and taxes on the land occupied. (Courtesy of Steere Engr. Co., Detroit, Mich.)

Producer Gas Costs per 1000 Cu. Ft. for Coal Costs Given			Costs at Which Other Fuels Must be Bought to Obtain the Same Number of B. T. U. as When Buying Producer Gas With Coal at the Price Given							
Cost of One Ton of Coal	Hot Raw Producer Gas at Offtake	Clean Cold Producer Gas	Natural Gas per 1000 Cu. Ft.		Fuel Oil per Gallon		Coal Gas or Carburetted Water Gas per 1000 Cu. Ft.		Blue Gas per 1000 Cu. Ft.	
			Hot Raw Gas	Clean Cold Gas	Hot Raw Gas	Clean Cold Gas	Hot Raw Gas	Clean Cold Gas	Hot Raw Gas	Clean Cold Gas
$2.00	3.13c	4.15c	23.7c	31.5c	2.91c	3.86c	12.6c	16.72c	6.45c	8.59c
2.50	3.55	4.57	26.9	34.67	3.3	4.25	14.3	18.40	7.34	9.45
3.00	3.96	4.98	30.1	37.84	3.69	4.64	16.6	20.09	8.20	10.32
3.50	4.38	5.40	33.3	41.01	4.08	5.03	17.65	21.77	9.07	11.18
4.00	4.79	5.82	36.3	44.18	4.46	5.42	19.3	23.45	9.92	12.05
4.50	5.21	6.24	39.5	47.35	4.85	5.81	21.	25.13	10.78	12.91
5.00	5.63	6.66	42.7	50.52	5.24	6.20	22.7	26.82	11.65	13.78
5.50	6.05	7.08	45.9	53.69	5.63	6.59	24.35	28.50	12.5	14.64
6.00	6.46	7.49	49.1	56.85	6.01	6.97	26.0	30.18	13.36	15.50

HEATING VALUES USED.

Producer Gas .... 145 B. T. U. per cu. ft.
Natural Gas .... 1,100 B. T. U. per cu. ft.
Fuel Oil ....135,000 B. T. U. per gallon
Coal Gas or Carburetted Water Gas.......... 585 B. T. U. per cu. ft.
Blue Gas .... 300 B. T. U. per cu. ft.

Note: These costs are based on the plant operating with a 100% load factor; that is, operating at rated capacity 24 hours per day, 365 days per year. Comparatively few plants have a 100% load factor; therefore, it is necessary to take this very important point into consideration when estimating the cost of gas.

The cost of Producer Gas, with a reasonable degree of accuracy may be estimated for any load factor by applying the formula:

$$C = T + \left[\left(\frac{400R}{AB}\right) - 2.38\right]$$

Where C = Cost of Producer Gas per 1000 cu. ft. under conditions specified.
A = Number of feet of gas used per day.
B = Days per week plant is in operation.
T = Cost figures shown in table at 100% load factor.
R = Rated hourly capacity of plant in cubic feet.

It also must be kept in mind that furnace efficiencies have a very great bearing on the cost of the finished product. Without regeneration or recuperation Producer Gas cannot be used as efficiently as the more concentrated fuels.

The expense of the distribution system and the furnaces also have an important bearing on the total cost of doing the work.

Colloidal Fuel.

So-called Colloidal Fuel is a mixture of fuel oil and powdered coal. The coal is suspended in the oil to an extent of as much as 65% by weight and yet remains sufficiently fluid that it may be pumped and atomized. The usual amount of coal is about 40% with possibly 1% of some emulsifying agent.

The suspended matter may be low grade pulverized combustible matter. This incorporated with fuel oil makes possible the use of low grade coals of the high fixed carbon or high ash types which have not heretofore been successfully burned.

This colloidal fuel has a specific gravity of 1.00 to 1.25, a weight of 8.3 to 11.0 pounds per gallon, a flash point the same as the fuel oil, a heating value of from 14,500 to 17,000 B.T.U. per lb.

Some practical advantages are:

(a) It is about 20% more valuable in thermal efficiency in all types of boilers, on account of clean combustion.

(b) It can be handled by pumping.

(c) It can be fired by atomization.

(d) It can be stored indefinitely without deterioration, or fire hazard.

(e) The same volume has nearly twice the power value of coal and 10% more than fuel oil.

(f) Labor costs are reduced (70% for boats).

(g) It can be covered with water and sinks in water, thus reducing the fire danger for boats.

The following table summarizes the principal properties of various fuels compared with colloidal fuel. Essentially, colloidal fuel is nothing more than powdered coal, the voids in which have been filled with fuel oil. It is quite obvious that such a mixture will be sufficiently stable that the coal particles will not settle out.

COMPARISON OF VARIOUS FUEL PRODUCTS.

	Spec. Grav.	Voids %	Weight per Cu. Ft.	B. T. U. per Lb.	Lbs. per Gal.	B. T. U. per Gal.	Ratio of Heating Value per Cu.Ft.
Bituminous Coal, crushed	1.33	39.7	50	13,000	6.685	86,900	1.000
Powdered Coal, 85%, 200-mesh	1.35	52.5	40	14,000	5.35	74,900	0.862
Fuel Oil	0.90	0.0	56.14	19,500	7.51	146,400	1.685
Mixture—Powdered Coal with voids filled with fuel oil	1.115	0.0	69.6	16,200	9.30	151,800	1.747

U. S. Specifications for Fuel Oils (1921).

FUEL OIL FOR DIESEL ENGINES.

General:

1. This specification covers the grade of oil used by the United States Government and its agencies as a fuel for Diesel engines.

2. Fuel oil shall be a hydrocarbon oil, free from grit, acid, and fibrous or other foreign matters likely to clog or injure the burners or valves. If required, it shall be strained by being drawn through filters of wire gauze of 16 meshes to the inch. The clearance through the strainer shall be at least twice the area of the suction pipe, and the strainers shall be in duplicate.

Properties and Tests:

3. Flash Point: The flash point shall not be lower than 150°F (Pensky-Martens closed tester).

4. Water and Sediment: Water and sediment combined shall not amount to more than 0.1%.

5. Carbon Residue: The carbon residue shall not exceed 0.5%.

6. Precipitation Test: When 5 cc of the oil is mixed with 9.5 cc of petroleum ether and allowed to stand 24 hours, it shall not show a precipitate or sediment of more than 0.25 cc (5% by volume of the original oil).

All tests shall be made according to the methods for testing fuel oils adopted by the Committee on Standardization of Petroleum Specifications.

FUEL OIL (NAVY STANDARD).

General:

1. This specification covers the grade of oil used by the United States Government and its agencies where a high grade fuel oil is required.

2. Fuel oil shall be a hydrocarbon oil, free from grit, acid and importanc of obtaining such a sample cannot be over-estimated. Top, fibrous or other foreign matters likely to clog or injure the burners filters of wire gauze of 16 meshes to the inch. The clearance through the strainer shall be at least twice the area of the suction pipe and the strainers shall be in duplicate.

Properties and Tests:

3. Flash Point: The flash point shall not be lower than 150°F (Pensky-Martens closed tester). In case of oils having viscosity greater than 30 seconds at 150°F (Saybolt Furol Viscosimeter) (8° Engler) the flash point shall not be below the temperature at which the oil has a viscosity of 30 seconds.

4. Viscosity: The viscosity shall not be greater than 140 seconds at 70°F (Saybolt Furol Viscosimeter). (40° Engler.)

5. Sulphur: Sulphur shall not be over 1.5%.

6. Water and Sediment: Water and sediment combined shall not amount to over 1.0%.

All tests shall be made according to the methods for testing fuel oils adopted by the Committee on Standardization of Petroleum Specifications.

BUNKER FUEL OIL "A."

General:

1. This specification covers the grade of fuel oil used by the United States Government and its agencies where a low viscosity oil is required.

2. Fuel oil shall be a hydrocarbon oil, free from grit, acid and fibrous or other foreign matters likely to clog or injure the burners or valves. If required, it shall be strained by being drawn through filters of wire gauze of 16 meshes to the inch. The clearance through the strainer shall be at least twice the area of the suction pipe and the strainers shall be in duplicate.

Properties and Tests:

3. Flash Point: The flash point shall not be lower than 150°F (Pensky-Martens closed tester). In case of oils having viscosity greater than 30 seconds at 150°F (Saybolt Furol Viscosimeter) (8° Engler) the flash point shall not be below the temperature at which the oil has a viscosity of 30 seconds.

4. Viscosity: The viscosity shall not be greater than 140 seconds at 70°F (Saybolt Furol Viscosimeter) (40° Engler).

5. Water and Sediment: Water and sediment combined shall not amount to over 1.0%.

All tests shall be made according to the methods for testing fuel oils adopted by the Committee on Standardization of Petroleum Specifications.

BUNKER FUEL OIL "B."

General:

1. This specification covers the grade of fuel oil used by the United States Government and its agencies where a more viscous oil than Bunker Oil "A" can be used.

2. Fuel oil shall be a hydrocarbon oil, free from grit, acid and fibrous or other foreign matters likely to clog or injure the burners or valves. If required, it shall be strained by being drawn through filters of wire gauze of 16 meshes to the inch. The clearance through the strainer shall be at least twice the area of the suction pipe, and the strainers shall be in duplicate.

Properties and Tests:

3. Flash Point: The flash point shall be not lower than 150°F (Pensky-Martens closed tester).

4. Viscosity: The viscosity shall not be greater than 100 seconds at 122°F (Saybolt Furol Viscosimeter).

5. Sediment and Water: The sediment and water combined shall not amount to over 1.0%.

All tests shall be made according to the methods for testing fuel oils adopted by the Committee on Standardization of Petroleum Specifications.

BUNKER FUEL OIL "C."

General:

1. This specification covers the grade of fuel oil used by the United States Government and its agencies where a high viscosity oil is satisfactory.

2. Fuel oil shall be a hydrocarbon oil, free from grit, acid, and fibrous or other foreign matters likely to clog or injure the burners or valves. If required, it shall be strained by being drawn through filters of wire gauze of 16 meshes to the inch. The clearance through the strainers shall be at least twice the area of the suction pipe and the strainers shall be in duplicate.

Properties and Tests:

3. Flash Point: The flash point shall be not lower than 150°F (Pensky-Martens closed tester).

4. Viscosity: The viscosity shall not be greater than 350 seconds at 122°F (Saybolt Furol Viscosimeter).

5. Water and Sediment: Water and sediment combined shall not amount to over 1.0%.

All tests shall be made according to the methods for testing fuel oils adopted by the Committee on Standardization of Petroleum Specifications.

Air Supply Required for Different Grades of Fuel.

(William Kent)

$$\text{Pounds air per pound coal} = 1.05\ [11.52\ C + 34.56\ (H - \frac{0}{8})]$$

ULTIMATE COMPOSITION OF FUELS.

Ultimate analysis of coal dried at 105°C.

KIND OF COAL	Anthracite	Semi-Anthracite	Semi-Bituminous	Bituminous, Pa.	Bituminous, Ohio	Lignite, Tex.	Crude Oil, Tex.
Carbon	76.86	78.32	86.47	77.10	75.82	64.84	84.8
Hydrogen	2.63	3.63	4.54	4.57	5.06	4.47	11.6
Oxygen	2.27	2.25	2.68	6.67	10.47	16.52	1.1
Nitrogen	0.82	1.41	1.08	1.58	1.50	1.30	0.8
Sulphur	0.78	2.03	0.57	0.90	0.82	1.44	1.7
Ash	16.64	12.36	4.66	9.18	6.33	11.43	....

Pounds of Air Required for Combustion.

Per Lb. Dry Coal	14.50	15.27	17.12	15.26	15.04	12.45	....
Per Lb. Combustible	17.39	17.42	17.96	16.81	16.05	14.06	20.60
Per Lb. Carbon	18.86	19.50	19.40	19.65	19.84	19.21	24.29

Having the proximate analysis only, a close approximation to the number of pounds or air required per pound of combustible, in order to have the air supply 50% in excess, is as follows:

	Pounds
Anthracite and semi-anthracite	17.4
Semi-bituminous	18.0
Bituminous, Pennsylvania	17.0
Bituminous, Ohio	16.0
Lignite, Texas	14.0
Crude Oil, Texas	20.6

Total Heat Losses Due to Chimney Gases.

$L^1 + L^2 + L^3$.

Loss From Unburned Carbon Monoxide.

$$L_1 = \frac{101.5\ m\ c}{m + d}$$

L_1 = heat lost in B.T.U. per lb. of fuel due to incomplete combustion of carbon in flue gases.
m = percent carbon monoxide in flue gas.
c = percent carbon in fuel.
d = percent carbon dioxide in flue gas.

Loss From Specific Heat of Gases.

$L_2 = 0.24\ W\ (T_2 - T_1)$
L_2 = heat lost in B.T.U. per lb. of fuel due to temperature of stack gases.
T_2 = stack temperature.
T_1 = air temperature.
W = weight of flue gases per pound of fuel as found by flue gas analysis or = A + 1, A being pounds air used per one pound of fuel.

Loss From Water Vapor.

$L_3 = V\ (T_1 - T_2) + 965.\ (V - Va)$.
L_3 = Loss due to water vapor in the flue gases per pound of fuel.
V = Pounds water vapor in flue gas per pound of fuel used.
Va = Pounds water vapor in air per pound of fuel used.

Fuel Loss in Ashes.

$$L_4 = \frac{H\ a_1}{a_2} \text{ or } = A\ P.$$

H = heating value of ashes or refuse per pound of fuel.
a_1 = percent mineral matter or ash in fuel used.
a_2 = percent mineral matter or ash in refuse.
P = pounds of ashes or refuse per pound of fuel used.
A = B.T.U. per pound of refuse.
L_4 = loss in B.T.U. per pound of original fuel.

Properties and Requirements of One Pound of Various Fuel Elements.

Product	Carbon (C) Carbon Dioxide CO_2	Hydrogen (H) Water H_2O	Sulphur (S) Sulphur Dioxide SO_2
B. T. U. per pound burned.....	14,600	62,000	4,050
Oxygen consumed, pounds.....	2.67	7.94	0.998
Nitrogen in air, pounds........	8.89	26.59	3.342
Air used, pounds..............	11.56	34.53	4.34
Oxygen consumed, cu. ft.......	29.9	89.0	11.2
Nitrogen in air, cu. ft..........	113.3	338.7	42.6
Air used, cu. ft., 32° F.........	143.2	427.7	53.8
Flue gas, pounds..............	12.56	35.53	5.34
Flue gas at 32° F., cu. ft.......	143.2	338.7	53.8
Flue gas at 525° F., cu. ft......	286.4	1033.0	107.6

Total amount of flue gas at 525° F per lb. of fuel:

In cubic feet $= 2.86\ C + 10.33\ H + 25\ N + 1.07\ S - 1.30$

In pounds $= .126C + .355H + .01\ N + .053S - .0550$

C = % Carbon, H = % Hydrogen, N = % Nitrogen, S = % Sulphur, O = % Oxygen.

Pounds water vapor in flue gas per pound of fuel = .0894 H.

B.T.U. lost per lb. fuel on account of water vapor in flue gas at 525°F = 117. H.

Heating value of fuel (Dulong Formula adopted by A.S.M.E.)

$$\text{B.T.U. per lb.} = 146\ C + 620\ (H - \frac{O}{8}) + 40\ S.$$

$$\text{Pounds air required per lb. fuel} = .116\ C + .345\ (H - \frac{O}{8}) + .43S.$$

$$\text{Cu. ft. air at 100°F per lb. fuel} = 1.63\ C + 4.87\ (H - \frac{O}{8}) + .62S.$$

Add 50% to these values for practice in which 50% excess air is used.

Fuel Losses in Practice.

Heat Absorbed and Losses Itemized	Highest Attainable Efficiency	Excellent Practice	Good Practice	Average Practice	Poor Practice
Heat absorbed by boiler......	89.86	80.0	75.0	65.0	60.0
Loss due to free moisture in coal.....................	0.50	0.5	0.6	0.6	0.7
Loss due to water vapor......	4.20	4.2	4.3	4.3	4.4
Loss due to heat in dry flue gases....................	5.33	10.0	13.0	17.5	20.0
Loss due to carbon monoxide..	0.00	0.2	0.3	0.5	1.0
Loss due to combustible in ash and refuse................	0.00	1.5	2.4	4.5	5.5
Loss due to heating moisture in air.....................	0.11	0.2	0.2	0.3	0.4
Loss due to unconsumed hydrogen, hydrocarbon, radiation and unaccounted for........	0.00	3.4	4.2	7.3	8.0
Calorific value of coal.........	100.00%	100.0%	100.0%	100.0%	100.0%

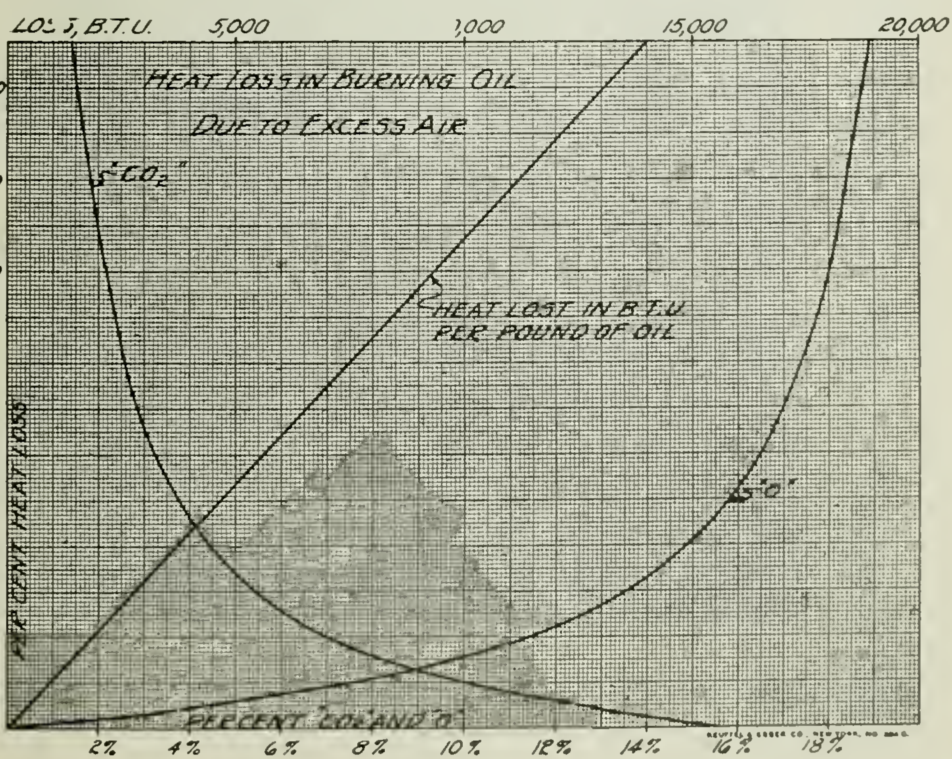


Fig. 70—Heat Losses in Oil Furnaces Due to Excess of Air.

Radiant Heat.

With poorly installed setting where insulation is not properly attended to, radiation losses may amount to as much as from 6 to 8%. Whatever the extent of the loss may be, it is usually neglected in the average plant and it is an actual fact that in 9 plants out of 10 it can be cut in two with a comparatively small expenditure for insulating material and careful attention to the work.

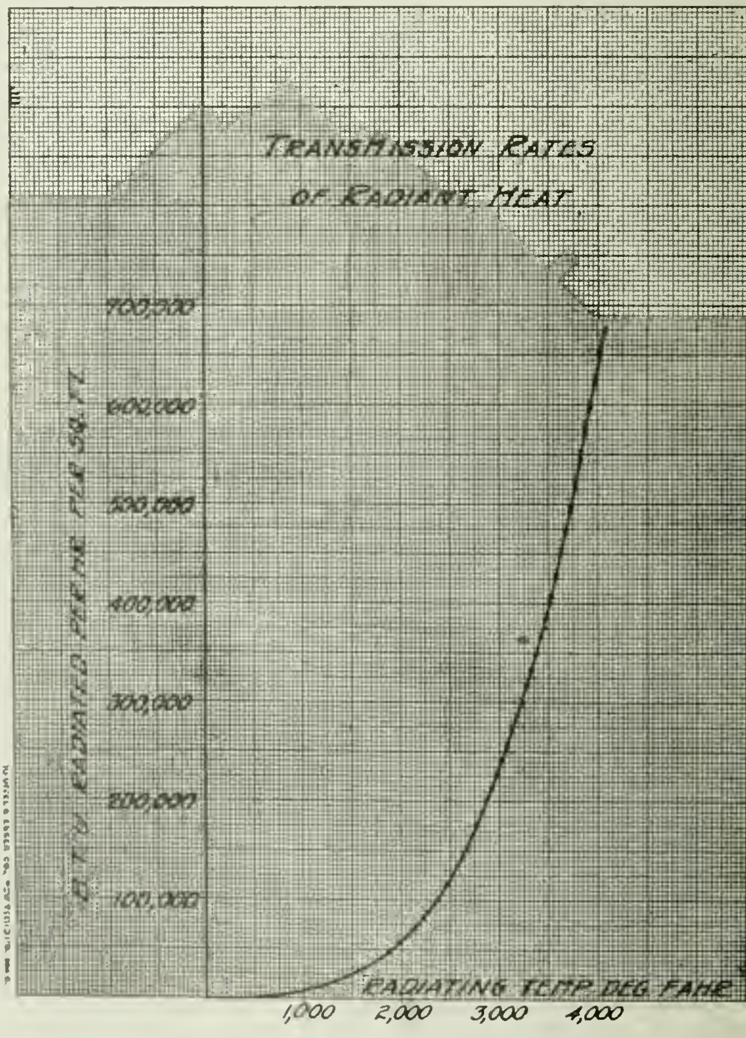


Fig. 71—Heat Transmission of Radiant Heat in Fuel Oil Furnaces.

Stack Design for Oil Furnaces.

Stacks for oil-burning equipment differ considerably from those for solid fuels as relatively slight drafts are required.

The following table prepared by Weymouth is based on actual test data. Centrally situated stacks, short flues, average operating efficiencies and a permissible overload of 50 per cent are assumed.

STACK SIZES FOR OIL FUEL.

Stack Diameter, Inches	Height Above Boiler-room Floor, Feet					
	80	90	100	120	140	160
	Nominal Rated Boiler, Horsepower					
33	161	206	233	270	306	315
36	208	253	295	331	363	387
39	251	303	343	399	488	467
42	295	359	403	474	521	557
48	399	486	551	645	713	760
54	519	634	720	847	933	1,000
60	657	800	913	1,073	1,193	1,280
66	813	993	1,133	1,333	1,480	1,593
72	980	1,206	1,373	1,620	1,807	1,940
84	1,373	1,587	1,933	2,293	2,560	2,767
96	1,833	2,260	2,587	3,087	3,453	3,740
108	2,367	2,920	3,347	4,000	4,483	4,867
120	3,060	3,660	4,207	5,040	5,660	6,160

Heat of Combustion of Various Substances.

	Calories per Gram of Combustible Matter	B. T. U. per Lb. of Combustible Matter
Acetylene	11,527	20,749
Alcohol, grain	7,054	12,697
Alcohol, wood	5,330	9,594
Asphalt, 60° penetration	9,532	17,159
Asphalt, hard, from petroleum	9,989	17,980
Asphalt, blown, from petroleum	10,210	18,380
Benzol	10,030	18,054
Cane sugar	3,961	7,130
Carbon or coke	8,137	14,647
Carbon Monoxide (CO)	2,435	4,383
Cellulose	4,208	7,575
Coal, Penn. Anthracite	8,266	14,880
Coal, West Va. Bituminous	8,778	15,800
Coal, Wyo. Lignite	7,444	13,400
Coal, No. Dak. Lignite	6,411	11,540
Coal, Kansas Bituminous	8,461	15,230
Coal, Illinois Bituminous	8,056	14,500
Coal, cannel (Missouri)	8,980	16,165
Coal, peat	5,940	10,692
Coke (from bituminous coal)	8,047	14,485
Coke, Petroleum	8,017	14,503
Cottonseed oil	9,500	17,100
Fuel oil	10,833	19,500
Gas, coal, min	4,440	7,990
max	7,370	12,266
Gas, methane	13,344	24,019
Gas, water	2,350	4,230
Gas, hydrogen	34,462	62,032
Gasoline, average	11,528	20,750
Gilsonite	9,944	17,900
Glycerin	4,316	7,769
Graphite	7,901	14,222
Hydrogen (H_2)	34,500	62,100
Iron	1,582	2,848
Methane (CH_4)	13,343	24,017
Naphthalene	9,690	17,442
Oil Gas	10,800	19,440
Paraffin wax	11,140	20,050
Producer gas	773+	1,391+
Shale oil	10,970	19,750
Shale (Bituminous—Colorado)	4,430	7,975
Shale (spent)	1,080	1,944
Starch	4,228	7,610
Stearic acid	9,374	16,873
Sulphur	2,241	4,034
Tallow	9,500	17,100
Wood	4,750	8,550

Heat of Combustion of Coal of the United States (Mine Run).

STATE	COUNTY	MINE	Thickness Seam. Feet	ULTIMATE ANALYSIS Ash and Moisture Free					PROXIMATE ANALYSIS				British Thermal Units, per Pound		
				C	H	N	S	O	H_2O	Vol.	F. C.	Ash	Natural	Dry	Combustible
Alabama	Blount	Blocton 7	5.0	83.92	5.58	1.29	0.65	8.56	3.21	32.05	60.79	3.95	14024	14490	15106
Alabama	Jefferson	Blue Creek 3	8.4	.....	.....	.....	1.08	.....	2.88	25.98	60.96	10.18	.....	.....	.....
Alabama	Jefferson	Dolomite 2	6.4	88.33	5.05	1.46	0.60	4.56	3.16	25.40	67.75	3.69	14616	15093	15691
Alaska	Bering River	Clear Creek	18.0	88.73	4.42	1.61	0.74	4.50	5.71	8.75	80.89	4.65	14185	15046	15826
Alaska	Seward Penins'a	Chicago Creek	88.0	70.78	5.05	1.08	1.21	21.88	39.66	25.38	31.07	3.89	.....	.....	.....
Arizona	Coconine	Tuba	4.3	.....	.....	.....	1.66	.....	9.15	33.27	43.86	13.72	10489	11545	13599
Arkansas	Sebastian	Banner	5.3	89.57	3.87	1.74	3.57	1.25	3.21	14.84	72.66	9.29	13588	14038	15530
California	Monterey	Stone Canyon	12.7	76.03	6.35	1.35	4.80	11.47	6.95	46.69	40.13	6.23	12447	13376	14336
Colorado	Boulder	Simpson	7.1	76.22	5.07	1.68	0.51	16.52	19.28	34.61	41.41	4.60	9064	12468	13239
Colorado	Garfield	Black Diamond	16.0	75.58	5.12	1.90	1.19	16.21	14.11	32.71	43.99	9.19	10355	12056	13502
Colorado	Los Animos	Bowen	7.0	83.84	5.85	1.18	0.80	8.33	3.04	28.01	50.61	18.34	11869	12242	15098
Georgia	Chattanooga	Lookout	1.95	86.39	4.77	1.33	1.55	5.96	3.80	15.88	65.83	14.49	12791	13297	15653
Idaho	Cassia	Worthington	4.2	.....	.....	.....	4.77	.....	34.28	26.64	25.70	13.38	8613	13106	13457
Illinois	Franklin	Benton	9.2	81.12	5.24	1.82	1.91	9.91	8.31	31.65	49.56	14.48	11727	12789	14450
Illinois	St. Clair	Shiloh	6.8	77.51	5.49	1.34	5.32	10.34	11.17	39.31	39.20	10.32	11223	12634	14296
Illinois	Sangamon	Springfield 2	6.0	77.85	5.39	1.44	5.51	9.81	12.77	34.68	40.77	11.78	10757	12332	14258
Indiana	Green	Linton	7.0	78.26	5.44	1.36	5.43	9.51	10.30	36.31	41.64	11.75	11218	12508	14391
Indiana	Vigo	Macksville	5.8	78.77	5.65	1.40	4.16	10.02	13.53	34.80	40.91	10.76	10948	12661	14459
Iowa	Polk	Altoona 4	4.5	75.83	5.52	1.16	8.53	8.96	13.88	36.94	35.17	14.01	10244	11894	14206
Kansas	Cherokee	Scammon 9	4.0	81.21	5.44	1.41	6.68	5.26	2.50	33.80	51.25	12.45	12900	13228	15167
Kansas	Leavenworth	Lansing	1.9	77.59	5.54	1.29	9.94	5.64	6.95	35.70	45.16	12.19	11905	12794	14724
Kentucky	Muhlenberg	Central 9	4.7	80.16	5.24	1.56	4.39	8.65	8.76	35.02	46.80	9.42	11965	13113	14623
Kentucky	Webster	Wheatcroft	5.4	81.04	5.56	1.59	1.57	10.24	9.29	31.97	54.13	7.61	12874	13738	14953
Kentucky	Johnson	Flambeau	4.3	82.45	7.25	1.34	1.13	7.83	2.20	50.64	36.70	10.46	13748	14058	15733
Maryland	Alleghany	Ocean 3½	7.0	89.48	4.67	1.91	1.13	2.81	2.70	14.50	74.00	8.80	13910	14290	15710
Michigan	Saginaw	Barnard	3.0	81.91	5.56	1.46	1.53	9.54	11.91	31.50	49.75	6.84	11785	13374	14499
Missouri	Macon	Bevier 8	4.9	76.48	5.36	1.34	7.20	9.62	11.50	33.63	38.01	16.86	10179	11502	14207
Missouri	Lafayette	Corder	1.8	77.73	5.85	1.41	5.96	9.05	12.34	34.36	41.97	11.33	10998	12546	14409
Missouri	Bates	New Homel	4.9	78.83	5.59	1.30	7.26	7.02	4.92	38.29	42.28	14.52	11975	12596	14864
Missouri	Cooper	Fortuna (pocket)	....	81.97	7.50	1.40	2.03	7.10	2.60	44.59	43.89	8.92	14333	14718	16200

Heat of Combustion of Coal of the United States (Mine Run)—Continued

STATE	COUNTY	MINE	Thickness Seam, Feet	ULTIMATE ANALYSIS Ash and Moisture Free					PROXIMATE ANALYSIS				British Thermal Units, per Pound		
				C	H	N	S	O	H_2O	Vol.	F. C.	Ash	Natural	Dry	Combustible
Oklahoma	Pittsburg	Hartshorne 8	4.1	83.54	5.75	2.10	1.66	6.95	3.53	36.34	55.22	4.91	13885	14393	15165
Oklahoma	La Flore	Panama	4.0	90.23	4.70	1.84	1.36	1.87	5.17	13.65	73.21	8.03	13662	14398	15728
Oregon	Coos	Beaver	6.0	72.20	5.29	1.67	1.15	19.69	16.10	31.10	39.63	13.17	9031	10764	12769
Pennsylvania	Alleghany	Bertha	5.0	84.57	5.39	1.72	1.38	6.94	2.61	34.92	56.30	6.17	13997	14371	15345
Pennsylvania	Cambria	Sterling 1	3.2	88.71	4.81	1.29	1.87	3.32	2.90	17.00	73.40	6.70	14310	14740	15840
Pennsylvania	Schuylkill	St. Nicholas	9.0	96.39	1.77	0.71	1.00	0.13	2.80	1.16	88.21	7.83	13298	13682	14882
Rhode Island	Newport	Portsmouth	2.3	95.62	0.48	0.29	0.16	3.45	22.92	2.78	58.37	15.93	8528	11063	13946
South Dakota	Harding	Outcrop	9.0	70.99	4.45	1.20	0.96	22.40	40.25	25.21	27.17	7.37	......	......	......
Tennessee	Campbell	Rex No. 2	3.5	82.30	5.27	1.76	1.93	8.74	3.03	34.01	58.05	4.91	13858	14290	15052
Texas	Houston	Wooter	5.7	72.55	5.67	1.33	1.46	18.99	34.70	32.23	21.87	11.20	7056	10805	13043
Utah	Carbon	Aberdeen	22.0	80.11	5.59	1.38	0.35	12.57	4.47	40.79	49.98	4.76	12892	13590	14303
Virginia	Wise	Coburn	6.4	86.89	5.22	1.72	0.72	5.45	3.05	31.65	60.82	4.48	14470	14926	15647
Washington	King	Black Diamond	4.5	77.11	5.56	1.67	0.53	15.13	7.77	37.97	45.10	9.16	11673	12656	14051
Washington	Lewis	Weikel	3.6	90.92	3.71	1.65	0.70	3.02	3.90	7.40	71.20	17.50	11900	12390	15150
West Virginia	McDowell	Carretta	4.1	90.48	4.64	1.46	0.74	2.68	1.72	17.85	73.56	6.87	14571	14827	15941
West Virginia	Marion	Kingmont	7.2	84.86	5.54	1.68	0.98	6.94	1.75	36.77	55.14	6.34	14107	14359	15349
Wyoming	Carbon	Hanna	8.0	75.24	5.29	1.08	0.35	18.04	11.30	40.32	41.07	7.31	10755	13125	13216
Wyoming	Sweetwater	Rock Springs	7.0	76.93	5.13	1.38	0.90	15.66	8.53	35.60	50.39	5.48	11833	12937	13761
Montana	Park	Maxey	8.7	76.21	4.76	1.17	0.58	17.28	16.33	30.12	40.05	13.50	9247	11052	13178
Montana	Valley	Bruegger	8.7	.....	.....	.....	0.57	.....	43.16	22.03	28.99	5.82	5999	10555	11759
Montana	Carbon	Bear Creek	8.0	71.06	5.11	1.67	1.72	20.44	10.05	37.22	46.70	6.03	11194	12445	13338
New Mexico	Colfax	Dawson 2	5.3	83.08	5.83	1.23	0.91	8.95	2.17	37.93	45.08	14.82	12586	12865	14967
New Mexico	McKinley	Clarksville	4.4	77.65	5.40	1.51	0.50	14.94	14.49	37.08	44.58	3.85	11468	13412	14043
North Dakota	Billings	Sand Creek	35.0	71.09	4.40	1.24	1.00	22.27	43.78	26.07	26.33	3.82	5972	10624	11398
Ohio	Belmont	Black Oak	5.0	79.69	5.30	1.40	5.17	8.44	3.44	36.04	47.58	12.94	12287	12724	14693
Ohio	Jefferson	....	4.5	82.04	5.45	1.50	3.97	7.04	3.53	37.45	49.90	9.12	13072	13550	14965
Oklahoma	Okmulgee	Henryetta 1	3.0	81.43	5.50	1.50	2.31	9.26	7.04	34.55	48.40	10.01	12202	13126	14711

Melting Point and Heat of Fusion of Various Substances.

NAME	MELTING POINT	Heat of Fusion	
		Calories per Gram	B. T. U. per Lb.
Acetic acid	3 ° C = 37.4° F	43.7	78.7
Ammonia (NH_3)	—75 ° C = 103.0° F	108.1	194.6
Anilin	—7 ° C = +19.4° F	21.0	37.8
Beeswax	62 ° C = 143.6° F	42.3	76.1
Benzol	2 ° C = 35.6° F	29.1	52.4
Bismuth	266.8° C = 514.0° F	12.64	22.7
Bromine	—7.3° C = 18.8° F	16.2	29.2
Cadmium	321 ° C = 610.0° F	13.7	24.7
Calcium Chloride ($CaCl_2$)	774 ° C = 1426.0° F	54.6	98.3
Carbon dioxide	—56.3° C = 133.4° F	43.8	78.8
Cast Iron—gray	1221 ° C = 2330.0° F	23.0	41.4
white	1093 ° C = 2000.0° F	32.0	57.6
Chlorine	—103.5° C = 154.0° F	22.96	41.4
Copper	1055 ° C = 1930.0° F	43.0	77.4
Cresol	34 ° C = 93.2° F	26.3	47.3
Gallium	13 ° C = 55.4° F	19.1	34.4
Glycerin	13 ° C = 55.4° F	42.5	76.5
Ice	0 ° C = 32 ° F	80.0	144.0
Lead	325 ° C = 617.0° F	5.86	10.5
Mercury	—38.7° C = 37.7° F	2.75	4.95
Naphthalene	79.2° C = 175.0° F	35.5	63.9
Nitrobenzol	—9.2° C = 15.4° F	22.3	40.1
Palladium	1500.0° C = 2732.0° F	36.3	65.3
Paraffin	50.0° C = 122.0° F	35.1	63.3
Phenol	25.4° C = 77.9° F	24.9	44.8
Phosphorus	27.4° C = 81.4° F	4.74	8.5
Platinum	1779.0° C = 3234.0° F	27.2	49.0
Potassium	58.0° C = 136.4° F	15.7	28.3
Potassium Hydroxide	360.4° C = 681.0° F	28.6	51.5
Silver	999.0° C = 1830.0° F	21.1	38.0
Silica	1750.0° C = 3183.0° F	258.0	464.5
Sodium	96.5° C = 206.0° F	31.7	57.1
Sodium Chloride	804.0° C = 1479.0° F	123.5	222.3
Sodium Fluoride	992.0° C = 1818.0° F	186.1	335.0
Sodium Hydroxide	318.0° C = 604.0° F	40.0	72.0
Spermeceti	45.0° C = 113.0° F	37.0	66.6
Stearic Acid	64.0° C = 147.0° F	47.6	85.7
Sulphur	115.0° C = 239.0° F	9.37	16.9
Thallium	290.0° C = 554.0° F	7.2	12.9
Tin	228.0° C = 442.0° F	13.3	23.9
Zinc	415.3° C = 780.0° F	28.1	50.6

Heat of Vaporization and Boiling Point of Various Substances.

NAME	Temperature of Boiling (Pressure not given)	Heat of Vaporization Calories per Gram	Heat of Vaporization B. T. U. per Lb.
Acetic acid	110.0° C = 230.0° F	92.8	167.0
Acetone	56.6° C = 133.8° F	155.2	279.3
Alcohol (ethyl)	70.0° C = 158.0° F	208.92	376.0
Alcohol (methyl, wood)	64.5° C = 148.2° F	267.5	481.5
Ammonia (1 atmos.)	—33.5° C = —28.3° F	341.0	614.0
Ammonia	17.0° C = 62.6° F	297.0	534.6
Ammonium Chloride	350.0° C = 662.0° F	709.0	1276.0
Amyl Alcohol	131.0° C = 268.0° F	120.0	216.0
Amyl Chloride	107.0 °C = 224.6° F	56.3	101.3
Amylene	12.5° C = 54.6° F	75.0	135.0
Aniline	183.0° C = 360.5° F	104.2	187.5
Benzol	80.0° C = 176.0° F	93.45	168.2
Butyl Alcohol	83.0° C = 181.4° F	130.4	234.7
Butyric Acid	163.0° C = 325.4° F	114.0	205.2
Carbon Dioxide	.0° C = 32.0° F	56.25	101.25
Carbon Disulphide	46.2° C = 115.2° F	86.67	156.0
Carbon Tetrachloride	76.2° C = 169.2° F	46.4	83.5
Chloroform	60.9° C = 141.6° F	58.49	105.30
Cresol	201.6° C = 395.0° F	100.5	180.9
Chlorine	—22.0° C = 7.6° F	67.4	121.3
Decane	159.5° C = 319.0° F	60.8	109.4
Ether	34.9° C = 94.8° F	91.11	164.0
Ethyl Acetate	73.1° C = 163.6° F	84.3	151.7
Formic Acid	100.0° C = 212.0° F	120.4	216.7
Gasoline	40-150.0° C = 104-300° F	75.00	135.0
Heptane	90.0° C = 194.0° F	77.8	140.0
Hexane	68.0° C = 154.4° F	79.4	142.9
Hexylene	.0° C = 32.0° F	92.7	166.8
Hydrogen Sulphide	—61.4° C = 78.5° F	132.0	237.6
Iodine	174.0° C = 345.0° F	23.95	43.10
Mercury	350.0° C = 662.0° F	62.0	111.60
Methyl Acetate	57.1° C = 134.8° F	97.0	174.6
Nitric Acid	86.0° C = 186.8° F	115.1	207.2
Nitrogen	—195.6° C = 320.0° F	47.65	85.8
Nitrous Oxide	—20.0° C = —4.0° F	67.0	120.6
Nitrobenzol	151.5° C = 305.0° F	79.2	142.5
Octane	120.0° C = 248.0° F	71.4	128.5
Oxygen	—188.0° C = —306.0° F	58.0	104.4
Pentane	30.0° C = 86.0° F	85.8	154.4
Propyl Alcohol	90.0° C = 194.0° F	169.0	304.2
Sulphur	316.0° C = 601.0° F	362.0	651.5
Sulphur Dioxide	0.0° C = 32.0° F	91.7	165.0
Sulphuric Acid	326.0° C = 619.0° F	122.1	219.8
Sulphur Trioxide	18.0° C = 64.4° F	147.4	265.3
Toluol	110.8° C = 231.0° F	84.0	151.2
Turpentine	160.0° C = 320.0° F	74.0	133.2
Xylol	139.9° C = 284.0° F	82.0	147.6
Water	108.0° C = 226.0° F	535.9	964.6

Specific Heat of Various Substances Solid and Liquid

Acetic acid—solid	0.627
liquid	0.502
Acetone	0.528
Alcohol Methyl—absolute	0.600
Alcohol Ethyl—95%	0.700
Alumina	0.197
Aluminum	0.2185
Allyl Alcohol	0.665
Ammonia (0° C)	0.876
(20° C)	1.190
(70° C)	1.233
Ammonium Nitrate (64%)	0.610
Amyl Alcohol	0.455
Amylene	1.060
Anilin	0.512
Antimony	0.495
Asphalt	0.550
Benzol—fluid	0.407
solid	0.397
Beeswax	0.820
Bismuth	0.305
Bismuth—liquid	0.0308
Brass	0.0939
Brick work and masonry	0.200
Brine, 25%	0.8073
Cadmium	0.1804
Carbon bisulphide	0.240
Carbon (diamond)	0.145
Carbon dioxide	0.215
Carbon (graphite)	0.186
Carbon tetrachloride	0.203
Calcium chloride sol.(40%)	0.636
Cast Iron	0.130
Cellulose	0.33
Chalk	0.215
Charcoal	0.214
Chlorine—solid (108° C)	0.1446
Chlorine—liquid (0° C)	0.2230
Coal, average	0.220
Coke	0.203
Copper	0.0933
Concrete	0.20
Corundum	0.198
Cresol	0.553
Ether	0.5034
Flint and rocks in general	0.200
Fuel oil	0.550
Fusel oil	0.5640
Gallium—solid	0.079
Gallium—liquid	0.80
Gasoline	0.475
Gas oil	0.500
Glass—plate	0.186
Glass—common	0.117
Glycerin	0.576
Gold	0.316
Granite	0.190
Graphite	0.202
Gypsum, sulphate of lime	0.197
Heptane	0.487
Hexane	0.504
Hexadecane	0.496
Ice	0.505
Iodine	0.057
Iron	0.1130
Kerosene	0.490
Lead—liquid	0.0402
Lead	0.0315
Limestone	0.210
Manganese	0.1217
Magnesium	0.245
Marble	0.208
Mercury	0.0331
Naphthalene	0.314
Nickel	0.1091
Nonane	0.503
Octane	0.505
Paraffin Wax	0.563
Pentane	0.476
Petroleum	0.505
Phenol	0.561
Phosphorus (red)	0.1698
Phosphorus (yellow)	0.202
Platinum	0.0323
Quartz and sand	0.190
Quick lime	0.217
Rubber	0.481
Selenium (cryst.)	0.084
Selenium (amorph.)	0.112
Seawater	0.951
Silver	0.0568
Soda Ash	0.231
Solium chloride (26%)	0.780
Sodium nitrate (47%)	0.708
Sulphuric acid (solid)	0.2349
Sulphuric acid (liquid)	0.3315
Sulphuric acid (85%)	0.406
Sulphur chloride	0.202
Sulphur	0.1844
Sulphur liquid	0.2340
Sulphuric acid (sp. gr. 1.87)	0.3350
Tin	0.0559
Toluol	0.363
Turpentine	0.472
Wood (dry)	0.327
Wood (wet)	0.500
Zinc Chloride (68%)	0.437
Zinc	0.0938

Specific Heat of Gases and Vapors.

	Constant Pressure	Constant Volume
Acetone	0.3740	0.16847
Acetic acid	0.4125	0.399
Air	0.23751	0.299
Alcohol	0.4534	....
Ammonia	0.508	....
Argon	0.123	....
Benzol	0.332	....
Blast furnace gas	0.2277	....
Carbonic acid, CO_2	0.217	0.171
Carbon monoxide CO	0.2479	0.1758
Chlorine	0.124	....
Chloroform	0.1567	....
Ether	0.4797	0.3411
Flue Gas, 10%, CO_2	0.318	....
Hydrogen	3.40900	2.41226
Hydrogen chloride	0.194	....
Methane, CH_4	0.5929	0.4683
Nitrous Oxide	0.224	....
Nitrogen	0.24380	0.17273
Olefiant gas, C_2H_4 (ethylene)	0.404	0.332
Oxygen	0.21751	0.15507
Sulphur dioxide (SO_2)	0.1553	0.1246
Superheated steam (water vapor) (atmospheric pressure	0.4805	0.346
Helium	1.250	....
Carbon bisulphide (CS_2)	0.1596	....
Nitric oxide	0.2317	....

Thermal Units.

The **BRITISH THERMAL UNIT** (B. T. U.) is the heat required to raise the temperature of one pound of water, one degree Fahr. (average between 32° and 212°F). As one kilogram is equal to 2.20462 pounds and one degree Cent. is equal to 9/5 degrees Fahr. the large calorie is 3.96832 (2.20462 × 9/5) times as great as the British Thermal Unit, the small calorie being 0.00396832 times the British thermal unit.

The **SMALL CALORIE** is the amount of heat required to raise the temperature of one gram of water one degree Cent. (from 0° to 1°, 4° to 5°, or 15° to 16° being used, giving slightly different values.)

The **LARGE CALORIE** is the amount of heat required to raise the temperature of one kilogram of water one degree Cent. It is therefore one thousand times as large as the small calorie.

The **HEAT OF COMBUSTION** of a substance is the number of small or large calories of heat evolved during the combustion of a gram or a kilogram of the substance.

Using the English weights and measures, it is the number of B.T.U. of heat evolved during the combustion of one pound of the substance. To convert the former into the latter value the number of calories must be multiplied by 1.8 (3.96832 ÷ 2.20462).

The **HEAT OF FORMATION** of a substance is the number of calories of heat evolved or absorbed when a gram molecular weight of the substance is formed. When heat is absorbed, the value found is negative.

The **MELTING POINT** of the substance is the temperature at which the solid or liquid forms are capable of existing together in equilibrium.

The **BOILING POINT** of a liquid is the highest temperature at which the liquid and its pure vapor can exist together in equilibrium. This temperature varies with the pressure.

The **SPECIFIC HEAT** of a substance is the ratio of the number of thermal units necessary to raise the temperature of a substance one degree, divided by the number of thermal units necessary to raise the same weight of water at 60°F one degree. It may also be defined as the number of thermal units required to raise the temperature of one gram of a substance one degree Centigrade.

The **HEAT OF FUSION** of a substance is the number of thermal units required to change a unit mass of the solid at its melting point into liquid at the same temperature.

The **HEAT OF VAPORIZATION** of a liquid is the number of thermal units required to change a unit mass of the liquid at its boiling point into vapor at the same temperature.

TEMPERATURE UNIT or thermal intensity is measured in degrees Centigrade (Celsius) or degrees Fahrenheit. One degree Cent. is one one-hundredth of the difference of temperature between the freezing point of water and its boiling point at 760 millimeters pressure as indicated by the expansion of mercury. A degree Fahr. is one one-hundred eightieth of the difference of temperature between the freezing point of water and the boiling point of water.

MECHANICAL EQUIVALENT OF HEAT—779.4 ft. pounds = 1 B.T.U.

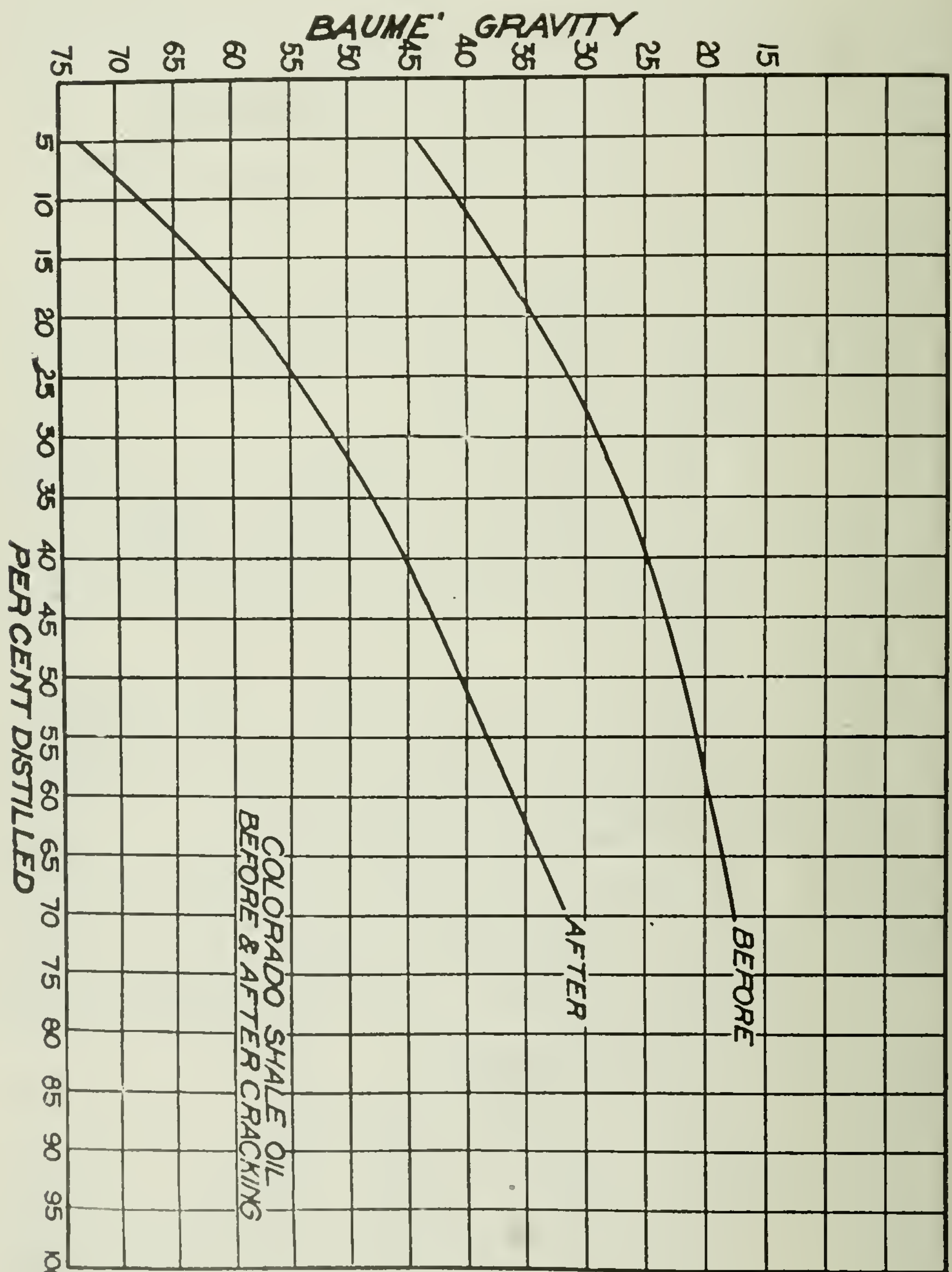


Fig. 72—Shale Oil Fractional Gravity Before and After Cracking.

Distillation Products of Coal and Oil Shale.

Oil shale is a stratified sedimentary rock in which are found numerous fragments of fossil plants and animals, principally aquatic form. Oil shale in its natural form does not contain any oil whatever but it does contain on the average about 35% of organic matter. The mineral base of oil shale presents a suggestion as to the origin of the organic matter. The mineral is a hydrous silicate of alumina and as a general rule hydrous silicates of alumina have great absorptive power for hydrocarbons of large molecular weight. A typical one, Bentonite, as well as Fuller's Earth, has the property of decolorizing and removing complex matter from hydrocarbon oils. Oil shale may then be compared with Fuller's Earth which has turned black or greenish black after absorbing a large amount of coloring matter from petroleum. This may readily have taken place while the petroleum was vaporizing. This organic matter when subjected to pyrogenic distillation forms the following products:

Fuel oil or shale oil, 20.25% equal to 405 lbs. or 54 gal. per ton.

Water, 4.08% equal to 83 lbs. or 10 gal.

Combustible gas 8.86% equal to 1,605 cubic cubic feet.

Ammonia as ammonium sulphate, 0.90% = 34 lbs. ammonium sulphate.

Mineral matter and carbonaceous residue 66.0%.

With a low temperature distillation, larger amounts of heavier fuel oil are obtained. With the higher temperature distillation, smaller amounts of shale oil containing more or less naphtha and burning oil are obtained.

A typical distillation of oil shale is as follows:

Commercial Fractions:

Naphtha (410°F) "gasoline"	10.0%	(46° Baume')
Burning oil	18.2%	
Gas and lubricating oil	61.8%	
Residue	10.0%	

Fractional Distillation of Oil:

Fraction	Boiling point	Gravity (25°C)
0- 10	100°C	0.794 = 46.3°Be'
10- 20	194	0.822 = 40.3°Be'
20- 30	230	0.846 = 35.5°Be'
30- 40	255	0.867 = 31.5°Be'
40- 50	285	0.885 = 28.2°Be'
50- 60	309	0.899 = 25.7°Be'
60- 70	328	0.912 = 23.5°Be'
70- 80	337	0.900 = 25.5°Be'
80- 90	345	0.910 = 23.8°Be'
90-100	350	0.910 = 23.8°Be'

This product in many respects resembles ordinary crude petroleum and for this reason the shale oil industry has aroused great interest on account of its possible substitution for petroleum. Shale oil, however, is utilized in only a few countries, chiefly Scotland, though oil shale is very widely distributed throughout the world. The oil shale resources of the United States are so extensive as to furnish an effective guarantee for the future when the underground reservoirs of petroleum are exhausted. The cost of obtaining the shale oil, however, will in all probability far exceed the present cost of obtaining petroleum. It is possible that the mining of petroleum by shafts will be resorted to before it is necessary to depend upon oil shale as a source of fuel oil. Many difficulties of mining, production, refining and marketing of shale oil must be overcome. Much of the known oil shale is remote from routes of transportation in a territory difficult of access and is far removed from points of fuel oil consumption. Methods of mining and transportation must be developed; processes of extracting the oil from the shale must be perfected; improved methods of refining which do not entail large losses must be worked out. Present methods of refining crude oil cannot be profitably applied to the refining of shale oil on account of the different chemical character. Most oil shale is a tough, brownish to black fine grained rock. It is not an article of commerce except possibly as a road building material and it cannot be transported any great distance from the point where it is mined. The mineral matter is the greater portion of its content and is essentially a disintegrated feldspar impregnated with the organic matter. The composition of the mineral ash of a shale found in Colorado is as follows:

Loss on ignition		11.05%
Silica	(SiO_2)	37.10%
Alumina	(Al_2O_3)	20.30%
Iron Oxide	(Fe_2O_3)	9.20%
Lime	(CaO)	12.05%
Magnesia	(MgO)	5.10%
Sulphur	(SO_3)	4.80%
Alkalies and difference		0.40%
		100.00%

It is estimated that in Colorado alone there is enough shale to produce 20,000 million barrels of oil and 300 million tons of ammonium sulphate.

Oil shale is mined somewhat like coal and is then crushed to convenient size and roasted in retorts, in which its volatile constituents are driven off. In Scotland and France, the only countries where the oil shale industry has yet been established, the shale is fed by gravity from a storage hopper into the top of a vertical cylindrical retort; in which it is allowed to move slowly downward while it is being roasted until it is discharged from the lower end as waste. The heat is applied externally in such a manner that the temperature increases downward in the retort. The temperature in the upper third of the retort where all the oil gases are driven off does not rise above 900°F; the temperature in the lower part of the retort is raised to about 1600°F in order to convert the maximum amount of nitrogen in the shale into ammonia. The gases and vapors formed in the retort are conveyed through condensing and scrubbing apparatus to separate and clean the oil and ammonia. The oil is then refined by methods similar to those used in refining petroleum and the ammonia is converted into ammonium sulphate by treatment with sulphuric acid.

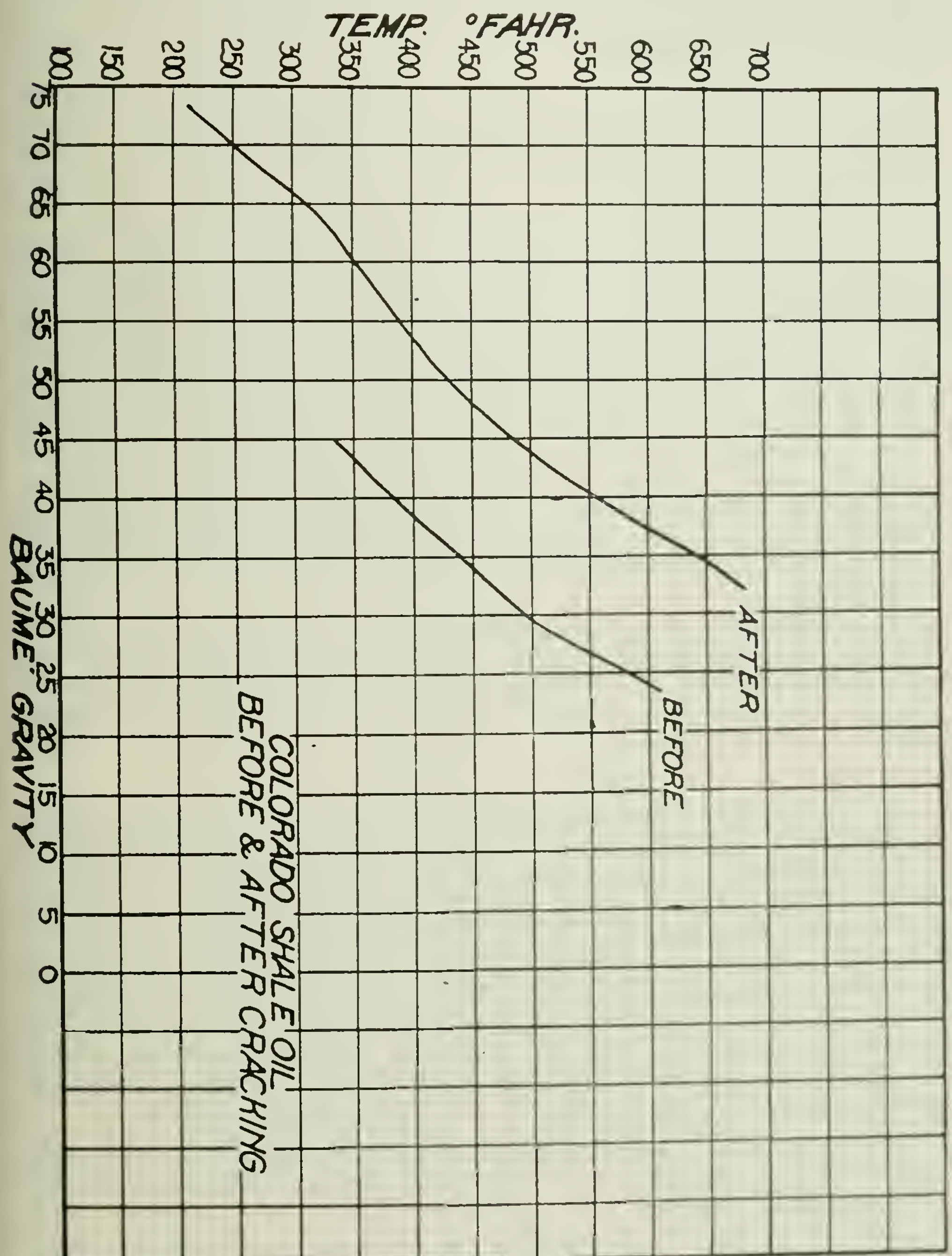


Fig. 73—Shale Oil Distilling Temperature Before and After Cracking.

Occurrence and Distribution.—Oil shale, like coal, occurs in beds that range in age from Devonian to Tertiary. The principal beds of oil shale in Scotland, France and Canada are in the older formations, but the richest and largest deposits in the United States are in the Green River formation, of Eocene (Tertiary) age.

Shale from which oil can be distilled probably occurs in nearly all countries but it has been reported in comparatively few, either because it is so similar in appearance to ordinary carbonaceous shale or because there has been so little demand for it while petroleum has been plentiful that no special search has been made for it.

In North America, oil shale occurs in both Canada and the United States but is commercially undeveloped. The richest shales in the Rocky Mountains region of the United States are of Tertiary age but large areas in the eastern part of the United States and eastern Canada are underlain by dark shales of Paleozoic age that are in many places as rich in organic matter from which oil can be distilled as those that are mined commercially in Scotland and France.

Comparatively little is known about oil shale in South America though it is said to occur in Argentina, at several localities in Brazil and in Chile. Unsuccessful attempts have been made to distill oil profitably from oil shale in eastern Brazil but the failure is reported to have been due to mismanagement rather than to the poor quality of the shale.

In Africa, thin beds of shale capable of yielding oil when distilled are reported from Angola, the Belgian Congo, Natal and the Transvaal but the shale is mined in none of these countries and the thickness, richness and extent of most of the deposits are not reported. Perhaps the largest area underlain by oil shale is in the Belgian Congo.

In Europe, the commercial development of the oil shale industry began early in the nineteenth century before the rise of the modern petroleum industry. In 1913, the world's output of oil shale was 3,591,810 metric tons of which 3,573.810 tons were mined in Europe. About 91 per cent was produced in Scotland, 8 per cent in the Autun and Aumance districts in France and the remainder in Australia, Germany and Italy. In Scotland, the oil shale industry has been able to compete successfully with the petroleum industry because of the output of valuable by-products made in connection with the oil and because of the remoteness of Scotland from the principal sources of petroleum—southern Russia and the United States. Large deposits of oil shale are reported to occur in northern Russia.

Oil shale in Asia is not mentioned in reports but valuable deposits may nevertheless exist there even in areas that have been covered by geologic studies.

In Oceanica some oil shale has been mined and distilled at several places in Australia (most of them in New South Wales) and in New Zealand, but the total shale of oil produced in all these places has been less than one per cent of the world's output and in none of them is oil shale now mined. In all the areas where oil shale is reported the beds are thin.

Position of the United States.—When petroleum was discovered in quantity in the United States in 1859, oil was being distilled from cannel coal (whence the term "coal oil") but no record has been found of large production of oil from shale in this country. There are, however, extensive reserves of material sufficiently rich to justify the hope that it may form the basis of a great industry and during the last ten years progress has been made in perfecting processes for the commercial distillation of oil from domestic oil shale. The valuable deposits of oil shale in North America are widely distributed and include beds ranging in age from Devonian to Eocene. Local conditions such as remoteness from a supply of petroleum and nearness to a sufficient market, have heretofore made it possible to develop an oil shale industry in Scotland, France, Australia and New Zealand and in view of a possible shortage in the world's supply of petroleum in the near future, it seems probable that an oil shale industry may be developed even in such countries as the United States where petroleum is now abundant. The largest foreign deposits of oil shale are apparently in Brazil and Russia but the most valuable deposits in the world are probably those of Colorado, Utah and Wyoming.

While shale unquestionably is an enormous reserve for fuel oil, it is not so valuable for gasoline. Shale oil holds a position between petroleum and coal tar. Coal tar is not yet satisfactorily treated or cracked for the production of gasoline. Shale oil makes a very poor naphtha in that it contains a very large per cent of olefins. The olefins are decreased materially by cracking at high pressures particularly in the presence of hydrogen. The accompanying graphs show the effect of high pressure cracking in the character of the hydrocarbons in shale oil.

Refining Practice for Shale Oil.*

In refining Scotch shale oil a loss of about 22 per cent is incurred, chiefly in the form of compounds with chemicals used in the treatment. This is over four times the average loss incurred in refining American petroleum. Products made from the crude oil are naphtha, including scrubber naphtha, 9.9 per cent; burning oils, 24.7 per cent; gas and fuel oils, 24.4 per cent; lubricating oils, 6.6 per cent; paraffin wax, 9.5 per cent; still coke, 2 per cent. Satisfactory motor fuels, burning oils and fuel oils are produced. The lubricating oils are not particularly viscous and are not, therefore, adapted for heavy duty work, such as use in internal combustion motors, high pressure bearings, and the like. A very good quality of paraffin wax is produced which is used chiefly for candle making. The still coke is of rather poor quality, being contaminated with the chemicals used in refining the oils, and on this account does not bring a very good price. Some oil is recovered from the compounds or sludges formed in chemical treatment of the oils, and this recovered oil is used as part of the fuel in the refinery. At the same time considerable acid is recovered from the sludges, and is used either in treating other oil or in the production of ammonium sulphate.

At the present time it is impossible to accurately estimate the cost of producing shale oil from American oil shales, and therefore impossible to arrive at any satisfactory estimate of possible profit. By basing our calculations on Scotch practice, however, it is possible to give an idea of some of the requirements for an oil shale industry in this country. Assume that an industry producing and refining 50,000 barrels of shale oil per day had been developed in the State of Colorado. This could hardly be termed a large industry nor would it go far in supplying the demands of the nation, which at the present time is using nearly 1,250,000 barrels of petroleum per day, but if we assume that the shale yielded forty-two gallons of oil to the ton, 50,000 tons of shale would have to be mined each day. I will not venture to predict how many tons of shale a man can mine in this country per day, but in Scotland each man produces about four and one-half tons. Knowing that the American coal miner is a better producer than the British coal miner, for the sake of making an illustration, assume that the American miner will produce ten tons per day. The assumed industry would then require at least 5,000 miners, nearly half as many miners as are employed in producing coal in Colorado at the present time.

If Scotch shale retorts were used the retorting plant investment necessary for the 50,000-barrel industry would be over $160,000,000, based on present estimates of the cost of Scotch retorts, and the refining equipment necessary would require another $50,000,000, if we base estimates on the capital required for building refineries for the complete refining of petroleum. Of course, these figures may not apply to American shales and practice, but they give an idea of the capital required by an oil shale industry.

In addition to the large capital required for an oil shale industry, there are many serious technical and economic problems to be solved before the industry can hope to succeed in a large way. As yet we do not know what type of process will be required to handle our shales successfully and at a profit, and we know very little regarding the methods of refining these oils or what quality of finished products can be made from them. A large oil shale industry will require a large quantity of labor, and this labor must be obtained and housed.

Starting with shale, adding heat and steam, and treating the water and gas removed, there has now been produced spent shale of no value, gas which is burned in the retort furnaces to supply heat for the distillation operations, sulphate of ammonia which is ready for the market, and a crude oil which requires refining to yield marketable products. A ton of Scotch oil shale, in the treatment of which about 100 gallons of water have been used, produces at the present time about 24.5 gallons of crude oil, 36 pounds of ammonium sulphate, 10,000 cubic feet of gas of about 240 B. T. U. heat value and about 1,600 pounds of spent shale.

In general Scotch shale oil refining is similar to petroleum refining, but because shale oil contains a greater percentage of objectionable compounds than ordinary petroleum the refinery operation is more complicated and more costly than average petroleum refining. Briefly stated, Scotch shale oils are subjected to more distillation and more chemical treatments than is petroleum when the latter is refined.

*For complete references on oil shale see Reports of Investigations of Bureau of Mines No. 2256, 2176.

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF SHALE OIL BEFORE CRACKING.

Laboratory Number 46258, Original Shale Oil.

Specific Gravity, 0.920; °Be' U. S. 22.1°; °Be' Tag. 22.3°.

Color, Brownish Black; Sulphur=0.49% B.T.U.%18,425.

%	Temp. °F.	Gravity of Fract on	Gravity of Total Over	Gravity of Stream
				0.790=47.6° Be'
5	330	0.790=47.6° Be'	0.790=47.6° Be'	0.802=44.9° Be'
	368			0.814=42.3° Be'
10	378	0.814=42.3° Be'	0.802=44.9° Be'	0.823=40.4° Be'
	398			0.833=38.3° Be'
15	413	0.833=38.3° Be'	0.812=42.7° Be'	0.839=37.1° Be'
	426			0.845=35.9° Be'
20	446	0.845=35.9° Be'	0.820=41.0° Be'	0.853=34.4° Be'
	464			0.861=32.8° Be'
25	479	0.861=32.8° Be'	0.828=39.4° Be'	0.869=31.3° Be'
	494			0.876=30.0° Be'
30	516	0.876=30.0° Be'	0.836=37.7° Be'	0.883=28.7° Be'
	530			0.890=27.5° Be'
35	543	0.890=27.5° Be'	0.844=36.1° Be'	0.895=26.6° Be'
	552			0.900=25.7° Be'
40	576	0.900=25.7° Be'	0.851=34.8° Be'	0.905=24.8° Be'
	586			0.909=24.1° Be'
45	599	0.909=24.2° Be'	0.857=33.6° Be'	0.910=24.0° Be'
	604			0.911=23.8° Be'
50	613	0.911=23.8° Be'	0.867=31.7° Be'	0.916=23.0° Be'
				0.922=21.9° Be'
55	Gas	0.922=21.9° Be'	0.872=30.7° Be'	0.928=21.0° Be'
				0.934=20.0° Be'
60	Gas	0.934=20.0° Be'	0.877=29.8° Be'	0.937=19.5° Be'
				0.940=19.1° Be'
65	Gas	0.940=19.0° Be'	0.882=28.9° Be'	0.943=18.5° Be'
				0.947=17.9° Be'
70	Gas	0.947=17.9° Be'	0.887=28.0° Be'	0.950=17.4° Be'

Summary:

Water.............................. 2.1%
42.7° Benzine or Naphtha.......... 12.9%
31° Illuminating oil, unrefined...... 25.0%
24° Gas, Oil or Distillate........... 10.0%
18.5° Wax Distillate................ 30.0%
Residue.......................... 20.0%

Olefins.......................... 58.0%
Aromatics........................ 27.0%
Naphthenes and Paraffins......... 15.0%

Ammonia in water portion = 0.422% as NH_3.

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF SHALE OIL AFTER CRACKING.

Laboratory Number 46258, Shale Oil Residue Cracked at 800 lbs. Pressure.

Specific Gravity, 0.896; °Be' U. S. 26 2; °Be' Tag. 26.4.
Color, Dark Red;

%	Temp. °F.	Gravity of Fraction	Gravity of Total Over	Gravity of Stream
0	119	....	....	....
5	210	0.681=76.3° Be'	0.681=76.2° Be'	0.681=76.3° Be' 0.690=73.6° Be'
10	281	0.717=65.8° Be'	0.699=70.9° Be'	0.699=70.9° Be' 0.710=67.8° Be'
15	334	0.765=53.5° Be'	0.721=64.7° Be'	0.721=64.7° Be' 0.730=62.3° Be'
20	368	0.798=45.8° Be'	0.740=59.7° Be'	0.740=59.7° Be' 0.748=57.7° Be'
25	395	0.823=40.4° Be'	0.757=55.4° Be'	0.757=55.4° Be' 0.764=53.7° Be'
30	435	0.846=35.7° Be'	0.771=52.0° Be'	0.771=53 0° Be' 0.777=50.6° Be'
35	454	0.861=32.8° Be'	0.784=49.0° Be'	0.784=49.0° Be' 0.790=47.6° Be'
40	486	0.881=29.1° Be'	0.796=46.2° Be'	0.796=46.2° Be' 0.801=45.1° Be'
45	518	0.898=26.1° Be'	0.807=43.8° Be'	0.807=43.8° Be' 0.812=42.7° Be'
50	543	0.911=23.8° Be'	0.818=41.5° Be'	0.818=41.5° Be' 0.823=40.4° Be'
55	582	0.930=20.7° Be'	0.828=39.4° Be'	0.828=39.4° Be' 0.833=38.3° Be'
60	623	0.945=18.2° Be'	0.838=37.3° Be'	0.838=37.3° Be' 0.844=36.1° Be'
65	651	0.959=16.0° Be'	0.855=34.0° Be'	0.855=34.0° Be' 0.859=33.2° Be'
70	679	0.965=15.1° Be'	0.862=32.6° Be'	0.862=32.6° Be' 0.865=32.0° Be'

Naphtha in oil charged........ None
Synthetic Oil—
Naphtha.................... 30.0%
Illuminants................. 25.0%
Olefins 27.5%.

Coal Distillation Plants in the United States.

The following list of manufacturers of by products coke in the United States May 1, 1921, has been compiled by the United States Geological Survey:

OPERATOR	ADDRESS	Name or Location of Works	No. and Kind of Ovens
Alabama—	Birmingham		
Alabama By-Products Corporation	American Trust Bldg	Birmingham	50 Koppers
Gulf States Steel Co	Brown Marx Bldg	Alabama City	37 Koppers
Tennessee C. I. & R. R. Co	Birmingham	Ensley	240 Semet-Solvay
Sloss-Sheffield Steel & Iron Co	American Trust Bldg	Birmingham	120 Semet-Solvay
Tennessee Coal, Iron & R. R. Co	Birmingham	Fairfield	434 Koppers
Woodward Iron Co	Woodward	Woodward	80 Koppers
			60 Wilputte
Colorado—			
Colorado Fuel & Iron Co	Boston Bldg., Denver	Minnequa	120 Koppers
Illinois—			
Chicago By-Products Coke Co	Peoples Gas Bldg., Chicago	Chicago	100 Koppers (Bldg.)
Coal Products Manufacturing Co	Aurora	Joliet	35 Koppers, 18 Wilputte
Illinois Steel Co	208 S. LaSalle St., Chicago	Joliet	280 Koppers
International Harvester Co	606 S. Michigan Ave., Chicago	South Chicago	88 Wilputte
North Shore Gas Co	Waukegan	Waukegan	13 Semet-Solvay
St. Louis Coke & Chemical Co	208 S. LaSalle St., Chicago	Granite City	80 Roberts
By-Products Coke Corporation	Chicago	South Chicago	280 Semet-Solvay
Indiana—			
Central Indiana Gas Co	Muncie	Muncie	22 Klonne
Citizens Gas Co	Majestic Bldg., Indianapolis	Langsdale	41 Semet-Solvay
Citizens Gas Co	Majestic Bldg., Indianapolis	Prospect	100 United Otto, 40 Wilputte
Illinois Steel Co	208 S. LaSalle St., Chicago	Gary	700 Koppers
Indiana Coke & Gas Co	Terre Haute	Terre Haute	30 Koppers, 30 Gas Mac'y
Inland Steel Co	S. Dearborn St., Chicago	Indiana Harbor	130 Koppers
Linton Gas Co	Linton	Linton	3 Gas Machinery
Steel & Tube Co. of America	111 W. Washington, Chicago	Indiana Harbor	120 Semet-Solvay
Kentucky—			
Kentucky-Solvay Coke Co	Ashland	Ashland	108 Semet-Solvay
Maryland—			
Bethlehem Steel Co	Bethlehem, Pa	Sparrows Point	300 Koppers
Massachusetts—			
New England Fuel & Trans. Co	111 Devonshire St., Boston	Everett	400 United-Otto
Michigan—			
Ford Motor Co	Dearborn	Dearborn	120 Semet-Solvay
Michigan Alkali Co	Wyandotte	Wyandotte	54 United-Otto
Semet-Solvay Co	Syracuse, N. Y	Detroit	215 Semet-Solvay

Coal Distillation Plants in the United States—Continued.

OPERATOR	ADDRESS	Name or Number of Works	No. and Kind of Over
Minnesota—			
Minnesota By-Product Coke Co	1000 Hamline Ave., St. Paul	St. Paul	65 Koppers
Minnesota Steel Co	Morgan Park Sta., Duluth	Duluth	90 Koppers
Zenith Furnace Co	West Duluth	West Duluth	65 United Otto
Missouri—			
Laclede Gas Light Co	1017 Olive St., St. Louis	St. Louis	56 Koppers
New Jersey—			
Camden Coke Co	80 Park Place, Newark	Camden	150 United-Otto
Seaboard By-Product Coke	Box 267, Jersey City	Kearney	165 Koppers
New York—			
Donner-Union Coke Corporation	Box 193, Buffalo	Buffalo	150 Koppers
Empire Coke Co	Geneva	Geneva	46 Semet Solvay
Lackawanna Steel Co	Buffalo	Lackawanna	94 United-Otto, 282 Rothberg 60 Semet-Solvay
Wickwire Steel Co	Buffalo	Buffalo	60 Semet-Solvay
Ohio—			
American Steel & Wire Co	West. Reserve Bldg	Cleveland	180 Koppers
Brier Hill Steel Co	Youngstown	Youngstown	85 Koppers
Hamilton-Otto Coke Co	Hamilton	Kokotto	100 United-Otto
McKinney Steel Co	Perry-Payne Bldg., Cleveland	River Furnaces	204 Koppers
National Tube Co	Frick Bldg., Pittsburg, Pa	Lorain	208 Koppers
Penn Iron & Coal Co	Leader-News Bldg., Cleveland	Canal Dover	24 Roberts
Republic Iron & Steel Co	Republic Bldg., Youngstown	Youngstown	143 Koppers
Otis Steel Co	Cleveland	Cleveland	100 Semet-Solvay
Ironton Solvay Coke Co	Ironton	Ironton	60 Semet-Solvay
Portsmouth Solvay Coke Co	Portsmouth	Portsmouth	108 Semet-Solvay
Toledo Furnace Co	West. Reserve Bldg., Cleveland	Toledo	94 Koppers
United Furnace Co	West. Reserve Bldg., Cleveland	Canton	47 Koppers
Youngstown Sheet & Tube Co	Stambaugh Bldg., Youngstown	Youngstown	306 Koppers
Pennsylvania—			
Alleghany By-Product Coke Co	McKeesport	Glassport	120 United-Otto
Bethlehem Steel Co	Bethlehem	Bethlehem	424 Koppers
Bethlehem Steel Co	Bethlehem	Lebanon	90 Semet-Solvay
Bethlehem Steel Co	Bethlehem	Steelton	60 Koppers, 120 Semet-Solvay

Coal Distillation Plants in the United States—Continued.

OPERATOR	ADDRESS	Name or Location of Works	No. and Kind of Ovens
Cambria Steel Co	Widener Bldg., Philadelphia	Rosedale	60 Cambria-Belgian
Cambria Steel Co	Widener Bldg., Philadelphia	Franklin	92 Koppers, 210 United-Otto, 190 Cambria- Belgian
Carnegie Steel Co	Carnegie Bldg., Pittsburg	Clairton	768 Koppers
Carnegie Steel Co	Carnegie Bldg., Pittsburg	Farrell	212 United-Otto
Jones & Laughlin Steel Co	Pittsburg	Pittsburg	300 Koppers
Pennsylvania—			
Philadelphia Suburban G. & R. Co	Chester	Chester	40 Semet-Solvay
Pittsburgh Crucible Steel Co	Pittsburg	Midland	100 Koppers
Rainey-Wood Coke Co	52 Vanderbilt Ave., New York City	Swedeland	110 Koppers
American Manganese Manufacturing Co	Philadelphia	Dunbar	110 Semet-Solvay
Rhode Island—			
Providence Gas Co	Turks Head Bldg., Providence	Sassafras Point	40 Koppers
Tennessee—			
Chattanooga Coke & Gas Co	James Bldg., Chattanooga	Alton Park	24 Semet-Solvay
Washington—			
Seattle Lighting Co	Stuart Bldg., Seattle	Seattle	20 Klonne
West Virginia—			
Domestic Coke Corporation	Drawer 436, Cleveland, Ohio	Fairmont	60 Koppers
LaBelle Iron Works	Steubenville, Ohio	Follansbee	94 Koppers
National Tube Co	Pittsburg, Pa	Benwood	120 Semet-Solvay
Wisconsin—			
Milwaukee Coke & Gas Co	Milwaukee	Milwaukee	120 Semet Solvay
Steel & Tube Co. of America	First National Bank Bldg., Milwaukee	Mayville	108 United-Otto

Products of Distillation of Coal—(a).

PRODUCT	1917		1918	
	Quantity	Value	Quantity	Value
Gas (M cubic feet)—				
Coal gas	42,927,728	$38,324,113	42,630,448	$43,016,085
Water gas	153,457,318	131,876,065	175,431,370	156,150,576
Oil gas	14,739,508	13,470,911	14,100,601	13,619,264
By-product gas	131,026,575	11,360,335	158,358,479	13,699,515
	342,151,129	$195,031,424	390,520,898	$226,485,440
Coke (short tons), b—				
Coal gas	1,857,248	$10,953,693	1,813,660	$14,022,818
	c22,439,280	c138,643,153	c25,997,580	c193,018,785
	24,296,528	$149,596,846	27,811,240	$207,041,603
Tar (gallons)—				
Coal gas	53,318,413	$1,774,326	48,522,987	$1,886,629
Water gas	59,533,208	1,258,683	53,419,753	1,731,714
Oil gas	727,556	32,682	550,006	15,967
By-product gas	221,999,264	5,566,302	200,233,002	6,364,972
	335,578,441	$8,631,993	302,725,748	$9,999,282
Ammonia Sulphate or equivalent (lbs.)—				
Coal gas	88,547,975	$1,362,125	56,900,464	$1,453,070
By-product gas	560,792,322	17,903,864	697,308,770	26,442,951
	649,340,297	$19,265,989	754,209,234	$27,896,021
Light oils (gals.), d—				
Coal gas	770,298	$448,855		
Water gas	6,420,717	1,655,204	12,292,026	$6,978,281
Oil gas	205,475	74,035	20,376	4,274
By-product gas	54,427,266	28,655,204	59,564,376	25,688,446
	61,823,756	$30,833.298	71,876,778	$32,671,001
Naphthalene (lbs.)—				
Coal gas } Water gas }	399,897	$9,687	508,202	$14,282
By-product	17,276,044	569,449	15,890,447	650,229
	17,675,941	$579,136	16,398,649	$664,511
Retort carbon (short tons)—				
Coal gas	252	$ 2,733	1,007	$13,275
Water gas	1,068	12,067	251	2,230
By-product	....	....	655	2,732
	1,320	$14,800	1,913	$18,237
Lampblack and carbon residue (short tons)—				
Oil gas	31,205	$169,425	17,678	$95,211

(a) Other products not included in this table, valued at $807,147 in 1917 and $1,808,515 in 1918 were: From coal-gas plants, creosote, tar, distillery products, pitch, coke breeze and spent iron oxide. From oil-gas plants: Sodium ferrocyanide. From by-product coke oven plants: Coke breeze, sodium ferrocyanide, residue, drip oil, spent oxide and pyridin oil.

Products from One Ton of Dry Coal at Different Temperatures.

(COAL WITH 35% VOLATILE AND 7% ASH.)

Coke or Carbonized Coal	Coke Oven (1700° F) 66% (1% Volatile)	Low Temperature Carbonization 68% (3% Volatile)
Gas, cubic feet per ton	10,000	9,000
Light oil from gas, gallons per ton	3	2
Ammonium sulphate, pounds per ton	20	20
Tar oils, gallons per ton	3.8	15
Pitch, gallons	8.2	0

Fuel Consumed or Lost in Coking.

	BEE HIVE	BY-PRODUCT
	Millions of B. T. U.	Millions of B. T. U.
Gas	11,000 cu. ft.=6.160	4,300 cu. ft.=2.480
Tar	9 gallons=1.401	none
Light oil	4 gallons=0.527	none
Coke	100 pounds=1.300	none
Total coal equivalent	671 pounds=9.388 33.55%	172 pounds=2.408 8.6%

One ton of coal tar may yield:

Pitch	1,000	lbs.
Naphthalene	112	lbs.
Anthracite oils	34	gals.
Creosote oils	20	gals.
Cresylic acid	2	gals.
Carboilc acid	2½	gals.
Heavy naphtha	1	gal.
Solvent naphtha	1½	gals.
Toluol	⅔	gal.
Benzol	⅓	gal.

Composition of Pitch:

	Hard	Soft
Carbon	93.2 %	91.8%
Hydrogen	4.4 %	4.6%
B. T. U. per pound	15,930	......
Moisture	0.05%	......
Volatile	66.85%	......
Fixed carbon	32.55%	......
Ash	0.60%	......
Specific gravity	1.35	......

Yield from Distillation of Eastern High Grade Coals.

(Howard N. Eavenson in Coal Age.)

Kentucky Coals, 24 Samples:

	Average	Maximum	Minimum
Ash, per cent	4.78	9.32	1.56
Sulphur, per cent	0.75	1.78	0.44
Phosphorus, per cent	0.006	0.027	0.001
By-product yield per net ton—			
Tar, gallon	7.8	10.2	5.4
Benzol, free, gallon	2.6	3.2	2.3
Ammonium sulphate, pound	28.1	34.1	22.4
Surplus gas, cu. ft	5,068	5,520	4,740
Yield of coke, per cent	69.5	75.0	67.0
Fusing point of ash, degrees F	2654	2940	2430

West Virginia Coals, 31 Samples:

Ash, per cent	5.29	9.09	2.59
Sulphur, per cent	0.99	2.76	0.63
Phosphorus, per cent	0.006	0.019	0.002
By-product yield, per net ton—			
Tar, gallon	8.0	10.6	5.8
Benzol, free, gallon	2.6	3.3	2.1
Ammonium sulphate, pounds	24.5	31.0	21.2
Surplus gas, cu. ft	5,069	5,340	4,770
Yield of coke, per cent	72.8	76.8	68.2
Fusing point of ash, degrees F	2743	2970	2610

Pennsylvania Coals, 20 Samples:

Ash, per cent	7.27	10.44	5.32
Sulphur, per cent	1.18	2.14	0.77
Phosphorus, per cent	0.012	0.018	0.005
By-product yield, per net ton—			
Tar, gallon	7.8	10.1	5.8
Benzol, gallons	2.2	......	......
Ammonium sulphate, pounds	25.1	29.8	22.8
Surplus gas, cu. ft	5,497	5,654	5,304
Yield of coke, per cent	67.5	70.0	64.2
Fusing point of ash, degrees F	2366	2390	2350

Gas-Manufacturing Processes in Use in the United States.

The manufactured gas distributed in the United States is of three principal kinds: Coal gas, carbureted water gas and oil gas.

The manufacture of water gas consists essentially of an intermittent process in which a bed of anthracite coal or coke is brought to a high temperature by an air blast and then steam under pressure is blown through the fuel, forming carbon monoxide, hydrogen and a small amount of carbon dioxide by reaction with the carbon in the fuel. The resultant gas, called blue water gas, has a heating value of approximately 300 B.T.U. per cubic foot and almost no luminosity when burned in an open flame. It is conducted into a fire-brick-lined chamber called the carburetor, which contains staggered rows of fire bricks, called checker brick, heated to incandescence during the blow period. Gas oil or fuel is sprayed into the carburetor while the gas is passing through, forming an oil gas which enriches the blue water gas to any desired heating value or candlepower. Another checker-brick-filled chamber, called the superheater, converts most of the oil-gas vapors into permanent gases, which will not condense again upon cooling. During the formation of the oil gas certain portions of the hydrocarbons which compose the oil are changed in their composition to form benzol, toluol and related hydrocarbons called aromatic compounds. Considerable tar is formed at the same time. This is condensed, scrubbed and washed out of the gas by various means, but usually at a temperature which permits most of the aromatics to go forward with the gas. The sulphur in the gas is removed by iron-oxide purifiers and the gas is metered and leaves the plant at or slightly above atmospheric temperature.

The manufacture of coal gas is essentially different from that of water gas. In this process certain classes of bituminous coals are distilled in fire clay or silica retorts or ovens and the resulting gases are condensed, scrubbed, washed and purified to remove water vapor, tar, ammonia and sulphur. As in the water gas process, certain of the hydrocarbons given off by the coal are transformed by the heat of the retort to aromatic compounds. A small part of these aromatics is washed out of the gas by the wash water and tar, but the larger part remains in the gas. In fact, the cooling of the gas is usually so regulated that most of these substances will remain in the gas to increase its heating value and candlepower. Coal gas retorts take a variety of forms. Among these are coke ovens, chamber ovens, horizontal D-shaped retorts, vertical retorts, inclined retorts, etc. Even those of a given class differ among themselves in details of construction. In most of them the distillation is an intermittent process, but some continuous methods are used. In all these processes the gas produced consists of the same constituents in somewhat different proportions. The form of apparatus used in a given case depends largely upon economic considerations or is governed by certain special qualities which are desired in one or more of the products produced. In all of these coal gas processes coke remains in the retort after distillation. In some of them, as for example in coke ovens, coke is the principal product, but in city gas plants gas is the chief product. The operation is carried out in any case to give most satisfactory qualities to the principal product and at the same time obtain as high yields and good quality as possible of the secondary or by-products.

Mixed gas is usually understood to be a mixture of carbureted water gas and coal or coke-oven gas. It is supplied in many cities in the United States where the requirements permit of a mixed gas being supplied. The manufacturing installation for mixed gas is practically two complete installations, one for coal gas and one for carbureted water gas, with their auxiliary scrubbing, condensing, purifying, and metering apparatus entirely independent and separate. The manufactured mixed gas, however, is stored in common holders and delivered through a single distribution system. The coal and water gas thus supplement each other. The uniform but more cumbersome coal-gas production furnishes coke as fuel for the water-gas plant. This in turn takes care of the irregularities of the output, and, where necessary, increases the quality of the gas production, especially where a high candlepower standard is in force.

The oil gas process is at present confined chiefly to the Pacific Coast States, where comparatively cheap oil and expensive coal make the coal and water gas processes less feasible. In oil gas manufacture oil alone is used as fuel for heating the checker bricks of the fixing chambers and oil is sprayed by steam into the chambers where, in contact with the bricks, lampblack and permanent gases are formed. In this process also aromatic compounds are included among the constituents of the gas.

Note.—See Bulletin of Bureau of Standards.

Products of Refining of Light Oil of Gas Works.

	Carbon Disulphide	Benzene	Toulene	M-zylene	Naphthalene
Molecular weight	76.12	78.05	92..06	106.08	128.06
Pounds per United States Gal. (60° F)	10.57	7.36	7.27	7.26	9.60
Specific gravity (0°C/4°C)	1.2921	.8999	.8845	.8823	....
Specific gravity (10°C/4°C)	1.2773	.8883	.8757	.8738	....
Specific gravity (15°C/4°C)	1.2698	.8839	.8714	.8697	1.1517
Specific gravity (20°C/4°C)	1.2623	.8786	.8659	.8655	....
Specific gravity (30°C/4°C)	1.2473	.8679	.8573	.8574	....
Change of Specific Gravity per 1° C	.00125	.0012	.0010	.00095	....
Boiling point at 760 mm.Hg. (°C)	46.2	80.36	110.3	139.1	217.7
Increase in boiling point (°mm.Hg.)	.041	.043	.047	.052	.059
Vapor pressure mmHg (0°C)	127.9	26.63	7.20	1.75	.022
Vapor pressure mmHg (10°C)	198 5	45.68	13.02	3.45	.047
Vapor pressure mmHg (15°C)	244.1	58 90	17.22	4.74	.062
Vapor pressure mmHg (20°C)	298.0	75.21	22.53	6.43	.080
Vapor pressure mmHg (30°C)	434.6	119.34	37.46	11.43	.135
Pounds per cu ft. vapor (60° F=30 in.)	.202	.209	.244	.281	.339
Kil per cu. m, vapor (0° C-760 mm.)	3.42	3.54	4.14	4.76	5.72
Heat combustion (net) 15°C-760 mmHg.					
Calories per kil. liquid	.3480	.9960	10.150	10.230	.9700
Calories per liter, liquid	.4420	.8805	.8850	.8910	11.170
B. T. U. per pound, liquid	.6260	17.930	18.270	18.410	17.460
B. T. U. per U. S. gal., liquid	66.100	132 100	132.600	133.500	167.300
Calories per cu. meter, vapor	11.550	33 600	40.150	46.500	52.400
B. T. U. per cu. ft, vapor	1300	.3780	.4500	.5210	.5910
Specific heat (calories per kil.)	0.240	0.419	0.440	0.383	0.314
Heat of vaporiz. (calories per kil.)	83.8	92.9	83.55	78.25	....
Sol. in water (22°C) grm subs. in 100 gH_2O	.219	.072	Insol.	Insol.	Insol.
Grams H_2O in 100g subs	.765	.241	Insol.	Insol.	Insol.
Melting point (°C)	—108.6	+5.4	—92.4	—54.8	+80.0

Average Content of Light Oils in Various Gases.

The amount of benzol and toluol formed in any one of these processes is by no means definite. It depends upon the operating conditions and the quality of the raw materials (coal or oil). It would therefore be impossible to predict exactly what the yield of products in a given case would be, but an extensive inquiry into the operation of a number of typical plants has given the following tabulation as the usual range of figures for the various processes. Individual results may vary widely from them in a particular case.

TABLE 1.—Approximate Yields of Crude Light Oil and Pure Products and Approximate Composition of Crude Light Oil.

APPROXIMATE YIELD OF CRUDE LIGHT OIL.

Coal gas—	
Horizontal retort	3.0-4.0 gallons per short ton coal carbonized
Continuous vertical retort	1.5-2.5 gallons per short ton coal carbonized
Inclined retort	1.8-2.3 gallons per short ton coal carbonized
Coke-oven gas, run of oven	2.6-3.6 gallons per short ton coal carbonized
Carbureted water gas	8-10 per cent of vol. of gas oil used
Oil gas	0.2-0.3 gal. per 1000 cu. ft. of gas.

APPROXIMATE COMPOSITION OF CRUDE LIGHT OIL.

Coal gas:	Benzol Per Cent	Toluol, Per Cent	Solvent Naphtha, Wash Oil, Naphthalene, Per Cent
Horizontal retort	50	13-18	35
Continuous vertical retort	30	10-15	55
Inclined retort	45	13-18	40
Coke-oven gas, run of oven	50	14-18	35
Carbureted water gas	40	20-25	37
Oil gas	80	8-10	10

APPROXIMATE YIELD OF PURE PRODUCTS.

Gallons per short ton coal carbonized:	Benzol	Toluol
Coal gas—		
Horizontal retort	1.5	0.4-0.5
Continuous vertical retort	.6	.2- .3
Inclined retort	.9	.2- .4
Coke-oven gas, run of oven	1.5	.3- .5
Gallons per 1000 cubic feet of gas:		
Carbureted water gas	.15	.06-.10
Oil gas	.25	.02-.03

Paraffins	Specific Gravity	Degrees Boiling Point in Centigrade
N—heptane	0.712, at 16° C	97
Triethylmethane	.689, at 27° C	96
N—octane	.708, at 12.5° C	125
Diispbutyl	.714, at 0° C	108.5

Yields of Oil from Distillation of Cannel Coal.

Locality	Yield of Crude Oil Per Ton, Gallons
England:	
Derbyshire	82
Wigan cannel	74
Newcastle	48
Scotland:	
Boghead cannel	120
Scotch cannel	40
Lesmahago cannel	96
New Brunswick:	
Albertite	110
American:	
Breckenridge, Ky., cannel	130
Erie R. R., Pa.	47
Falling Rock cannel	80
Pittsburgh	49
Kanawha semi-cannel	71
Elk River semi-cannel	60
Cannelton, Ind. cannel	86
Coshocton, Ohio	74
Darlington, Pa. (Cannelton)	56
Camden lignite, Ark.	64
Missouri, Cooper Co.	75

The coke resulting from cannel coal is not of satisfactory quality for ordinary purposes. However, it is satisfactory for making producer gas or burning as a domestic fuel in hard coal burners, provided a small amount of bituminous matter remains in it.

Refining of Oil for Road Building and Paving Purposes.

The various methods of refining which yield residues adaptable or used for road building and paving purposes are as follows:

Sedimentation.

Dehydration.

Fractional distillation by direct fire.

Forced fire distillation with direct fire.

Steam distillation.

Inert gas distillation.

Air blowing.

In the types of oil which are ordinarily used for making asphalt or road binders, water is one of the most common impurities. The water is ordinarily salt water and may contain more or less other mineral matter than the salt. These impurities are insoluble in the bitumen proper and as they differ from the bitumen in specific gravity, they may be removed wholly or in part by the process of sedimentation or separation by gravity. In the more fluid petroleums, sedimentation occurs during storage in the large tanks and the water is ordinarily automatically drawn off from the bottom of the tank by reason of the different heads produced by the salt water and by the oil. However, a small amount of emulsified water nearly always remains in all petroleums, so that there will always be a small amount of sediment. If the petroleum is very heavy and viscous, approximately equal in gravity to water, then the water will remain emulsified and will not separate by gravity. This type of oil happens to be the most suitable in quality for producing asphalt and special means of removing this water is necessary before the oil can be reduced to the desired consistency. The dehydration processes are designed primarily for removal of the water in the bituminous material which will not completely separate by sedimentation. It is desirable to do this before distillation because of the fact that the presence of the water will cause foaming when the mixture is heated to the temperature of boiling water. Dehydrating plants vary considerably in design, but those more commonly used for petroleum in California are spoken of as topping plants. In this sort of plant the oil is pumped with or without pressure through a length of pipe containing many bends and turns, so that the oil is considerably stirred. The pipe coils are set in furnaces, so that they may be suitably heated to a temperature above that of boiling water. This pipe discharges the foam into a large expansion chamber, where the water and more volatile constituents separate in the form of vapor which is condensed in an ordinary condenser for the recovery of the light products. This sort of plant is commonly spoken of as a pipe still. From the pipe still, the oil passes through another line, direct to a large batch still, where it is subjected to the ordinary fractional distillation.

The essential principle in the distillation of an oil for road purposes is that it shall distill at a temperature sufficiently low to prevent the decomposition of the hydrocarbons. Since asphalt hydrocarbons begin to decompose at a temperature of 600°F or slightly below, it is desirable that the fire distillation be carried only to that temperature. After this temperature has been reached, the usual method is to blow superheated steam, which mechanically carries over the more volatile hydrocarbons at a temperature much below the actual boiling point.

This distillation has a special action in removing the paraffin compounds which are particularly undesirable in that they have very little ductility and cementation value. The distillate will contain any light oils such as are used as spindle oils and for general lubrication, as well as any paraffin wax. It is particularly desirable in this distillation to prevent the formation of free carbon or coke. The distillation with steam may be carried down until the residue shows a penetration of about 10 millimeters.

A method of distillation which gives very great yields of solid or semi-solid asphalt even from semi-paraffin base oils is that of blowing the oil at moderately high temperature with air. The amount of air and rate in blowing is usually about 300 cubic feet per barrel of oil per hour (see p. 375). For delivering air to an asphalt blowing still with the oil at a temperature of 400°F and producing about 250 bbls. per day, 100 H. P. is required. Air blowing in many Mid-Continent oils gives much more asphalt than naturally exists in the oil. The action of the air is to produce a more viscous product which is very much less susceptible to temperature changes than the natural asphalt. It is strictly a chemical transformation process formed from the hydrocarbons in the oil which are ordinarily not useful for asphalt making purposes. It has been found from practical experience that this type of asphalt is not sufficiently cementitious and ductile to be used for ordinary paving purposes in producing first class asphalt pavement. It can, however, be successfully used and is in great demand for water-proofing purposes, for filler in brick and wood block pavement, for roofing purposes and for fluxing ductile asphalt.

The best types of petroleum for asphalt paving purposes are those from California, Mexico, Trinidad and Texas.

ASPHALT PAVEMENT.

Asphalt is a black non-oxidized bituminous hydrocarbon, semi-fluid to hard in consistency, the heavy residuum from petroleum or occurring naturally. The residua from petroleum are known as oil asphalts and come most largely from California, Mexican, Texas and Mid-Continent petroleums. The most commonly used natural asphalts are Trinidad, Bermudez, Cuban and Gilsonite.

The term asphalt is commonly applied to bituminous pavements, being mixtures usually of oil asphalt with dust, sand, gravel or rock in varying proportions from 6% to 20%. The terms "bitumen" or "asphaltic cement" are commonly applied to the pure asphalt material.

The types of asphalt construction now commonly used are:

1. Asphaltic concrete. This mixture is very common in localities where Joplin chats are available. It is known also as "Topeka Specifi-

cation Pavement" and "Bituminous Concrete," but it might be called bituminous gravel. The stone it carries is of ½" and ¼" size. (Fig. 76.)

2. Sheet asphalt is the original type of asphalt pavement laid in two courses, the bottom one with coarse stone, the top with sand mixed with the bitumen. (Fig. 77.)

3. Bituminous concrete (Warren) is laid with coarse stone in the wearing surface. (Fig. 78.)

4. Bituminous earth is laid without an appreciable amount of sand or rock. (Fig. 79.)

There are two different basic principles involved in proportioning the mineral matter of an asphalt pavement. One is to so grade the coarse mineral particles that they support each other and interlock. The other is to produce a mastic of bitumen and finely divided earthy material that is rigid and self-supporting because of surface tension action. This mastic fills the voids in the coarse material and has a much higher melting point than the pure bitumen and does not so readily allow softening or movement of the pavement.

COMPOSITION OF NATURAL ASPHALT.

	Natural Trinidad	Bermudez	Gilsonite	Grahamite	Cuban
Bitumen	56.0%	94.0%	99.4%	94.1%	75.1%
Mineral Matter	36.8%	2.0%	0.5%	5.7%	21.4%
Specific Gravity	1.400	1.085	1.045	1.171	1.305
Fixed Carbon	11.0%	13.5%	13.0%	53.3%	25.0%
Melting Point, °F	190	180	300	Cokes	240
Penetration	0.5	2.5	0	0	0
Free Carbon	6 0%	4.0%	0.1%	0.2%	3.5%
Sulphur (ash free basis)	6.5%	5.6%	1.3%	2.0%	8.3%
Petroleum ether soluble	65.0%	70.0%	30.0%	0.4%	41.1%
Total Carbon (ash free)	82.6%	82 5%	......	87.2%	......
Hydrogen (ash free)	10.5%	10.3%	......	7.5%	......
Nitrogen (ash free)	0.5%	0.7%	......	0.2%	......

COMPOSITION OF OIL ASPHALTS.

	Mexican	Mid-Continent Air Blown	California	Stanolind (cracked-pressure tar residue)
Bitumen	99.5%	99.2%	99.5%	99 8%
Mineral Matter	0.3%	0.7%	0.3%	0.3%
Specific Gravity	1.040	0.990	1.045	1.060
Fixed Carbon	17.5%	12.0%	15.0%	17.5%
Melting Point, °F	140	180	140	135
Penetration	55	40	60	50
Free Carbon	0.0%	0.0%	0.0%	0.0%
Sulphur (ash free basis)	4.50%	0.60%	1.65%	0.35%
Petroleum Ether Soluble	70.0%	72.0%	67.0%	70.0%
Cementing Properties	good	poor	good	good
Ductility	45 cm	2 cm	70 cm	100+
Loss at 325°F 5 hrs	0.2%	0.1%	0.2%	0.1%
Heat Test	adherent	smooth	adherent	scaly

Composition of Rock Asphalt.

	Ragusa, Sicily	Seyssel, France	Mons, France	Cass Co., Missouri	Buckhorn, Oklahoma
Bitumen	9.9%	5 9%	8.9%	6.9%	5.9%
Passing 200 mesh	37.1	44.1	53.1	20.0	9.0
80 mesh	23.0	15.0	13.0	21.0	8.4
50 mesh	14.0	9.0	7.0	17.0	9.0
40 mesh	4.0	7.0	5.0	6.0	9.9
30 mesh	2.0	7.0	3.0	6.5	15.0
20 mesh	5.0	6.0	5.0	5.1	8.8
10 mesh	5.0	6.0	5.0	7.5	8.0
4 mesh	0.0	0.0	0.0	10.0	26.0
Calcium carbonate	89.0	91.3	90.0	92.9	96.0

ASPHALTIC SANDSTONES.

	Breckenridge County, Ky.	Oklahoma	Higginsville, Missouri
Bitumen	9.2%	9.2%	7.9%
Passing 200 mesh	5.2	1.5	25.7
80 mesh	45.5	56.5	71.3
40 mesh	36.3	30.4	3.0
10 mesh	3.8	2.4	0.0
Calcium carbonate	0.0	0.0	0.0

SHEET ASPHALT PAVEMENT.

Sheet asphalt is the standard asphalt pavement. Specifications call for two courses of the following composition and properties:

BINDER OR BOTTOM COURSE.

	Limits	Standard
Bitumen	5½%— 8%	6.0%
Mineral passing 200 mesh	7 —12	8.0
Mineral passing 80 mesh	10 —20	12.0
Mineral passing 40 mesh	10 —20	15.0
Mineral passing 10 mesh	7 —20	13.0
Mineral passing 4 mesh	10 —20	17.0
Mineral passing 2 mesh	10 —20	16.0
Mineral passing 1 mesh	10 —20	13.0
		100.0
Thickness		1½ in.
Density		over 2.30

TOP COURSE.

	Limits	Standard
Bitumen	9.75%—11.0%	10.0%
Mineral passing 200 mesh	12 —18	13.0
Mineral passing 80 mesh	20 —34	23.0
Mineral passing 40 mesh	20 —40	27.5
Mineral passing 10 mesh	12 —35	26.5
Mineral passing 4 mesh	0	0.0
Mineral passing 2 mesh	0	0.0
Mineral passing 1 mesh	0	0.0
		100.0
Thickness		1½ in.
Density		over 2.17

Composition of Asphalt Pavements.

The following table gives a comparison of a typical composition and properties of good mixtures representing the various types of asphalt wearing surface pavements:

	Bituminous Concrete (Topeka Spec.)	Bituminous Concrete (Warren)	Sheet Asphalt	Bituminous Earth
Asphaltic cement	8.0%	6.0%	10 0%	20.0%
Dust passing 200 mesh screen	12.0	5.5	12.0	62.0
Dust passing 80 mesh screen	12.0	2.8	16.0	15.0
Dust passing 40 mesh screen	20.0	6.7	38.0	3.0
Dust passing 10 mesh screen	20.0	24.5	24 0	0.0
Dust passing 4 mesh screen	18.0	15.3	0.0	0.0
Dust passing 2 mesh screen	10.0	13.3	0.0	0.0
Dust passing 1 mesh screen	0.0	25 0	0.0	0.0
	100.0	100.0	100.0	100.0
Weight per sq. yd. 2 in. surface, lbs.	215	225	205	185

EFFECT OF MINERAL MATTER ON THE PENETRATION OF ASPHALTIC CEMENT (Typical Case).

% Dust	Penetration	Melting Point
0	200	100
35	128	110
55	92	120
70	34	150

In a general way, 1% of dust in asphaltic cement decreases the penetration 2 points with A. C. of ordinary penetration. This will vary somewhat according to the character of the asphaltic cement. A pavement having a relation of 2 parts dust and 1 part bitumen cannot soften or flow in hot weather.

FLUXING OF HARD ASPHALT.

As a general rule, 30% of 10-12°Be′ asphaltic flux is required to bring Trinidad asphalt to a penetration of 50. Less of paraffin flux is required. For each 1% of asphaltic flux added to about 50° asphalt the penetration is raised 3 points. For exact results a test should be made with the actual materials in question.

MATERIALS REQUIRED FOR 1000 YARDS OF ASPHALTIC CONCRETE PAVEMENT ARE AS FOLLOWS (Typical):

For wearing surface:

"Chats" or Gravel	= 32	tons
Sand (Coarse)	= 32	tons
Sand (Fine)	= 32	tons
Dust	= 7	tons
Asphaltic Cement	= 8½	tons

For concrete base:
(6 inches of 1:3:6 mix.)

Cement	= 732 sacks = 183 bbls.
Sand	= 77 cubic yards =
Rock	= 155 cubic yards
Water	= 7,000 gallons

RELATION OF THE DEFECTS OF AN ASPHALT PAVEMENT TO ITS PHYSICAL PROPERTIES.

Cracking is caused by asphaltic cement without sufficient ductility, with too low penetration, insufficient in quantity or that has been over-heated; Imperfections in the base, such as a cracking in the base or the lack of a rigid base or lateral support; Insufficient compression when laid; Lack of traffic.

Disintegration and Hole Formation are caused by asphaltic cement with poor ductility and cementing value, or insufficient to coat mineral aggregate and fill voids; Dirty sand; Non-uniform thickness of surface mixture; Weak foundations in spots; Water from beneath.

Scaling of the Surface Mixture is caused by asphaltic cement lacking in cementing power, insufficient in quantity or subject to decomposition by the weather; Improper grading of mineral, particularly insufficient dust; Dirt conglomerates in sand; Insufficient density.

Waviness and Displacement are caused by asphaltic cement without cement power, too soft or in too large quantity; Irregularity of surface thickness, or of composition of asphaltic surface mixture; Insufficient dust or filler; Non-rigid base or expansion of the base; Street with heavy grade.

Marking is caused by asphaltic cement that is too soft or in too large quantity; and that is too uniform; Insufficient dust or filler; Insufficient density.

FUNCTIONS OF VARIOUS CONSTITUENTS OF ASPHALTIC SURFACE MIXTURE.

Gravel and Coarse Sand in proper relation diminish voids, insure greater stability and increase density, allow the use of less asphaltic cement, decrease tendency to displacement, waviness and marking, increase susceptibility to damage by erosion and abrasion.

Sand in proper relation increases stability by filling voids in stone, increases capacity to resist abrasion, diminishes tendency to raveling.

Filler or Very Fine Dust in proper relation increases density and stability by filling voids in sand, increases capacity to resist abrasion, allows wider range in penetration of A. C., diminishes or overcomes tendency to marking, displacement and waviness, increases cementation of mixture, increases capacity for A. C., increases the need for much compression and softer A. C. in laying mixture, eliminates lakes of A. C., decreases brittleness of pavement.

A. C. in proper quantity and relation cements mineral particles together, keeps out water, imparts pliability, resiliency and noiselessness, prevents erosion and disintegration of coarse mineral of pavement.

Specifications for Asphaltic Cement for Asphalt Surface Mixture.

Impurities.

The asphaltic cement shall contain no water, decomposition products, granular particles or other impurities, and it shall be homogeneous.

Ash passing the 200-mesh screen shall not be considered an impurity, but if greater than 1% corrections in gross weights shall be made to allow for the proper percentage of bitumen.

Specific Gravity.

The specific gravity of the asphaltic cement shall not be less than 1,000 at 77°F.

Fixed Carbon.

The fixed carbon shall not be greater than 18%.

Solubility in Carbon Bisulphide.

The asphaltic cement shall be soluble to the extent of at least 99% in chemically pure carbon bisulphide at air temperature and based upon ash free material.

Solubility in Carbon Tetrachloride.

The asphaltic cement shall be soluble to the extent of at least 98.5% in chemically pure carbon bisulphide at air temperature and based upon ash free material.

Melting Point.

The melting point shall be greater than 128° F and less than 160°F (General Electric method).

Flash Point.

The flash point shall be not less than 400°F by a closed test.

Penetration.

The asphaltic cement shall be of such consistency that at a temperature of 77°F a No. 2 needle weighted with 100 grams in five seconds shall not penetrate more than 9.0 nor less than 5.0 millimeters. For asphaltic cement containing ash 0.2 millimeter may be added for each 1.0% of ash to give the true penetration.

Loss by Volatilization.

The loss by volatilization shall not exceed 2%, and the penetration after such loss shall be more than 50% of the original penetration. The ductility after heating as above shall have been reduced not more than 20%, the value of the ductility in each case being the number of centimeters of elongation at the temperature at which the asphaltic cement has a penetration of 5.0 millimeters. The volatilization test shall be carried out essentially as follows:

Fifty grams of the asphaltic cement in a cylindrical vessel 55 millimeters in diameter and 35 millimeters high shall be placed in an electrically heated oven at a temperature of 325°F and so maintained for a period of 5 hours. The oven shall have one vent in the top 1 centimeter in diameter, and the bulb of the thermometer shall be placed adjacent the vessel containing the asphaltic cement.

Ductility.

When pulled vertically or horizontally by a motor at a uniform rate of 5 centimeters per minute in a bath of water, a cylinder of asphaltic cement 1 centimeter in diameter at a temperature at which its penetration is 5 millimeters shall be elongated to the extent of not less than 10 centimeters before breaking.

EPITOME OF THE PURPOSES OF CERTAIN SPECIFICATIONS FOR ASPHALTIC CEMENT.

Impurities are a measure of the care with which the asphaltic cement has been refined and handled. Usually the presence of impurities in large quantities indicates a poor grade of asphalt. Water as an impurity would act as a diluent and would cause foaming in the kettle. Ash or mineral matter is not considered an impurity if it is a natural constituent of the asphaltic cement, but the mix and cementing value must be figured on the bitumen alone.

Specific Gravity of the asphaltic cement should be over 1.000. The advantage of a specific gravity more than 1.000 is that there will be less tendency for water to float out the asphaltic cement. The specific gravity is raised by the presence of mineral matter. Asphaltic oils of a penetration satisfactory for paving purposes always have a specific gravity greater than 1.000. Paraffin base oil and air-blown products usually have a specific gravity less than 1.000.

Fixed Carbon is a measure of the chemical constitution of an asphalt to some extent. Certain types of asphalt such as Mexican have naturally a constitution that yields a large amount of fixed carbon. Fixed carbon is largely used for determining the source and uniformity of an asphalt. Fixed carbon is not free carbon, but includes free carbon, which is practically absent in asphaltic cements.

Solubility in Carbon Bisulphide is a measure of the purity of an asphaltic cement. The cementing value, other things being equal, is proportional to the carbon bisulphide solubility. Any carbonaceous material such as coal tar or pitch is detected by the carbon bisulphide solubility test.

Solubility in Carbon Tetrachloride is very nearly the same as the solubility in carbon bisulphide. It is claimed that an asphalt having more than 1½% difference in the solubility in carbon bisulphide and carbon tetrachloride has been subjected to excessive heat in refining.

Melting Point is the temperature at which the asphaltic cement will flow readily. The melting point desired is dependent upon the mixture. If the amount of fine dust in the mineral aggregate is low, the asphalt should have a melting point higher than the highest temperature to which the pavement is subjected.

Flash Point is a measure of the amount of volatile hydrocarbons that are present in the asphalt and its readiness to decompose by heat.

Penetration is a measure of the consistency of the asphaltic cement. It is merely a quick, convenient test for checking up numerous individual samples. The penetration is expressed in degrees and in accordance with the method of the American Society for Testing Materials, each degree representing 1-10 of a millimeter or 1-250 of an inch. The penetration, then, is the number of degrees that a No. 2 sewing needle when weighted with 100 grams will pass vertically into the A. C. at a temperature of 77°F (25°C) in 5 seconds. The penetration to be desired will depend upon the climate, the nature of the traffic, the grading of the mineral particles, the amount of voids, the amount of compression attainable, the ductility and cementing strength of the A. C. and the amount of dust filler.

Loss of Volatilization is a measure of the amount of light hydrocarbons that are present in asphalt and is also a measure of the tendency of an asphalt to oxidize and to lose its ductility and penetration. Asphalt cement which has no ductility after this volatilization test will not be satisfactory for paving purposes.

Ductility is the measure of the ability of an asphaltic cement to expand and contract without breaking or cracking. The same asphalt at a higher penetration should have a higher ductility, so all ductility tests should be based on a certain definite penetration regardless of the temperature, or should be based upon a temperature of 32°F. Ductility is also a measure of the cementing strength.

Viscosity is a measure of ability of the asphaltic cement to impart plasticity and malleability.

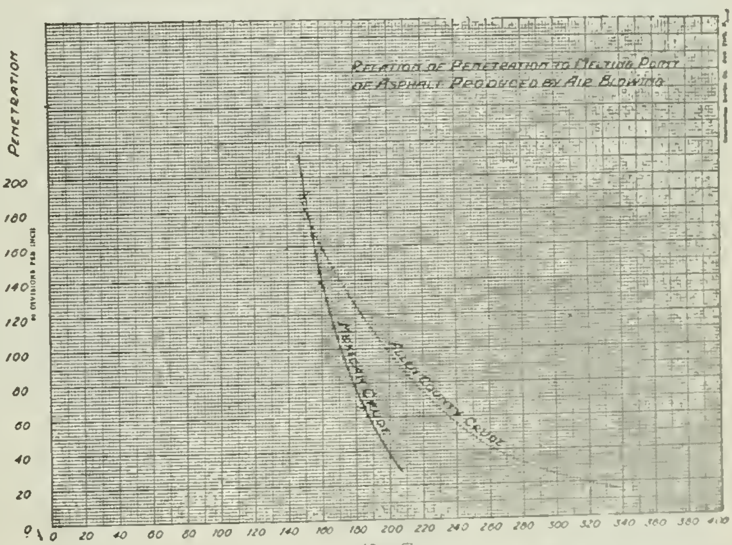


Fig. 74—Relation of Penetration to Melting Point of Asphalt Produced by Air Blowing.

Typical Specifications for Wearing Surface of Asphaltic Concrete

The wearing surface shall be composed of a properly prepared mixture of bitumen, dust, sand and chats, gravel or trap rock.

The amount of asphaltic cement, dust, sand and chats shall be so regulated that the average mixture shall be within the following limits by weight:

	Size of Opening, In. Square	Lower Limit	Upper Limit	Average Typical
Bitumen		7.0%	10.0%	8.0%
Dust passing 200 mesh	0 0029	8.0	18.0	12.0
Sand passing 80 mesh	0.0068	10.0	20.0	12.0
Sand passing 40 mesh	0.0150	15.0	25.0	20.0
Sand passing 10 mesh	0.065	15.0	40.0	20.0
Sand passing 4 mesh	0.185	10.0	22.0	20.0
Sand passing 2 mesh	0 380	0.0	10.0	8.0

Ordinarily this mixture is to be obtained by the use of rock, coarse sand, fine bank sand and limestone dust or cement.

All of the mineral ingredients except the dust shall be heated and mixed in a suitable drier to a temperature of from 300 to 350°F. The bin containing the mineral shall be permanently equipped with a recording or an observation thermometer.

The asphaltic cement shall be added after it has been heated to a temperature not exceeding 360°F. The heating of the asphaltic cement must be by steam or if by direct fire vigorous mechanical stirring must be used. A recording thermometer should be used in the A. C. kettle and the aggregate.

The dust shall be added dry to each batch separately prior to the addition of the A. C. All materials shall be weighed.

The mixing shall be for a sufficient time to thoroughly and uniformly mix all materials and for a period of not less than one minute.

The temperature of the mixture shall be between 270°F and 350°F when it leaves the plant.

It shall be between 250°F and 350°F on the street (preferably 300°F).

The surface of the concrete shall be dry and clean at the time the surface mixture is applied.

The mixture shall be applied and raked to a uniform thickness, none being allowed to remain at the point of dumping and all lumps being thoroughly raked out.

The amount of hot mix applied shall be at least 210 pounds per square yard and shall be of a uniform thickness of 2 inches after rolling.

The compression shall be applied with a 5-ton roller until complete and sufficient in the judgment of the inspector and as indicated by the tests of the preceding day's laid surface. Hydraulic cement may be dusted over and rolled into the finished pavement.

The specific gravity of the compressed surface mixture shall average 2.20 or more and shall not at any time be less than 2.16. A piece of the compressed surface mixture after being placed in water for 24 hours shall not have absorbed water and shall not have become crumbly or weakened.

Table for Calculating Voids in Sand and Limestone.

Weight in Pounds per Cubic Foot	% Voids	Weight in Pounds per Cubic Foot	% Voids
60	63.9		
61	63.3	96	42.2
62	62.6	97	41.6
63	62.1	98	41.0
64	61.5	99	40.4
65	60.9	100	39.8
66	60.3	101	39.2
67	59.6	102	38.6
68	59.1	103	38.0
69	58.5	104	37.4
70	57.9	105	36.7
71	57.3	106	36.2
72	56.7	107	35.6
73	56.0	108	35.0
74	55.4	109	34.4
75	54.8	110	33.8
76	54.2	111	33.2
77	53.6	112	32.5
78	53.0	113	32.0
79	52.4	114	31.4
80	51.8	115	30.7
81	51.2	116	30.2
82	50.6	117	29.6
83	50.0	118	28.9
84	49.4	119	28.3
85	48.8	120	27.8
86	48.2	121	27.2
87	47.6	122	26.6
88	47.0	123	26.0
89	46.4	124	25.4
90	45.8	125	24.7
91	45.2	126	24.1
92	44.6	127	23.5
93	44.0	128	22.9
94	43.4	129	22.3
95	42.8	130	21.7

Grams per 100 cc × .6243 = pounds per cubic foot.

% voids = 100 — (0.376 × grams per 100 cc).

Specifications of the National Paving Brick Mfgrs. Assn.

Oil Asphalt Filler.
(Squeegee Method.)

Section 1. Description: Asphalt filler shall be homogeneous, free from water and shall not foam when heated to 200°C (392°F). It shall meet the following requirements:

(a) Flash point—Not less than 200°C (392°F).

(b) Melting point—(Ring and Ball) Not less than 65°C (149°F).

(c) Penetration: At 0°C (32°F) 200 gms. 1 min. not less than 10. At 25°C (77°F) 100 gms. 5 sec. (30-50). At 46°C (115°F) 50 gms. 5 sec. not more than 110.

(d) Loss on evaporation: 163°C (325°F) 5 hrs. less than 1%.

(e) Ductility—Not less than 3.

(f) % total bitumen (soluble in carbon tetrachloride) not less than 99%.

(g) % total bitumen (soluble in carbon bisulphide) not less than 99%.

(h) Reduction in penetration—At 25°C (77°F) due to heating specified under loss on evaporation, not more than 50%.

Section 2. Tests: Tests for the above requirements shall be made according to the following methods:

(a) Flash point—(open cup). U. S. Department of Agriculture Bulletin 314, page 17.

(b) Melting point—American Society for Testing Materials, Standard Method, Serial Designation D 36-19.

(c) Penetration—American Society for Testing Materials, Standard Method, Serial Designation D 36-19.

(d) Loss on evaporation—(Volatilization). U. S. Department of Agriculture Bulletin 314, page 19, 50 gram sample.

(e) Ductility—American Society of Civil Engineers, Transactions. Vol. LXXXII, 1918, page 1460.

(f) Total Bitumen—U. S. Department of Agriculture Bulletin 314, page 25.

(g) Percent of Total Bitumen—(Carbon Tetrachloride). U. S. Department of Agriculture, Bulletin 314, page 29.

(h) Reduction in Penetration: See test for Penetration.

Section 3. Samples: The contractor shall submit with his bid a one (1) pound sample of the asphalt filler proposed to be used in the work, together with a statement as to its source and character.

Section 4. Heating: Filler shall be heated to a temperature not exceeding 200°C (392°F). It shall be applied at a temperature of not less than 150°C (300°F). The heater shall be equipped with a thermometer capable of registering at all times the temperature of the filler.

Section 5. Cleaning the Surface: Brick shall be clean and dry when the filler is applied. Immediately before filling the joints, the surface of the brick shall be swept clean. All brick shall be filled and a surface dressing applied on the day of laying. Filler shall not be applied if the brick are wet nor if air temperatures are such that the filler will not flow freely to the bottom of the joints.

Section 6. Filling and Squeegeeing: Filler shall be removed from the heater and applied promptly to the pavement before cooling. Filler shall be worked into the joints by means of hot iron squeegees operated slowly backward and forward at an angle with the joints. Squeegee irons shall be kept hot and every precaution taken completely to fill the joints. Squeegeeing shall continue until the joints are full and a thin coating of asphalt remains upon the surface of the brick. Filler shall be applied and squeegeed until the joints remain full.

Section 7. Surface Dressing: Immediately after the joints are filled, a thin coating of dry stone screenings, sand or granulated slag shall be spread upon the surface of the pavement, provided the wearing surface of the brick is wire-cut. Top dressing shall be of such sizes that all will pass a number 4 sieve. As soon as the dressing is spread the surface of the pavement shall be rolled thoroughly to bed the dressing into the asphalt coating.

Section 8. Opening to Traffic: The brick roadway may be opened to traffic immediately upon completion of the surface dressing.

Classification of Solid Bituminous Substances.

CLASS		Spec. Gravity	Ash	Solubility in CS$_2$	Solubility in 88° P. E.	Melting Point	Fixed Carbon	Ash and Moisture Free: Car-bon	Hydro-gen	Sul-phur	Nitro-gen
1. Ozokerite	Utah (waxy)	0.891	0.05	99.5	81.7	160° F	9.6	85.4	13.9	0.3	0.4
Montan Wax		1.00	0.4	99.5	85.0	200	10.0				
Paraffin Wax		0.90	0.0	100.0	100.0	125	0.5	85.2	14.8	0.0	0.0
2. Baku Pitch	Russia	1.110	0.1	91.6	61.3	150	26.8				
Trinidad	Venezuela	1.400	36.5	56.5	35.6	190	10.8	82.3	10.7	6.2	0.8
Bermudez	Venezuela	1.082	2.5	95.0	62.2	180	13.4	82.9	10.8	5.9	0.8
Cuban	Cuba	1.305	21.4	75.1	32.4	240	25.0			8.3	
Maracaibo	Venezuela	1.064	1.8	96.8	45.7	210	18.0				
La Patera	California	1.063	6.8	89.8	53.4	180	8.0				
Chapapote	Mexico	1.034	0.7	99.2	74.1	272	21.5				
Gilsonite	Colorado	1.044	0.0	99.0	47.2	275	13.0				
"D" Grade	California	1.071	0.1	99.7	70.0	135	18.8				
Residual	Texas	1.070	0.1	98.2	69.6	164	19.5				
Ebano "E"	Mexico	1.000	0.1	99.4	69.0	163	19.2				
Tabbyite	Utah	1.010	6.0	94.7	61.0	178	9.0	82.0	11.0	2.0	3.0
Air-blown asphalt	Kansas	0.99	0.7	99.2	72.0	180	12.0	84.4	10.4	0.6	4.6
Pressure Tar asphalt	(Stanolind)	1.06	0.3	99.5	70.0	135	17.5			0.4	
3. Grahamite (Dull, irregular fracture.)	Colorado	1.160	0.1	98.2	0.8			86.0	7.6	0.9	5.4
	Oklahoma	1.171	5.7	94.1	0.4	dec.	53.3				
	West Virginia	1.137	2.1	97.8	3.3	dec.	41.0	86.6	8.7	1.8	2.9
Glance Pitch	Egypt	1.097	0.1	99.7	23.5	260	15.0	80.9	10.4	8.5	0.2
Manjak	Barbadoes	1.084	0.3	99.3	26.9	250	25.0				
Coal tar pitch—low		1.15	0.1	55.0	5.0	90	30.0	90.0	3.0	0.5	
high		1.40	0.1	90.0	30.0	345	45.0	95.0	5.0	1.0	
4. Albertite	Nova Scotia	1.075	0.0	5.9	1.5	dec.		85.5	13.2	1.2	0.4
	Utah	1.092	0.2	5.6		dec.				1.1	
	Mexico		26.2	11.9	3.2	dec.					
	Cuba	1.204	1.1	0.5							
	Oklahoma		10.7	1.6	0.0						
Wurtzilite	Utah	1.054	2.5	12.0	1.0	dec.		81.0	11.0	5.5	2.5
Impsonite	Oklahoma	1.235	2.5	6.0	trace	swells		75.0		1.7	
Elaterite—low		0.90	0.1	10.0	5.0	dec.	2.0				
high		1.05	10.0	20.0	10.0	dec.	5.0				

Classification of Solid Bituminous Substances—Continued.

CLASS	Spec. Gravity	Ash	Solubility in		Melting Points	Fixed Carbon	Ash and Moisture Free			
			CS_2	88° P. E.			Carbon	Hydrogen	Sulphur	Nitrogen
5. Peat (dry)	1.15	2.0+	trace	0.0	dec.	35.0	......	......	......	......
Lignite (dry)	1.25	2.0+	trace	5.0	dec.	50.0	......	......	......	......
Bituminous coal	1.25	2.0+	0.0	0.0	dec.	60.0	......	......	......	......
Cannel coal	1.20	5.0+	0.0	0.0	dec.	40.0	......	......	......	......
Anthracite coal	1.75	2.0+	0.0	0.0	dec.	90.0	......	......	......	......
Oil shale	1.75	70.0	0.0	0.0	dec.	20.0	80.0	12.0	......	4.8

Class 1. Substances freely soluble in carbon bisulphide and in U.S.P. petroleum ether (75% or more). This class includes paraffin base petroleum residues, Ozokerite, Montan Wax and Paraffin.

Class 2. Substances freely soluble in carbon bisulphide and largely soluble in petroleum ether (40-75%). This class includes all commercial asphalts such as asphaltic base petroleum residuals, Trinidad asphalt, Bermudez asphalt, Gilsonite, Cuban asphalt, Tabbyite, air blown asphalt and pressure tars.

Class 3. Substances freely soluble in carbon bisulphide and slightly soluble in petroleum ether under 40%. This class includes the usual binders and pitches such as coal tar pitch, Grahamite, Glance pitch and Manjak.

Class 4. Substances slightly soluble in carbon bisulphide. This class includes Albertite, Wurtzilite, Elaterite, Impsonite.

Class 5. Substances practically insoluble in carbon bisulphide. This class includes coals and carboniferous shales such as peat, lighnite, bituminous coal, cannel coal, anthracite coal, bituminous or oil shales.

References: Ladoo, Bureau of Mines Report No. 2121. Abraham, Asphalts and Allied Substances.

Characteristics of Typical Blown Petroleum Asphalts.

	Specific Gravity, 77° F	Penet., 32° F	Penet., 77° F	Penet., 115° F	Ductility in Cms., 77° F	Melting Point, R. & B. Method	Fixed Carbon	Soluble in Carbon Bi-sulphide	Soluble in 88° Naphtha
NON-ASPHALTIC PETROLEUM—									
Ohio-Indiana	0.987	1.5	4.8	15.9	29.5	106	8.4	99.86	88.5
	0.995	5.85	10.0	25.0	9.0	144	9.1	99.69	82.0
	1.005	9.8	17.5	31.7	2.5	174.5	9.6	99.43	72.8
	1.015	14.1	21.5	41.9	1.0	209	10.3	99.22	70.5
	1.021	18.3	26.7	49.3	0.5	234.5	11.8	99.13	67.7
	1.012	18.7	28.0	51.9	0.5	259	12.5	98.67	61.9
	1.002	19.6	29.6	58.5	0.125	294	15.7	97.58	53.6
MIXED-BASE PETROLEUMS—									
Illinois	0.958	2.7	4.3	16.9	56	110	7.8	98.75	85.2
	1.010	10.3	14.6	28.0	1.5	181	10.0	99.20	76.5
Mid-Continent	1.009	2.7	5.5	23.5	87.0	108	8.6	99.60	86.5
	1.002	4.8	6.7	24.2	51.0	124	9.3	99.08	85.1
	0.980	3.8	8.1	29.4	88.0	135	9.9	99.83	84.8
	0.985	4.9	11.4	24.1	2.5	144	9.1	98.45	80.8
	1.029	5.6	15.7	32.1	2.0	150	12.7	99.25	76.2
	1.054	10.6	18.8	38.0	1.5	171.5	15.3	99.28	70.1
	0.988	14.1	18.2	33.3	0.5	236	11.4	98.93	68.0
	1.016	22.9	28.3	62.1	0.25	272	12.3	98.30	60.8
Mexico	1.005	0.0	4.3	21.2	50.0	110	12.8	99.80	88.0
	1.015	3.4	4.9	21.5	13.0	126	15.9	99.83	80.2
	1.022	0.0	7.6	28.4	93.5	144	15.2	98.80	84.0
	1.038	4.1	22.9	50.7	20.0	161	15.7	99.05	82.2
	1.037	9.0	22.9	61.3	1.0	183	17.0	99.50	78.3
	1.032	9.7	25.2	57.5	2.5	182	18.0	98.70	73.4
ASPHALTIC PETROLEUMS—									
Gulf	1.004	2.4	7.7	26.7	56.0	116	10.2	99.50	79.9
	1.032	9.4	17.4	34.2	3.0	157	10.8	99.22	80.7
California	1.008	0.0	6.9	30.7	54.5	106.5	9.7	99.78	78.0
	1.050	3.4	12.6	47.9	40.0	155	11.0	99.60	71.8
	1.045	7.05	22.2	50.7	23.0	162	12.4	99.25	72.0
	1.038	8.5	25.2	65.4	0.5	165	18.0	98.68	73.8
	1.060	9.1	25.2	60.4	0.5	180.5	13.2	99.25	68.7
	1.070	20.6	36.1	70.5	0.0	195.5	20.0	98.70	62.5

Properties of Typical Road Oils.

No.	Gravity and Weight per Gallon	Viscosity 210° F Universal	Viscosity Furol 104° F	Asphalt, %	Character of Asphalt	Loss 350° C 24 hrs., %
1	.933=20.2° Be' 7.77 lbs.	46.0	20.8	55.0	waxy	50.2
2	.933=20.2° Be' 7.77 lbs.	126.0	172.0	65.0	ductile	22.2
3	.951=17.3° Be' 7.92 lbs.	80.0	79.0	66.0	granular	30.8
4	.973=13.9° Be' 8.10 lbs.	47.0	25.0	51.5	ductile excellent	60.2
5	1.028= 6.1° Be' 8.57 lbs.	124.0	430.0	66.0	ductile excellent	27.0
6	1.005= 9.3° Be' 8.38 lbs.	99.0	72.0	60.0	ductile excellent	33.0
7	0.953=17.0° Be' 7.93 lbs.	139.0	252.0	75.0	waxy	15.0
8	0.940=19.0° Be' 7.83 lbs.	122.0	182.0	69.0	ductile good	29.6
9	0.940=19.0° Be' 7.83 lbs.	127.0	183.0	69.0	ductile good	29.5
10	0.950=17.5° Be' 7.91 lbs.	135.0	252.0	75.0	waxy	15.0
11	0.935=19.8° Be. 7.79 lbs.	99.0	117.0	63.5	ductile good	32.6
12	0.931=20.5° Be. 7.75 lbs.	115.6	159.0	66.0	ductile good	26.4

Open Specifications for Road Oil.

Water . . . . None
Specific gravity . . . . Over .940
Soluble in carbon bisulphide 99.5%
Per cent asphalt . . . . Over 60
Ductility of 100° asphalt at 77° F . . . . Over 5 cm.
Viscosity S. U. at 210° F=100-150 (must be under 100 if for cold application).
Viscosity Furol at 104° F=100-500 (must be under 199 if for cold application).

Illinois State Highway Specification for Road Oil.

SPECIFICATION S1.

(Heavy Oil, Hot Application.)

HEAVY OIL FOR SURFACE TREATMENT OF BITUMINOUS OR WATERBOUND MACADAM ROADS. The road oil shall be homogeneous, free from water and shall not foam when heated to 150°C (302°F). It shall conform to the following requirements:
Specific gravity 25°C/25°C (77°F/77°F), not less than 0.980.
Flash point, not less than 150°C (302°F).
Specific viscosity at 100°C (212°F), 30.0 to 70.0.
Float test at 50°C (122°F), 100 seconds to 200 seconds.
Loss at 163°C (325°F) 5 hours, not over 5.0%.
Float test of residue at 50°C (122°F), 120 seconds to 240 seconds.
Total bitumen, not less than 99.5%.
Per cent of total bitumen insoluble in 86° Be′ naphtha, 10 to 25%.
Fixed carbon, 7 to 15%.

SPECIFICATION S2.

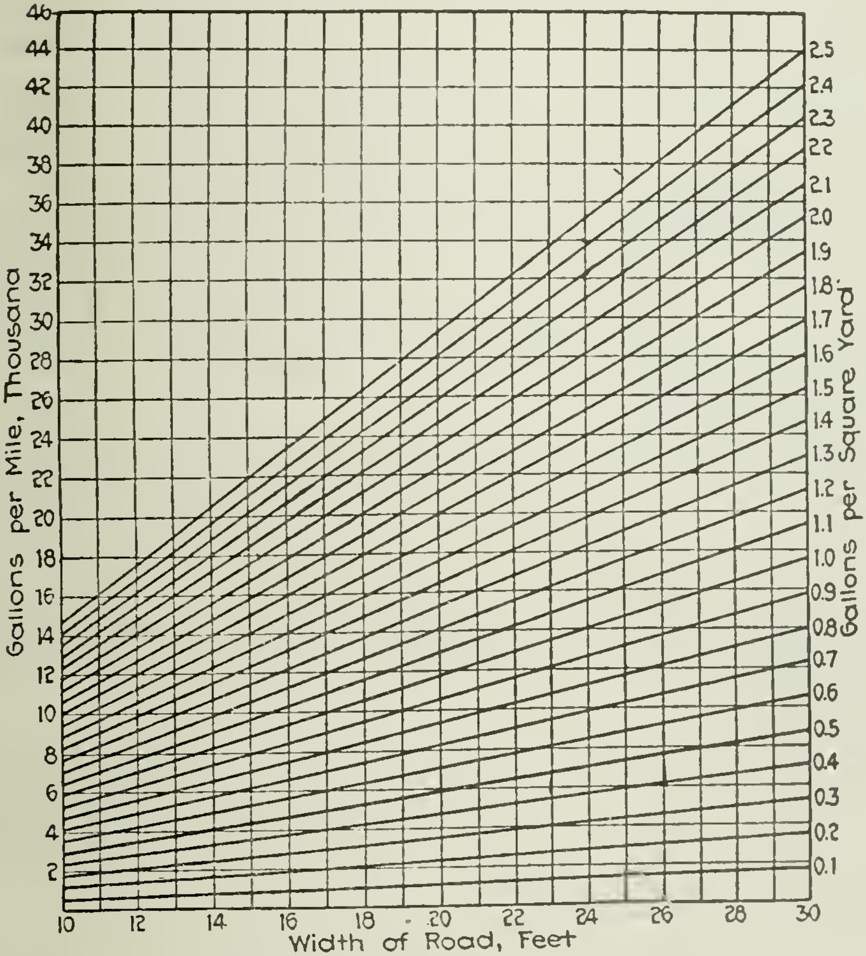
(Medium Oil, Hot Application.)

MEDIUM OIL FOR SURFACE TREATMENT OF BITUMINOUS OR WATERBOUND MACADAM ROADS. The road oil shall be homogeneous, free from water and shall not foam when heated to 100°C (212°F). It shall conform to the following specifications:
Specific gravity 25°C/25°C (77°F/77°F), 0.960 to 1,010.
Flash point, not less than 100°C (212°F).
Specific viscosity at 100°C (212°F), 5.0 to 15.0.
Float test at 32°C (90°F), 30 seconds to 90 seconds.
Loss at 163°C (325°F) 5 hours, not over 15.0%.
Float test of residue at 50°C (122°F), 90 seconds to 180 seconds.
Total bitumen, not less than 99.5%.
% total bitumen insoluble in 86° Be′ naphtha, 7.0% to 20.0%.
Fixed carbon, 5.0% to 10.0%.

SPECIFICATION S3.

(Light Oil, Cold Application.)

LIGHT OIL FOR SURFACE TREATMENT OF BITUMINOUS OR WATERBOUND MACADAM OR OF GRAVEL ROADS: The road oil shall be homogeneous and free from water. It shall conform to the following requirements:
Specific gravity 25°C/25°C (77°F/77°F), 0.920 to 0.970.
Specific viscosity at 25°C (77°F), 30.0 to 70.0.
Loss at 163°C (325°F) 5 hours, 20.0% to 30.0%.
Total bitumen, not less than 99.5%.
% total bitumen insoluble in 86° Be′ naphtha, 5.0% to 20.0%.
Fixed carbon, 4.0% to 10.0%.



GALLONS OF ROAD OIL REQUIRED PER MILE OF ROAD AT GIVEN WIDTH AND RATE

Fig. 75—Amount of Road Oil Required for Different Rates of Application.

Bituminous Acid-Proof Coatings for Acid-Proofing Concrete Surfaces. (Bureau of Standards.)

Acid-Proof Black.

This material shall be composed of a high grade of bitumen thinned with suitable volatile solvents to furnish a smooth, black product which shall dry in twenty-four hours and be unaffected by mineral acids of specified concentration.

It must contain at least 40% of non-volatile, shall not settle, liver or thicken in the container and shall conform to the following requirements.

(a) When flowed on a piece of clean sheet iron approximately 4x6 in. and 0.016 in. thick and allowed to dry for one week at room temperature the film must withstand bending double quickly over a rod of 5 mm. in diameter without cracking or flaking.

(b) A test piece prepared as above and dried for one week at room temperature shall be laid flat and in different places several drops each of sulphuric acid, specific gravity 1.3, nitric acid, specific gravity 1.23 and hydrochloric acid, specific gravity 1.09 shall be allowed to remain on the surface of the film for six hours. On examination, the film shall show only slight dulling and the metal beneath shall show no corrosion.

Bituminous Enamel.

The enamel shall consist of a homogeneous mixture of a bitumen of relatively high melting point and finely powdered siliceous mineral filler. The total amount of mineral filler as determined from the ash, shall not exceed 40% nor be less than 15% by weight. Within the above limits the satisfactory working qualities of the enamel shall control the quantity of mineral filler to be used. The mineral filler must be resistant to hydrochloric, sulphuric and nitric acids, and must pass a sieve the openings of which are not greater than 0.14 mm. (0.0055 in.) (This corresponds to about 100 mesh sieve).

Bituminous Primer.

The primer shall consist of a like bituminous material containing no added mineral matter, thinned with a solvent to a satisfactory brushing consistency. It shall dry to a tacky state in thirty minutes and shall not flash below 30°C by the Abel closed tester. The solvent used shall have a minimum toxic effect upon workmen applying the primer within an enclosed space.

Bituminous Acid-Proof Mastic.

The bituminous mastic shall be composed of asphalt cement, clean, sharp grained sand, and fine absorbent siliceous dust. These materials shall be mixed in the proper proportions and shall be applied hot to the concrete surface, which shall be dry and free from dust and shall have been previously coated with a priming or bonding solution which has just reached the tacky state.

Asphalt Cement.

The asphalt cement must be of refined asphalt and shall be homogeneous and free from water.

It shall meet the following requirements:

Melting point (ring and ball) 150 to 180°F.

Penetration at 25°C, 100 g. 5 sec. 15 to 40.

Total bitumen soluble in carbon bisulphide, not less than 90%.

The sand shall be clean, hard grained and moderately sharp, and shall be free from clay, silt and organic matter.

It shall be well graded from coarse to fine, and when tested by means of the laboratory sieves, shall meet the following requirements:

Passing 4 mesh sieve, 100%.
Total passing 20 mesh sieve, 50 to 80%.
Total passing 50 mesh sieve, not more than 30%.
Passing 100 mesh sieve, not more than 5%.

Mineral Filler.

The mineral filler shall be any finely powdered acid-resistant siliceous material, 85% of which shall pass a 100 mesh screen.

Priming Solution.

The priming solution shall consist of an asphaltic base similar to the asphalt cement and shall be thinned to a good brushing consistency with a suitable volatile solvent.

Mixing.

The sand or the mixture of the sand and mineral matter and the asphalt cement shall be heated separately to about 300°F. When the asphalt cement is completely fluid, the hot dry aggregate is stirred in and thoroughly mixed until the mass is homogeneous and sufficiently fluid for pouring. The temperature of pouring should be between 350 and 400°F. The aggregate if dry may be stirred in without previous heating but in that case a longer period of heating and stirring will be required.

Laying.

The concrete surface shall be primed and allowed to dry to the tacky state. The hot mixture, prepared as above, shall then be poured spread on, soothed out and worked into place with suitable tools. After the surface has begun to set, it shall be sprinkled with hard-grained sand and a little mineral dust and rubbed down until it is smooth. The finished layer should be at least 1 in. thick.

Approximate Formula.

The composition varies within narrow limits according to the service required of the material, and when ready for laying should be as follows:

Asphalt cement	12 to 15%
Mineral filler	20 to 25%
Sand or other aggregate	60 to 70%

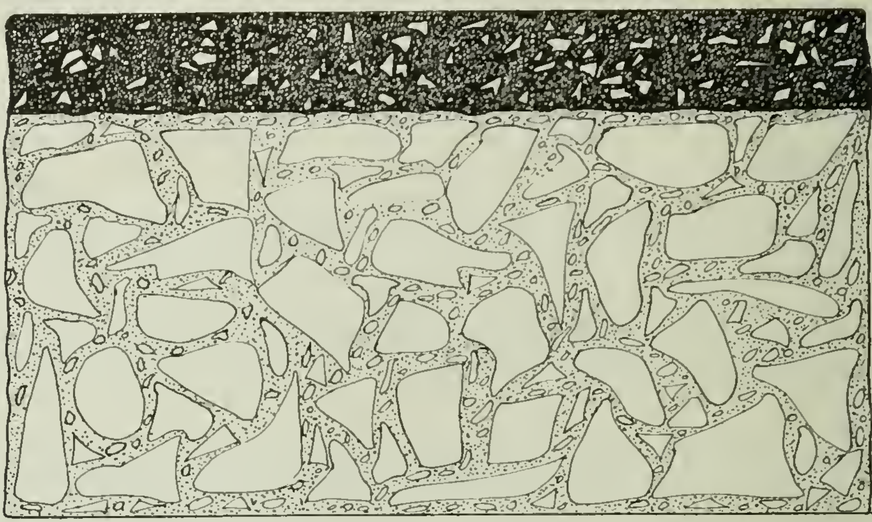


Fig. 76—Topeka Bituminous Concrete.

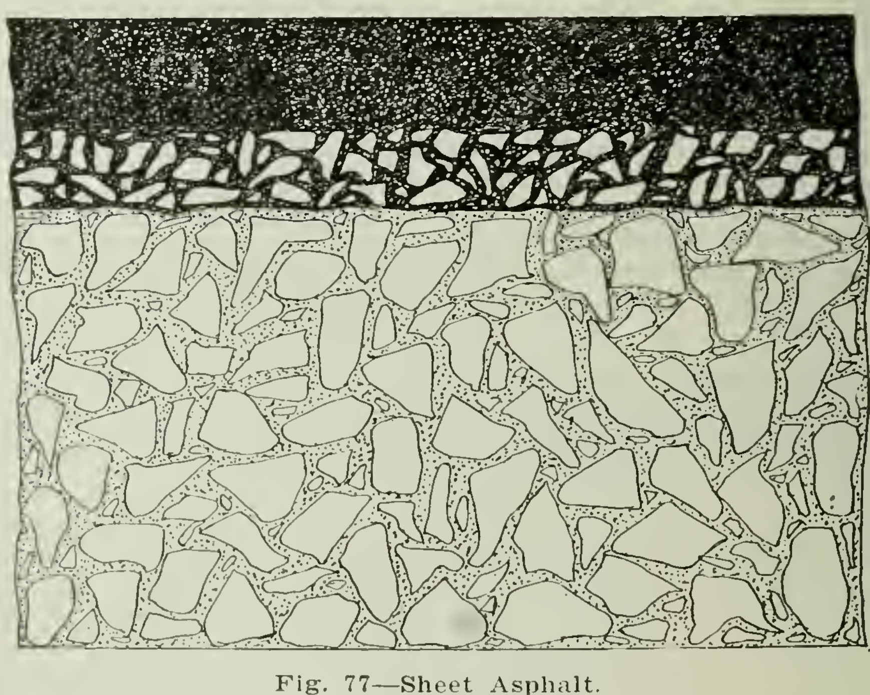


Fig. 77—Sheet Asphalt.

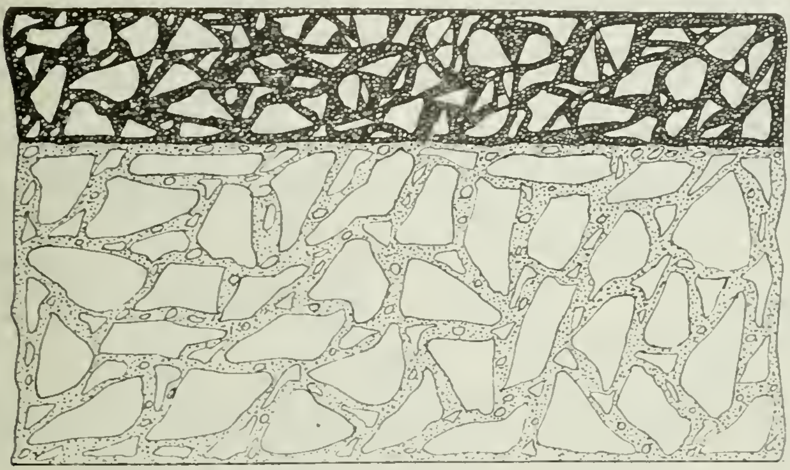


Fig. 78—Asphaltic Concrete (Warrenite.)

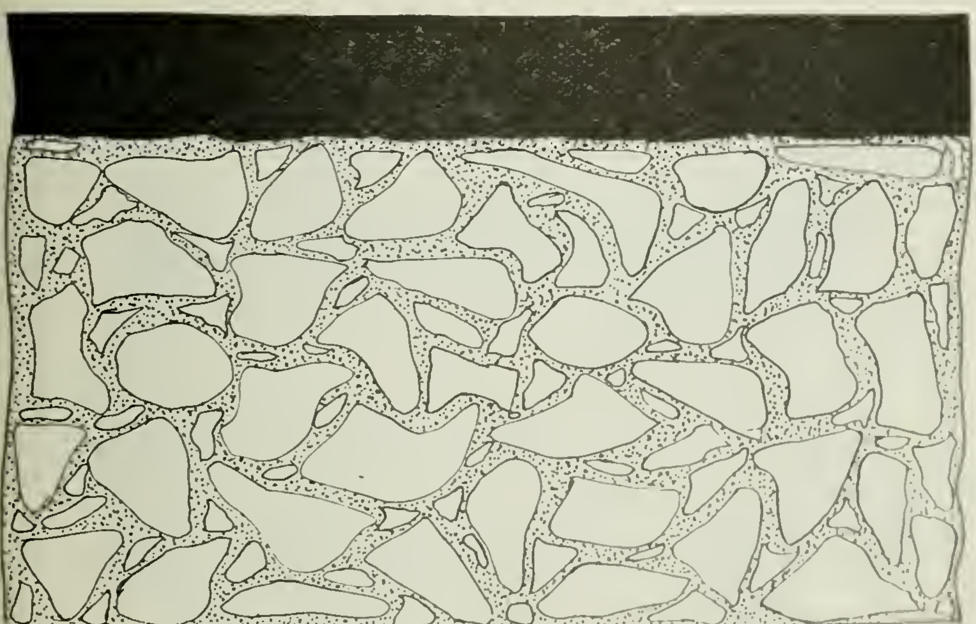


Fig. 79—Bituminous Earth Pavement.

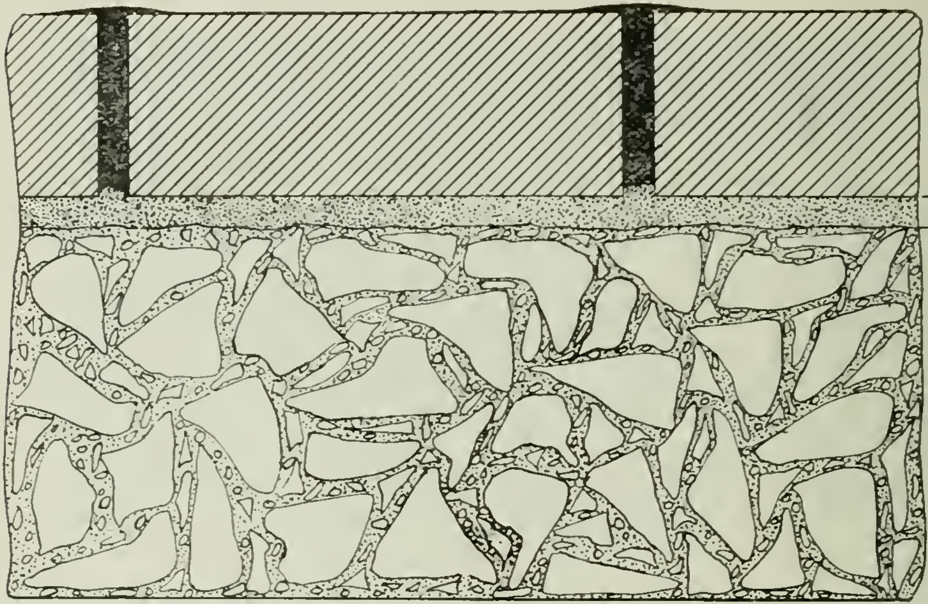


Fig. 80—Brick Pavement With Asphalt Filler.

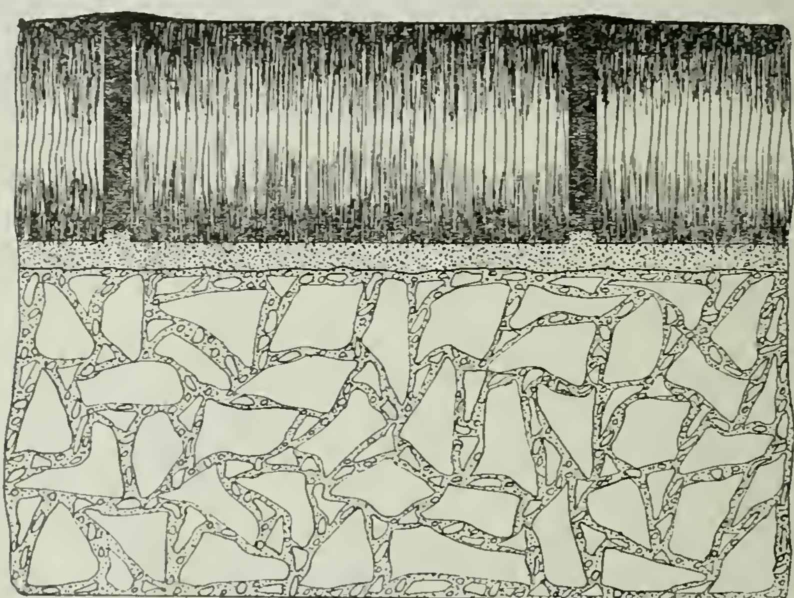


Fig. 81—Wood Block With Asphalt Filler.

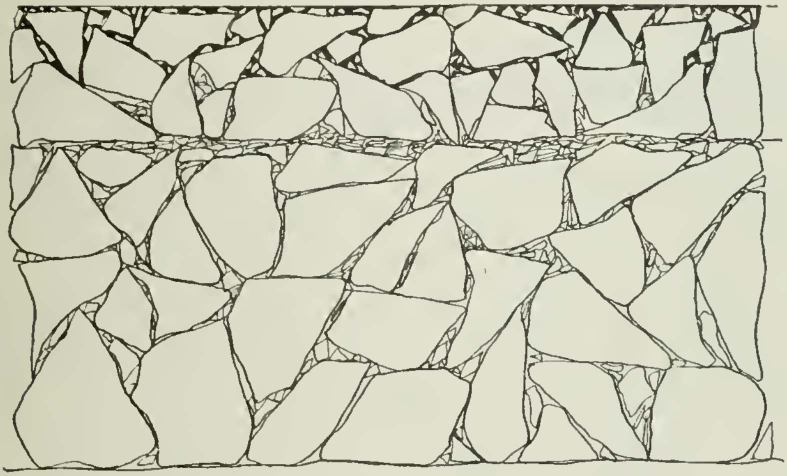


Fig. 82—Asphalt Macadam Pavement.

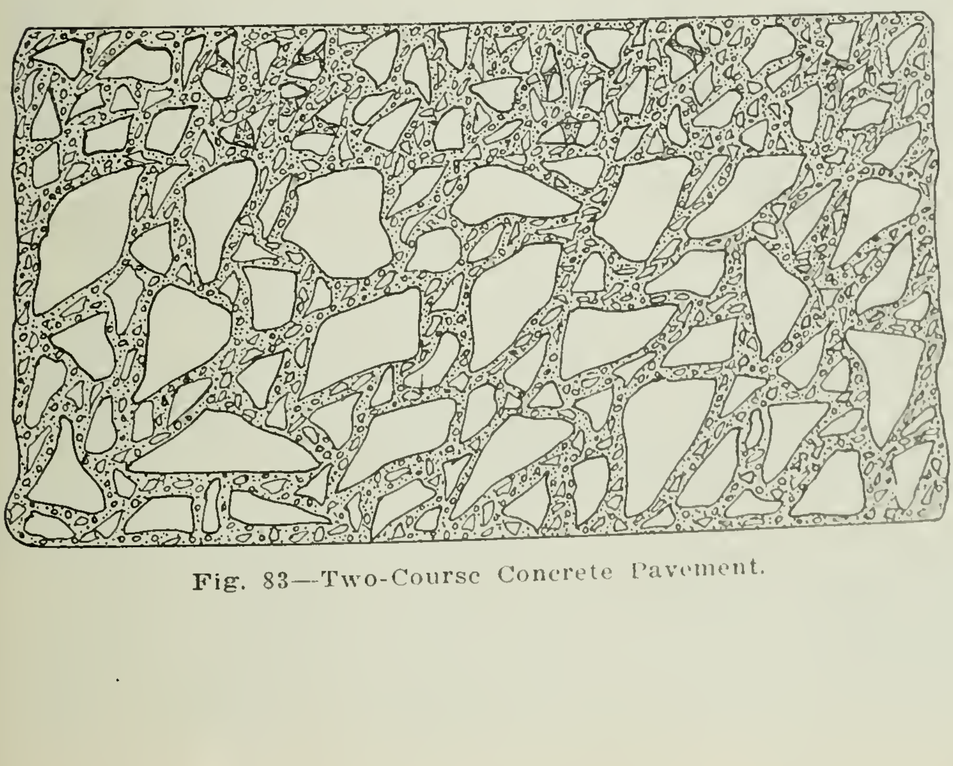


Fig. 83—Two-Course Concrete Pavement.

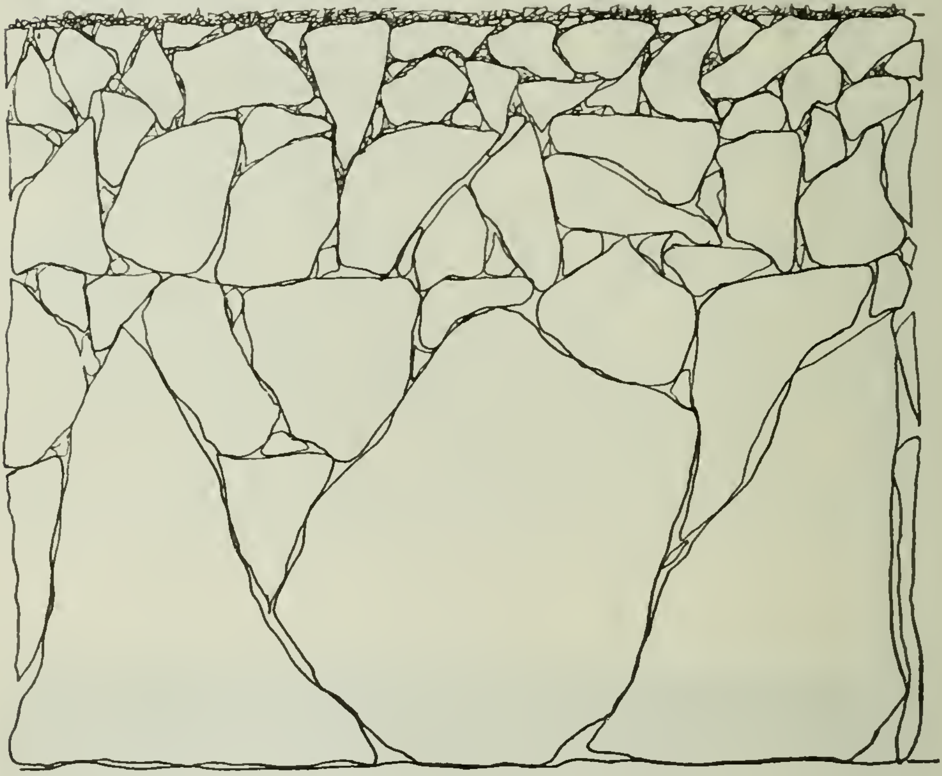


Fig. 84—Oil Treated Macadam Pavement.

Natural Gas.

Natural gas is an ideal domestic fuel and an almost equally ideal industrial fuel. It is a large item in interstate but not in international trade. About one-fourth of the natural gas consumed in the United States is used for generating power, and its use affects international industry and commerce, for it supplements the supply of coal and oil.

As it saves man power, is especially adapted to certain industrial processes and is cheap, natural gas is used as fuel in many glass works, cement plants, brickyards, factories and metallurgical plants. It is also used in large quantities as raw material in making carbon black, 30 per cent of the natural gas consumed industrially in West Virginia in 1917 having been used in the carbon black industry.

Some natural gas is valuable because of its content of gasoline, and the extraction of gasoline from natural gas is now an industry of increasing magnitude. Some of the gasoline thus obtained is so light that it must be blended with naphthas and other distillates obtained from crude oil before it can be used as a motor fuel. A recently developed process is that of extracting the gas helium from natural gas. It is used in balloons as a non-inflammable substitute for hydrogen.

Natural gas is now used by about 16,500 industrial consumers of whom more than 10,000 employ it for generating power and by about 2,500,000 domestic consumers. The field operations undertaken to exploit natural gas have been accompanied by enormous waste, which will hasten the exhaustion of this fuel.

Character and Occurrence—Pure natural gas is odorless and colorless, burns with a luminous flame and is highly explosive when mixed with air. Its chief constituent is marsh gas, or methane, a member of the paraffin series. Besides methane, it may contain ethane, a closely related gas and varying amounts of ethylene or olefiant gas, carbon monoxide, carbon dioxide and nitrogen as well as a little oxygen and helium.

Natural gas is classified as either "wet" or "dry" according to its content of gasoline. Wet gas is commonly associated with oil in oil fields and is generally obtained from the same sand or formation that yields the oil or even from the same well. It contains not only ethane, propane, butane and pentane, the lighter members of the methane series, which predominate in the dry gas, but some heavier hydrocarbons. Dry gas contains chiefly methane or marsh gas, the lightest known hydrocarbon, which has a specific gravity of 0.559. It is usually not associated with oil in the sand and is generally under high pressure.

The close association of oil and gas in both occurrence and origin makes it difficult to consider the two resources separately. Gas invariably accompanies oil wherever the conditions are favorable to its accumulation but it is also found in places far removed from oil fields. Many of the natural gas fields coincide areally with oil fields and the production of oil and that of natural gas are closely related.

The gas being lighter usually accumulates in the upper parts of the oil and gas bearing deposits. The accumulation of natural gas is governed by features of geologic structure similar to those that govern the accumulation of oil and the origin of natural gas is accounted for by the same theories that account for the origin of oil. Natural gas is found in rocks that range in geologic age from Cambrian to Recent, but most of the world's supply of natural gas is derived from beds of Devonian, Carboniferous and Tertiary age.

Geographic Distribution—The chief natural gas fields of the United States are the Appalachian field, comprising parts of the States of West Virginia, Pennsylvania, New York, Ohio, Kentucky and Tennessee; the Mid-Continent field, including parts of Kansas and Oklahoma; and isolated fields in the states of Louisiana, Texas, Arkansas, California, Illinois and Indiana. Gas is also found in small quantities in Wyoming, Washington, Colorado, Oregon, South Dakota, North Dakota, Montana, Idaho, Iowa, Michigan, Missouri, New Mexico, Utah and Alabama. In foreign countries, natural gas is found in considerable quantities in the provinces of Ontario, Alberta and New Brunswick in Canada and in Great Britain, Italy, Rumania, Galicia, Hungary, Russia, Persia, India, Japan, Mexico, Peru and Argentina. Undoubtedly as the search for petroleum is continued, productive gas fields will be discovered in foreign countries even in countries where natural gas is not now supposed to be present in great quantities.

Production—The commercial production of natural gas is restricted almost wholly to the United States, the available statistics showing that about 95 per cent of the world's output is produced in this country. Canada stands second in rank. The United States is likely to lose this remarkable predominance, for she has already apparently passed her maximum production. (See U. S. Geol. Survey.)

The table on page 395 shows the production of the principal natural gas producing countries in the world in 1913 and 1917:

Typical Composition of Commercial Gases.

	Methane C_nH_{2n+2}	Ethylenes C_nH_{2n}	Hydrogen H_2	Carbon monox. CO	Carbon diox. CO_2	Nitrogen N_2	Oxygen O_2	B.T.U. per cu. ft.
Coal gas, Germany	34.02	5.09	46.20	8.88	3.01	2.15	0.65	700
Coal Gas, United States	40.00	4.00	46.00	6.00	0.45	2.05	1.50	755
Lignite gas	15.59	3.25	45.16	17.24	11.51	5.49	1.76	500
Wood distillation gas	21.70	6.00	18.30	31.50	17.40	5.10	0.00	....
Cannel coal gas, low temperature	60.10	6.30	21.20	....	....	....	....	....
Cannel coal gas, high temperature	34.20	3.50	54.50	....	....	....	....	....
Water gas	2.00	0.00	45.00	45.50	4.00	2.00	1.50	350
Natural gas	91.58	0.00	0.00	0.00	0.00	7.95	0.00	970
Pressure still gas	73.92	10.43	9.30	0.45	0.22	5.46	0.22	....
Oil gas	57.70	38.10	3.40	0.50	0.30	....	....	1390
Producer gas	1.20	....	12.00	27.00	2.50	57.30	....	154
Blast furnace gas	0.5	....	3.00	26.00	9.5	56.0	....	....
*Still gases from lub stills	77.0	3.5	....	16.5	3.0	....	....	....
*Still gases from coking stills	71.0	17.0	5.0	5.0	1.0	....	....	....

NATURAL GAS PRODUCED BY PRINCIPAL COUNTRIES 1913 AND 1917 IN THOUSANDS OF CUBIC FEET.

Country—	1913	1917
United States	581,898,239	795,110,376
Canada	20,487,000	27,408,940
Austria	250,000	....
Italy	210,525	6,750,000
Great Britain	87	85
Japan	Small Amount	....
Russia	Small Amount	....
World	603,000,000	829,000,000

REPORT OF BUREAU OF LABOR STATISTICS ON PRICE OF 1,000 CUBIC FEET OF GAS USED FOR HOUSEHOLD PURPOSES IN VARIOUS CITIES.

Natural Gas.

Buffalo	$0.35
Cincinnati	.35
Cleveland	.35
Columbus	.30
Dallas	.45
Kansas City	$0.80
Little Rock	.45
Louisville	.648
Pittsburgh Co.	.35

Manufactured and Natural Mixed.

Los Angeles	$0.75

Manufactured Gas.

	1919.
Atlanta	$1.00
Baltimore	.75
Birmingham	.95
Boston Co.—A	1.00
Boston Co.—B	1.10
Boston Co.—C	.95
Bridgeport	1.10
Buffalo	1.45
Butte	1.485
Charleston (S. C.)	1.10
Chicago	.88
Cleveland	.80
Denver	.95
Detroit	.79
Fall River	.95
Houston	1.00
Indianapolis	.60
Jacksonville	1.25
Manchester	1.10
Memphis	1.00
Milwaukee	.75
Minneapolis	.95
Mobile	$1.35
New Haven	1.10
New Orleans	1.30
Newark	.97
New York	.80
Norfolk	1.20
Omaha	1.15
Peoria	.85
Philadelphia	1.00
Pittsburgh	1.00
Portland, Me.	1.40
Portland, Ore.	.779
Providence	1.30
Richmond	1.00
Rochester	.95
San Francisco	.90
Scranton	1.30
Seattle	1.25
St. Louis	.75
St. Paul	.85
Washington	.95

Natural gas is found trapped in the various strata of the earth, principally in sandstone formations of loose texture, in shale seams and in cavities. It is usually associated with petroleum or coal and occurs in the carboniferous strata or in more recent formations. In coal mines it constitutes what is known as fire damp, being given off from the exposed seams of coal. It is most commonly associated with petroleum in petroleum bearing sand and occupies the space in the sand above the oil. Occasionally it occurs in strata without any oil being present, in which case it is of a slightly different composition than the gas which is found in contact with the oil. In many cases it appears that the gas has been obtained from the atmosphere, the oxygen having been removed by its combination with reducible substances such as sulphides, leaving a residue of nitrogen. This gives to such natural gases the peculiarity of having a very large amount of nitrogen. Associated with the nitrogen there occasionally is found a small amount of helium which is also an ordinary constituent of air in small quantities. It may be that the difference of solubility of the different gases of the air in water may account for the tendency of accumulation of helium in such instances. As a rule, however, natural gas consists of hydrocarbons of the same type as petroleum and identical with the hydrocarbons which are given off by the cracking of petroleum.

The proportions in which the different hydrocarbons exist in ordinary gas such as is delivered to Kansas City, Missouri, is something like the following:

Methane	84.7%
Ethane	9.4%
Propane	3.0%
Butane	1.3%
Nitrogen	1.6%

This gas has the greater portion of the heavy hydrocarbons condensed out on account of the high pressure in the pipe lines. Such a gas is a mixture of methane with a varying amount of the other gases. As shown by the above table, the gases ethane, propane and butane furnish much of the heating value of the gas. A gas with a considerable amount of gasoline vapor in it will have a considerably higher heating value than one from which it has been removed, or known as a dry gas.

The compositions of the natural gas used in eight cities in the United States are as follows:

City	Methane, Per cent	Ethane, Per Cent	Nitrogen, Per Cent
Pittsburgh, Pa.	79.2	19.6	1.2
Louisville, Ky.	77.8	20.4	1.8
Buffalo, N. Y.	79.9	15.2	4.9
Cincinnati, O.	89.8	19.5	.7
Cleveland, O.	80.5	18.2	1.3
Springfield, O.	80.3	14.7	5.0
Columbus, O.	80.4	18.1	1.5
Chelsea, Okla.	75.4	17.7	6.6

These analyses were made by the ordinary combustion method and hence show only the two predominating paraffin hydrocarbons.

The composition of gases found in Kansas and Oklahoma as given by Allen and Lyder are shown by the following table:

Location	Methane	Ethane	Nitrogen	B.T.U. per Cubic Foot
Augusta, Kas.	10.54	1 64	87.69	129
Cowley County, Kas.	16.27	3.01	80.23	209
Chautauqua County, Kas.	42.38	1.85	55.29	441
Chautauqua County, Kas.	49 01	3.89	46.67	541
Elsworth, Kas.	61.09	1.09	37.20	609
Ponca City, Okla.	44.60	14.86	40.10	688
Kay County, Okla.	57.91	9.89	31.65	735
Chautauqua County, Kas.	85.53	0.15	12.95	839
Chautauqua County, Kas.	79.13	7.79	11.39	894
Butler County, Kas.	62 15	18.38	18.64	930
Montgomery County, Kas.	83.04	8.54	7.95	970
Blackwell, Okla.	70.69	18.65	9.32	1025
Cushing, Okla.	70.74	21 64	7.49	1059
Bartlesville, Okla.	70.50	24.60	3.21	1125

The presence of such a large amount of nitrogen in some cases makes the gas almost valueless unless some process is used whereby the nitrogen may be adapted to chemical processes.

While natural gas has a very high heating value in comparison with water gas, water gas has the advantage in that it gives a more intense flame. The comparison of various commercial gases is shown in the following table:

Natural gas may have its origin from a sand which is entirely separated from sand containing oil or it may come from above the oil in the same sand as oil.

In the latter case the lighter portions of the oil will have been volatilized and carried into the gas. Such a gas is known as a "wet" gas. In other words, the wet gas is composed of the usual constituents of dry gas; that is, methane, ethane, propane and butane, and in addition pentane, hexane and heptane. These last three are liquid at ordinary temperatures and are the most desirable components of gasoline.

Gas coming from a sand containing no oil is "dry" gas and does not contain the pentane, hexane and heptane.

A "wet" gas coming from an unknown sand indicates the presence of oil in that sand.

In the ordinary oil well the gas is allowed to escape between the casing of the well and the tube which has been inserted for withdrawal of the oil. The gas so collecting in the casing is known as casinghead gas and may be used or allowed to escape.

This gas collecting in the casinghead of an oil well is "wet" gas and contains some of the gasoline from the oil. The gasoline which may be compressed from it or refrigerated from it is then known as "casinghead" gasoline.

Comparative Gas Statistics of American Cities, 1918.

CITY	Approximate Population Served	C. F. Annual Sales in Millions	Consumers and Meters	No. of Co.'s	Kind of Gas	Heat Units	Process	Rate per 1000 Feet
*New York	5,300,000	56,184	1,510,173	18	Artificial	708	Coal-Lowe	$0.80-$1.00
Chicago	2,200,000	21,693	689,983	2	Artificial	600	Lowe	$0.80
Philadelphia	1,767,000	12,643	406,776	2	Artificial	....	Coal-Lowe	1.00
Boston	730,600	7,150	201,030	3	Artificial	600	Coal-Lowe	.80
St. Louis	750,000	....	160,206	1	Artificial	610	Coal-Lowe	.85
*Pittsburgh	579,000	....	270,298	4	Natural	....	Natural	$0.28½-$0.32
†Los Angeles	625,000	6,629	186,482	3	Mix. and Nat.	825-900	Oil and Nat.	$0.68-$0.64½
Cleveland	765,000	....	290,000	1	Natural	....	Natural	.33
Baltimore	700,000	4,487	126,550	1	Artificial	600	Lowe	.85
New Orleans	375,000	1,335	45,710	1	Artificial	600	Lowe	1.19
St. Paul	262,000	1,463	43,827	2	Artificial	610	Lowe	1.05
Minneapolis	363,000	2,655	83,162	1	Artificial	600	Coal-Lowe	.92
Washington	331,000	2,903	74,608	2	Artificial	637	Coal-Lowe	$0.75-$0.95
San Francisco	560,000	4,595	123,272	1	Artificial	606	Oil	.85
Detroit	750,000	8,000	173,000	1	Artificial	....	Coal-Lowe	.85
Newark	637,000	4,553	168,642	1	Artificial	....	Coal-Lowe	.90
Kansas City	312,000	5,277	69,823	1	Natural	....	Natural	.30
Seattle	348,000	1,078	46,731	1	Artificial	....	Coal-Lowe	1.25
Portland	295,000	1,308	46,525	1	Artificial	570	Lowe	1.00
Denver	260,000	1,269	43,199	1	Artificial	615	Coal-Lowe	.95
Buffalo	468,000	....	96,428	3	Natural	....	Natural	$0.32-$0.35
Cincinnati	410,000	....	114,498	1	Natural	....	Natural	.40
Louisville	264,000	....	....	1	Natural	....	Natural	.40
Milwaukee	436,000	3,700	99,200	1	Artificial	600-650	Coal-Lowe	.75
Indianapolis	250,000	2,390	59,107	1	Artificial	....	Coke-Water	.55

Note—*Value of gas sold by four companies for year $19,870,991.03.

†One company serves natural gas at 64.5c and the other two companies a mixture of natural and manufactured gas.

The lighter the oil with which the casinghead gas has been associated, the greater ordinarily will be the amount of gasoline contained in the gas.

Ever since natural gas has been conducted in pipe lines it has been known that gasoline could be separated by pressure and much has been incidentally so produced. More recently the great demand for gasoline has encouraged the design of hundreds of special plants for the extraction of gasoline from natural gas.

In 1904, at Titusville, Pennsylvania, Fasenmeyer made casinghead gasoline by pumping the gas under pressure through a coil under water.

In the early methods pressures of about 50 pounds per square inch were used. Later condensing with a pressure of 400 pounds per square inch was found to produce too "wild" a gasoline or one that escaped too easily on handling. A pressure of 250 pounds per square inch is now used, and the pressure of the condensed liquid is controlled by absorbing it directly into heavier naphtha.

At first the compression was done in one stage, but it is the custom now to do it in two stages. The gravity of the product is from 80 to 100° Baume'.

The amount of casinghead gasoline present in a gas well depend upon the character of the oil associated with it, the temperature, the pressure, the compactness of the sand and the condition in the sand at the point tapped.

The amount of gasoline obtained from casinghead gas in the Mid-Continent field varies from ½ to 8 gallons per 1,000 cubic feet. A typical gas yields 2½ gallons per 1,000 cubic feet. Many yield 3 to 4 gallons per 1,000 cubic feet.

The total production of casinghead gasoline in the United States is shown on page 400.

The cost of plants for producing casinghead gasoline has varied from $12 to $25 per thousand cubic feet of gas handled, and the operation of the plants has been uniformly successful and highly profitable.

While the type of plant ordinarily constructed is for compression methods, it is probable that the absorption method will be more generally adopted. The operation of the absorption method is similar to that of extracting toluol from coal gas and may be applied to a natural gas capable of yielding 1 pint of gasoline per 1,000 cu. ft. By the use of the absorption process 50 million cu. ft. of natural gas would be available per day and 100 million gallons of light gasoline would be made.

Natural Gas Gasoline Produced in the United States, 1911-1920.

Prepared by U. S. Geological Survey, Department of the Interior.

YEAR	Number of Operators	Number of Plants	GASOLINE PRODUCED		Av. Yield Gasoline per M Cu. Ft. (Gallons)
			Quantity (Gallons)	Average Price per Gallon (Cents)	
1911	132	176	7,425,839	7.16	3.00
1912	186	250	12,081,179	9.60	2.60
1913	232	341	24,060,817	10.22	2.43
1914	254	386	42,652,632	7.28	2.43
1915	287	414	65,364,665	7.88	2.57
1916	460	596	103,492,689	13.85	.496
1917	750	886	217,884,104	18.45	.508
1918	503	1,004	282,535,550	17.83	.63
1919	611	1,191	351,535,026	18.26	.73
1920	577	1,151	383,311,817	18.7	.772
1921 (Est.)	600	1,200	410,000,000	....	....

Unblended Natural Gas Gasoline Produced in the United States in 1920. (By States).

STATE	No. of Oper-ators	No. of Plants	GASOLINE PRODUCED			Perc. Prod. of State	% Total
			Quantity (Gallons)	Av. Price (Cts.)	Av. Yield (Gals.)		
Oklahoma................	141	312	177,424,824	18.0	2.10	91.7	46.3
West Virginia............	74	210	58,941,488	22.0	.34	27.0	15.4
California................	29	70	48,207,976	17.3	1.10	73.3	12.6
Texas....................	20	42	32,956,028	18.0	2.10	91.5	8.6
Pennsylvania.............	207	306	21,151,135	21.0	.35	52.0	5.5
Louisiana................	14	31	10,609,629	16.1	.28	57.3	2.8
Ohio.....................	32	59	10,015,638	22.0	.25	23.0	2.6
Wyoming.................	4	4	8,711,037	20.0	1.81	94.0	2.3
Illinois..................	38	92	6,054,916	22.0	2.09	100.0	1.6
Kentucky.................	6	9	4,497,320	24.0	.24	4.0	1.2
Kansas...................	8	10	4,330,748	19.0	.37	36.4	1.1
New York.................	4	4	411,078	18.4	2.53	100.0	.1
Totals, 1920............	577	1,149	383,311,817	18.7	.772	73.0	100.0

Charcoal is now used for the absorption of the gasoline from natural gas at atmospheric pressure. Activated charcoal with the gas passing at the right velocity will absorb all of the gasoline and 22-25% of its weight in gasoline. The gasoline is distilled from the charcoal by means of superheated steam. Bentonite or similar hydrous silicates of alumina have somewhat the same absorption qualities as charcoal.

References for Casinghead Gasoline: Auerswald, Mech. Engr., 43,601, 1921. Oil & Gas Journal, 20, 74, 1921. U. S. Patent 1402340, Jan. 3, 1922.

FORMULA FOR THE CAPACITY OF ABSORPTION TOWERS OF CASINGHEAD GAS PLANTS.

$C = 2d^2h\ s\ p$

C=capacity in cubic feet of gas per day.

d=diameter of tower in inches

h=height of tower in feet—baffled portion

s=fraction of unobstructed cross section

p=pressure of gas in pounds

With S=.50

$C = d^2h\ p$

Amount of Absorption Oil required.

$O = .02\ C\ G$

O=gallons of oil necessary to circulate per day

C=capacity in cu. ft. of gas per day

G=gallons of extractable gasoline per 1000 cu. ft.

$$A = 2\ g$$

A=area of condenser in square feet

g=gallons of gasoline to condense per hour.

Properties of Hydrocarbons Found in Natural Gas and Casinghead Gas.

	Methane	Ethane	Propane	Butane	Pentane	Hexane	Heptane	Octane
Formula	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	C_6H_{14}	C_7H_{16}	C_8H_{18}
Molecular Weight	16.03	30.05	44 07	58.08	72.10	86.12	100.13	114.15
Specific Gravity of Liquid	....	.432= 194° Be′	.515= 142° Be′	.585= 109° Be′	.630= 92.2° Be′	.670= 78.9° Be′	.697= 70.9°	.718= 65.0°
Specific Gravity of Gas	0.555	1.049	1.526	2.008	2.496	2.982	3.467	3.952
Boiling point at atmospheric pressure	—165° C =265° F	—93° C =135° F	—45° C =49° F	+1° C 34=° F	36.3° C =97° F	69° C= 156° F	98.4° C =200° F	125.5° C =258° F
Pressure to liquefy at 60° F lbs	....	475	105	35	6.5	1.8	0.5	0.15
Vapor pressure 70° F in per cent of atmosphere	100+	100+	100+	100+	55	10	2.7	0.7
Gallons per 1000 cu. ft. at B. P. reduced to 60° F	....	4.13	7.17	10.72	14.35	18.22	22.05	25.86
Weight 1000 cu. ft. vapor at B. P. reduced to 60° F, lbs.	42	79.7	116	152.6	189.7	226.6	263.5	300
Shrinkage in volume by 1 gal. liquid removed per 1000 cu. ft	....	....	....	....	7.0%	5.5%	4.5%	3.9%
Max. possible removable gal. per 1000 cu. ft. at 70° F, gal	....	....	....	....	7.8	1.8	0.6	0.18
Heating value in B. T. U. per cu. ft	1065	1861	2685	3447	4250	5012	5780	6542
B. T. U. per lb	25360	23350	23150	22590	22400	22120	21935	21807
Cu. ft air to burn 1 cu. ft. gas	9.57	16.72	23.92	31.10	38.28	46.46	53.6	60.8
Carbon per cent	75.0	80.0	81.8	82.8	83.3	83.7	84.0	84.2
Explosive mixture per cent in air, maximum	14.5	5.0	3.5	3.0	2.5	2.2	1.9	1.6
Minimum	5.6	3.0	2.1	1.6	1.3	....	....	....

About Natural Gas and Its Usefulness.

An average sample of natural gas has 950 B.T.U. per cubic foot.
1 lb. mill coal will evaporate 9 lbs. water.
1 gal. oil will evaporate 100 lbs. water.
1 cu. ft. gas will evaporate 0.85 water.
1 ton coal used under boilers=18,500 cu. ft. of gas.
1 bbl. oil (42 gal.) under boilers=5,000 cu. ft. of gas.
40 to 50 cu. ft. of gas = 1 boiler H.P.

Gas Engines:
Highest grade gas engines develop a brake H.P. on 8,500 B.T.U.
Average engine develops a H.P. on 10,500 B.T.U.
Oil well engine develops a H.P. on 20,000 B T.U.
In a steam turbine plant of over 500 K.W. capacity 30 cut. ft. gas per K.W. is a fair average.
It requires 40,000 cu. ft. of gas to pump one million gallons of water against 200-foot head.

Brick Plants—Gas Used per Thousand Brick Made:
1,800 cubic feet for power.
1,800 cubic feet for drying.
15,000 cubic feet for kilns.

Ice Plants:
2,000 feet gas per ton of refrigeration.

Zinc Plants:
15,000 cubic feet for roasting per ton of metal produced.
65,000 cubic feet for smelting per ton of metal produced.
20,000 cubic feet for power and miscellaneous uses per ton of metal produced.

Cement Plants:
60 to 100 cubic feet per barrel for power.
80 to 100 cubic feet per barrel for roasters.
1,800 to 2,600 cubic feet per barrel for kilns.

Salt Plants:
Direct-fire pans, 9,000 cubic feet per ton.
Steam pans, 10,000 cubic feet per ton.
Single-effect vacuum pan, 15,000 cubic feet per ton.
Double-effect vacuum pan, 10,000 cubic feet per ton.
Triple-effect vacuum pan, 6,000 cubic feet per ton.

Flour Mills:
200 to 400 cubic feet per barrel.

Gas Compressors:
Horsepower required to compress 1,000 cu. ft. of gas per minute:

To 15 lbs.	50 H.P.	
To 30 lbs.	85 H.P.	
To 45 lbs.	111 H.P.	
To 60 lbs.	134 H.P.	
To 80 lbs.	117 H.P.	(2 stages)
To 100 lbs.	151 H.P.	(2 stages)
To 200 lbs.	212 H.P.	(2 stages)

Horsepower required to compress 1,000 cu. ft. of gas per hr.

To 15 lbs.	1 H.P.
To 30 lbs.	1.75 H.P.
To 45 lbs.	8.25 H P.
To 60 lbs.	2.75 H.P.

The specific heat of average natural gas is 0.60 B.T.U. per pound, or 0.028 B.T.U. per cubic foot at 32°F.

Gasoline, Natural Gas and Coal Dust Explosions.

An explosion or a detonation is a chemical reaction which goes on with increasing velocity and is accompanied by a rise of temperature. The lowest temperature at which combustion or explosion of a mixture may take place is called the ignition temperature. This varies greatly with different kinds of gas, about 650°C. The vapors of some substances such as carbon bisulphide and hydrogen sulphide are capable of ignition at much lower temperatures, even as low as 100°C. Some gases even inflame spontaneously at room temperature. These are phosphorus tri-hydride, boron and silicon hydride and cacodyl. Ordinarily, explosive mixtures are ignited by the presence of a flame or spark at any point in the mixture ordinarily greater than .2 of a millimeter in length. In order that the gaseous mixture explodes it is necessary that the heat generated by the local combustion be greater than the heat absorbed by the surrounding gases. This means of course that if the mixture is heated to a high temperature it will be more readily explosive though the pressure will exert very little influence. An excess of either the combustible agent or the oxidizing agent in the mixture will have the same cooling effect that is exerted by any inert gas. The result is that the limits of explosibility of various mixtures of combustible gases and air are dependent upon the heat generated by the combination and by the heat absorbed in raising the temperature of the gases.

In the same manner that mixtures of gas or vapor and air will explode, coal dust, oil mists and dusts of other combustible materials will explode. As a general fact, these explosions will not take place at ordinary room temperature unless there is over one-half pound of dust of suspended matter per 500 cubic feet of air.

For ordinary gases the following limits hold as to the range of combustion with combustible mixtures when air is the oxidising agent:

Limits of Explosibility of Mixtures of Combustible Gases and Air.

Gasoline vapor	1.5- 6.0% by vol. of mixture
Methane	5.5-14.5% by vol. of mixture
Ethane	2 5- 5.0% by vol. of mixture
Natural gas	5.0-12.0% by vol. of mixture
Acetylene	3.0-73.0% by vol. of mixture
Artificial illuminating gas	7.0-21.0% by vol. of mixture
Hydrogen	5.0-72.0% by vol. of mixture
Carbon monoxide	15.0-73.0% by vol. of mixture
Blast furnace gas	36.0-65.0% by vol. of mixture
Water gas	9.0-55.0% by vol. of mixture
Coal gas	6.0-29.0% by vol. of mixture
Ethylene	4.0-22.0% by vol. of mixture
Coal dust	+ 1 lb. per 500 cu. ft. of air

The striking back of a flame in a burner is caused by the presence of an explosive mixture in the burner. While the usual rate of striking back of the flame or the propagation of an explosion is over 6,000 feet per second and about seven times the rate of sound in the same medium, this rate exists only when there is no retardation of the explosive wave caused by the cooling effect of the orifice or tube through which it passes.

Chemical Products from Natural Gas.

Natural gas offers peculiar opportunities for research on the development of various oxidized and chlorinated products of methane and ethane. It is well known that the ordinary natural gas burner if not properly adjusted will emit great quantities of formaldehyde gas probably according to the following reaction: $CH_4 + 0_2 = CH_20 + H_20$. The conditions governing the quantitative production of formaldehyde by partial oxidation of natural gas are those of proper mixing, exact temperature and catalysis. Many different methods have been attempted in the production of formaldehyde but most of them will not produce more than 25% of the theoretical yield. Other remote possibilities in the controlled oxidation of natural gas include the production of alcohol and acetone.

The greatest success in the manufacture of chemical compounds has resulted from the chlorination of natural gas. The commercial preparation of mono-chloro-methane or methyl chloride CH_3Cl is now being carried out successfully by a firm of manufacturing chemists. This compound is used largely as a refrigerant and in the dye stuff industry. Other chlorination products such as chloroform, $CHCl_3$ and carbon tetrachloride CCl_4 are not yet made cheaply enough from natural gas to compete with other established ways of making them. They are however successfully made. These chlorination processes are ordinarily carried out by the slow action of chlorine on the natural gas at carefully regulated temperatures and with a proper catalyzer. Catalyzers that have been successfully used are finely divided tin, nickel, copper, lead, dense charcoal, palladium, platinum and the like. Unless low temperatures are used, the chlorine reacts explosively forming only hydrochloric acid and carbon.

Hydrogen may also be made by the heating of natural gas at very high temperature. However, this method of manufacture has always been a method of convenience rather than a commercial method where the making of hydrogen is a business. Amyl acetate may also be indirectly made from natural gas by means of a chlorination process but it is not yet done in competition commercially with other methods of making this chemical.

Methods of Manufacture of Carbon Black.

The processes of manufacturing carbon black now in use or contemplation are as follows:

(1) Channel Process. This process consists in the use of steel channels carried on trucks above gas flames burning from lava tips. The lava tips are fitted so that they burn without sufficient air giving a yellow smoky flame. This flame impinges upon the bottom of the channel bars which are moving slowly so as to present a cool surface to the flame. The channel bars usually are about seven inches wide and weigh about twelve pounds per foot. Scrapers are adjusted to the bottom of the channels to take off the carbon as collected. The carbon falls as the channel passes over the scraper and is conveyed to the packing department. Each lava tip burns from four to fourteen cubic feet of gas per hour and one tip produces about 35 grams of carbon per day. Thirteen tips produce one pound of carbon per day. A sixty barrel plant or one making 3,000 pounds of carbon black per day requires 38,400 lava tips.

(2) Disc Process. This process was invented by Blood in 1883 and in principle is the same as the channel process except that the cold surface on which the gas flame impinges is a cast iron disc about 40 inches in diameter. The disc rotates at the rate of about four revolutions per hour. The carbon is scraped off in much the same manner as the channel process.

(3) Plate Process. This is known also as the Cabot Process. This consists in perforated circular plates about 24 feet in diameter and is essentially the same in principle as the disc and channel processes. The spent gas passes through the perforated or ventilator holes whereas in the disc process, they pass out over the edge of the disc and in the channel process, between the channel bars.

(4) Roller or Cylinder Process. In this process, the face of the cylinder is exposed to the gas flame. The cylinders are from three to eight feet long and about eight to nine inches in diameter, each weighing about 100 pounds. The cylinder rotates on a horizontal axis.

(5) Thermal Decomposition Methods. In this, the primary object has been to produce hydrogen. There is no oxidation of the gas and the carbon is produced purely by cracking. The carbon in this method is comparatively poor, being rather hard and containing some bituminous matter. The temperature of cracking usually is about 1500°F.

(6) Explosion Method. This method is not operated at present on a commercial scale but has the advantage of being highly efficient and giving a good grade of carbon. A charge of the gas mixed with either air or oxygen is compressed into a heavy metal cylinder and ignited by a spark. The explosion wave goes through the whole cylinder. The cylinder is opened and the carbon brushed out and a new charge placed in. This is repeated indefinitely.

YIELD OF CARBON BLACK IN DIFFERENT FIELDS.

Plant No.	State	Process	Lbs. of Carbon Black per 1000 Cu. Ft. Gas
1	Louisiana.......	Channel, 2-table....	0.78
2	Louisiana	Channel, 1-table....	0.95
3	Louisiana.......	Channel, 1-table....	0.80
4	Louisiana.......	Large plate........	0.80
5	West Virginia...	Large plate........	1.10
6	West Virginia...	Rotary disc........	0.95
7	West Virginia...	Roller.............	0.80
8	West Virginia...	Rotary disc........	1.00
9	West Virginia...	Channel, 2-table....	1.12
10	West Virginia...	Channel, 1-table....	1.30
11	West Virginia...	Rotary disc........	1.40
12	Oklahoma......	Channel...........	1.20
13	Wyoming.......	Channel...........	1.40

COMPARISON OF DIFFERENT METHODS.

Plant No.	Location	Method	*Sq. ft. per Burner Tip	Sq. ft. per Lb. of Carbon Black	Sq. ft. per 100 Cu. ft. of Gas Burned
1	Louisiana.....	Channel, 2-table..	0.21	4.87	3.73
2	Louisiana.....	Channel, 1-table..	0.26	4.23	4.04
3	West Virginia.	Roller...........	....	9.10	7.33
4	West Virginia.	Large plate.......	....	6.53	7.16
5	West Virginia.	Channel, 2 table..	....	5.05	6.75
6	West Virginia.	Small disc........	....	3.10	2.90
7	Oklahoma....	Channel. 1-table..	....	3.70	3.50

*Square foot of depositing surface.

The total quantity of carbon black produced from natural gas in the United States in 1920 was 51,320,892 pounds, according to E. G. Sievers of the U. S. Geological Survey, a decrease of 1.4 per cent from 1919, notwithstanding an increase in the number of plants. In 1919, the plants were still operating at or near full capacity on account of the war, but since normal conditions have been restored, the production has decreased. The output in 1920 was made by 39 plants operated by 19 producers. The total value was $4,032,286 as computed from the prices received by the producers. The prices ranged from 4 cents to 27 cents a pound. The average daily production in 1918 was 120,830 pounds, in 1919 it was 144,600 pounds, and in 1920 it was 140,608 pounds.

About 40,600,000 cubic feet of natural gas was consumed in the manufacture of carbon black in 1920. In 1919, the quantity consumed was 49,896,200,000 cubic feet and in 1918 it was estimated at 45,000,000,000 cubic feet. In 1920 the production of carbon black per thousand cubic feet of gas consumed ranged from 0.45 to 2 pounds, but the average production during the year for all states was about 1.26 pounds.

Range in Production of Carbon Black at Plants in the United States in 1919 and 1920.

Production	Plants 1919	Plants 1920
Less than 1 pound	6	6
From 1 to 1.2 pounds	17	19
From 1.3 to 1.6 pounds	11	6
From 1.7 to 2.0 pounds	2	8
Totals	36	39

The daily capacity of the plants in volume of gas treated ranges from 172,000 to 20,350,000 cubic feet and in quantity of carbon black produced from 90 to 23,250 pounds.

Production in 1919.

State	Plants	Pounds
West Virginia	23	29,925,614
Louisiana	7	14,024,606
Wyoming and Montana	2	4,868,947
Oklahoma and Kentucky	2	2,922,274
Pennsylvania	2	315,500
Totals	36	52,056,491

Gas = 49.9×10^9 cu. ft.

Production in 1920.

State	Plants	Pounds
West Virginia	19	26,659,469
Louisiana	15	18,565,498
Wyoming	1	
Montana	1	5,850,313
Kentucky	1	
Pennsylvania	2	246,612
Totals	39	51,321,892

Gas = 40.6×10^9 cu. ft.

Uses of Carbon Black.

The uses of carbon black are, in order of importance: (1) the manufacture of printing inks, (2) incorporation with rubber, (3) varnishes and black points, (4) the blackening of ironware, (5) phonographic records, pencils, carbon paper, typewriter ribbons, Chinese inks, artificial stones, insulators and crucibles for steel.

The quantities employed in 1918 were: Printing ink, 5,000 to 6,000 tons, rubber, 10,000 tons, ironware, 2,000 to 3,000 tons and other uses, 500 tons. In regard to printing inks, lamp black has been used since the invention of the printing press and was used exclusively up to 1864. For certain qualities, where a very fine grain of black was required, much trouble was taken to purify it, but after the discovery of carbon black in 1864 and the lowering of the price of the latter in 1880, the use of the former diminished and at the present day very small quantities of lamp black are being used.

Before 1914, the use of carbon black in the rubber industry was scarcely known, and no differentiation was made between it and lamp black. The rise in price of zinc oxide then led to the employment of carbon black as a filler in rubber and its valuable properties were for the first time realized. It increases resistance to abrasion, gives softness and in the opinion of many chemists has a favorable effect upon the aging of the rubber. From the economic point of view, carbon black is cheaper than zinc oxide. Its density is 1.8, that of zinc oxide is 5.8, so taking equal volumes and the price of carbon black at 10c per pound, the black costs 33 per cent less than the zinc oxide.

By reason of its fine state of division, carbon black constitutes an ideal filling material for rubber, because it can be so intimately mixed with the plastic rubber. It also protects the rubber against the destructive effects of light and it possibly retards oxidation. Carbon black for the rubber industry is usually required to comply with the following specifications:

(1) Moisture, less than 4 per cent.
(2) Acetone soluble matter, less than 0 5%.
(3) Ash, less than 0.25%.
(4) No gritty particles to be present.

SPECIFIC HEAT OF GASES ENCOUNTERED IN NATURAL GAS AND "CRACKED" GAS.

(H. L. Payne, J. A. & Appl. Chem.)

	B.T.U. per lb. per 1°F	B.T.U. per cu. ft. per 1°F
Air	0.234	0.018
Carbon dioxide	0.234	0.027
Carbonic oxide	0.245	0.019
Hydrogen	3.41	0.019
"Illuminants"	0.404	0.040
Methane	0.593	0.027
Nitrogen	0.244	0.019
Oxygen	0.217	0.019
Aqueous vapor	0.480	....

CALORIFIC VALUE OF NATURAL AND OIL GASES IN BRITISH THERMAL UNITS PER CUBIC FOOT.

Name	Symbol	60°F Initial	From and to 32°F	Ignition Point °F
Hydrogen	H_2	326.2	345.4	1085
Carbonic oxide	CO	323.5	341.2	1200
Methane	CH_4	1009.2	1065.0	1230
Illuminants		....	2000.0	...
Ethane	C_2H_6	1764.4	1861.0	1140
Propane	C_3H_8	2521	2657.0	1015
Butane	C_4H_{10}	3274	3441.0	...
Pentane	C_5H_{12}	....	4255.0	...
Hexane	C_6H_{14}	....	5017.0	1400
Ethylene	C_2H_4	1588	1674.0	1010
Propylene	C_3H_6	2347.2	2509.0	940
Benzene	C_6H_6	3807.4	4012 0	.....
Acetylene	C_2H_2	1476.7	1477.0	788

NATURAL GAS PRODUCED IN THE UNITED STATES IN 1916.

State	Quantity M. cu. ft.	Price, cents per M. cu. ft.	Value
West Virginia	299,318,907	15.90	47,603,396
Pennsylvania	129,925,150	18.74	24,344,324
Oklahoma	123,517,358	9.70	11,983,774
Ohio	69,888,070	22.32	15,601,144
Louisiana	32,080,975	8.29	2,660,445
Kansas	31,710,438	15.31	4,855,389
California	31,643,266	17.19	5,440,277
Texas	15,809,579	18.89	3,143,871
New York	8,594,187	29.37	2,524,115
Illinois	3,533,701	11.22	396,357
Arkansas	2,387,935	10.13	241,896
Kentucky	2,106,542	35.73	752,635
Indiana	1,715,499	29.34	503,373
Wyoming and Colorado	575,044	14.97	86,077
Montana	213,315	18.21	38,855
Dakotas and Alabama	77,478	40.75	31,573
Missouri	69,236	25.41	17,594
Tennessee	2,000	57.50	1,150
Michigan	1,298	73.04	948
Iowa	275	100.00	275
Totals	753,170,253	15.96	120,227,468

Testing of Capacity of Casinghead Gas Wells.

To use the orifice well tester the specific gravity of the gas must be taken. This is fully described on page 419.

To test a well, close all openings but one or if the well is shut in at the casinghead, blow off the well before inserting the orifice well tester. Allow the well to blow into the atmosphere for half an hour or until there is no appreciable decrease in the volume of the gas flowing from it. Screw in the orifice well tester, which carries a two-inch thread, and allow the gas to flow into the atmosphere through the proper size of orifice.

Connect a syphon gauge to the nipple on the side of the orifice well tester, using a short piece of common three-eighths-inch rubber hose. The syphon gauge should be filled with water up to the zero mark on the scale. If the well appears to be large use the large-sized orifice. To correctly determine the proper size of orifice it is necessary to read the gauge and note the height of the water in the glass. Read both sides of the scale and add them together. In other words, measure the difference between the two water levels which is the true pressure in inches of water. By referring to tables that accompany each instrument, or as found on pages 420-424, the flow of a well for a twenty-four hour period will be found under the proper gravity and opposite the pressure.

The specific gravity bottle can be used to take the water pressure of the gas flowing through the orifice in place of the syphon gauge. In this case measure the difference between the two levels of the water.

Use as large an orifice as possible so as not to permit the gas to create a back pressure in the well. A back pressure in the well will decrease the flow of the gas.

Pitot Tube for Testing Open Flow of Gas Wells.

The most accurate way of testing the flow of a gas well is by means of the Pitot tube, which is an instrument for determining the velocity of flowing gas by means of its momentum. The instrument,

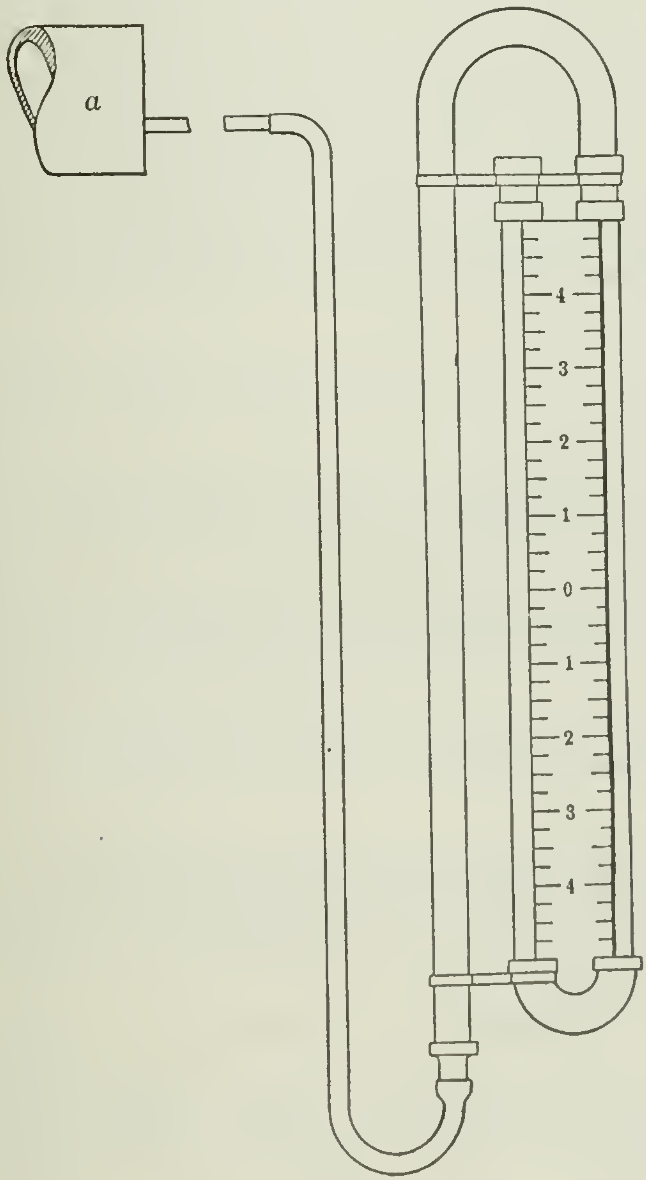


Fig. 85—Pitot Tube.

as shown in figure usually consists of a small tube, with one end bent at right angles, which is inserted in the flowing gas, just inside the pipe or tubing a, at a point between one-third and one-fourth of the pipe's diameter from the outer edge of the pipe. The plane of the opening in the tube is held at right angles to the flowing gas. At a convenient distance, varying from 1 to 2 feet, an inverted siphon or U-shaped gage, usually half filled with mercury or water, is attached to the other end. If the pressure of the flow is more than 5 pounds per square inch, a pressure gage is required.

In small-sized wells with a flow of not more than 4,000,000 cubic feet per 24 hours, a 12-inch U-gage with water can be used for flows ranging from 4,000,000 to 15,000,000 feet, mercury in a 12-inch U-gage; for 15,000,000 to 35,000,000 feet, a 50-pound spring gage, and for more than 35,000,000 feet, a 100-pound spring gage should be used. The foregoing figures are based on a 6-inch hole.

For convenience, a scale graduated from the center in inches and tenths of an inch is attached between the two limbs of the U-gage. The distance above and below this center line at which the liquid in the gage stands should be added, the object being to determine the exact distance between the high and low side of the fluid in inches and tenths of an inch.

The top joint of the tubing or casing should be free from fittings for a distance of 10 feet below the mouth of the well where the test is made. The test should not be made in a collar or gate or at the mouth of any fitting. The well should be blown off at least three hours prior to making the test.

After the velocity pressure of the gas flowing from the well tubing has been determined in inches of water, inches of mercury, or pounds per square inch, as outlined above, the corresponding flow may be obtained from the following table*. The quantities of gas stated in the table are based on a pressure of 4 ounces above atmospheric, or 14.65 pounds per square inch absolute pressure, a flowing temperature of 60°F., a storage temperature of 60°F., and a specific gravity of 0.60 (air = 1). If the specific gravity is other than 0.60 the flow should be multiplied by $\sqrt{\dfrac{0.60}{\text{specific gravity of gas}}}$

*Westcott, H. P.: Handbook of Natural Gas, 1915, pp. 176, 177.

For pipe diameters other than those given in the following table, the following multipliers should be applied to the figures for 1-inch tubing given in the table.

Multipliers for Pipe Diameters Ranging from 1½ to 12 Inches.

Diameter of Pipe, Inches	Multiplier	Diameter of Pipe, Inches	Multiplier	Diameter of Pipe, Inches	Multiplier
1½	2.25	5	25	8	64
2½	6.25	5⅝	31.64	8¼	68
4¼	18	6	36	9	81
4⅝	21.39	6¼	39	10	100
		6⅝	43.9	12	144

Table for Determining Flow of Gas Wells by Means of Pitot Tube.

(Figures show the rate of flow of gas of 0.6 specific gravity from gas well tubing of different sizes in cubic feet per 24 hours for different pressures.)

Pressure			Volume of Gas, in Cubic Feet per 24 Hours, Discharged Through—				Pressure	Volume of Gas, in Cubic Feet per 24 Hours, Discharged Through—			
Inches of Water	Inches of Mercury	Pounds per Sq. In.	1-Inch Tubing	2-Inch Tubing	3-Inch Tubing	4-Inch Tubing	Pounds per Sq. In.	1-Inch Tubing	2-Inch Tubing	3-Inch Tubing	4-Inch Tubing
0.10	....	....	11,880	47,520	106,920	190,080	2.75	321,000	1,284,000	2,889,000	5,136,000
.20	....	....	17,136	68,544	154,224	274,176	3	340,200	1,360,800	3,061,800	5,443,200
.30	....	....	20,568	82,272	185,112	329,088	3.25	354,120	1,416,480	3,187,080	5,665,920
.40	....	....	23,520	94,080	211,680	376,320	3.50	367,680	1,470,720	3,309,120	5,882,880
.50	....	....	26,544	106,176	238,896	424,704	3.75	380,400	1,521,600	3,423,600	6,086,400
.60	....	....	29,112	116,448	262,008	465,792	4.00	392,880	1,571,520	3,535,920	6,286,080
.7	....	....	31,440	125,760	282,960	503,040	4.25	405,000	1,620,000	3,645,000	6,480,000
.8	....	....	33,624	134,496	302,616	537,984	4.50	416,640	1,666,560	3,749,760	6,666,240
.9	....	....	35,640	142,560	320,760	570,240	4.75	428,280	1,713,120	3,854,520	6,852,480
1.0	....	....	37,320	149,280	335,880	597,120	5.00	439,920	1,759,680	3,959,280	7,038,720
1.25	....	....	41,712	166,848	375,408	667,392	6	476,040	1,904,160	4,284,360	7,616,640
1.5	....	....	45,960	183,840	413,640	735,360	7	517,320	2,069,280	4,655,880	8,277,120
1.75	0.12	....	49,680	198,720	447,120	794,880	8	542,400	2,169,600	4,881,600	8,678,400
2.0	.147	....	53,136	212,544	478,224	850,176	9	569,640	2,278,650	5,126,760	9,114,240
2.5	.184	....	59,400	237,600	534,600	950,400	10	595,560	2,382,240	5,350,040	9,528,960
3.0	.22	.108	65,088	260,352	585,792	1,041,408	11	621,960	2,487,840	5,597,640	9,951,360
3.5	.257	.126	70,272	281,088	632,448	1,124,352	12	642,600	2,570,400	5,783,400	10,281,600
4.0	.294	.144	75,120	300,480	676,080	1,201,920	13	664,680	2,658,720	5,982,120	10,634,880
4.5	.331	.162	79,704	318,810	717,336	1,275,261	14	683,880	2,735,520	6,154,920	10,942,080
5.0	.368	.18	84,000	336,000	756,000	1,344,000	15	703,080	2,812,320	6,327,720	11,249,280
6	.441	.216	92,016	368,060	828,144	1,472,256	16	721,080	2,884,320	6,489,720	11,537,280
7	.515	.252	99,360	397,440	894,240	1,589,760	17	738,120	2,952,480	6,643,080	11,809,920
8	.588	.288	106,272	425,088	956,448	1,700,352	18	753,960	3,015,840	6,785,640	12,063,360
9	.662	.324	112,656	450,624	1,013,904	1,802,496	20	785,520	3,142,080	7,069,680	12,568,320
10	.736	.36	118,800	475,200	1,069,200	1,900,800	22	803,280	3,213,120	7,229,520	12,852,480
11	.8	.396	125,160	500,640	1,126,440	2,002,560	25	854,880	3,419,520	7,693,920	13,678,080
12	.88	.432	130,128	520,512	1,171,152	2,082,048	30	910,680	3,642,720	8,196,120	14,570,880
....	1.02	.5	138,960	555,840	1,250,640	2,223,360	35	960,960	3,843,840	8,648,640	15,375,360
....	1.52	.75	170,280	681,120	1,532,520	2,724,480	40	1,006,680	4,026,720	9,060,120	16,106,880
....	2.03	1.00	196,680	786,720	1,770,120	3,146,880	45	1,046,520	4,186,080	9,418,680	16,744,320
....	2.54	1.25	219,960	879,840	1,979,640	3,519,360	50	1,081,920	4,327,680	9,737,280	17,310,720
....	3.05	1.5	240,720	962,880	2,166,480	3,851,520	60	1,137,120	4,548,480	10,234,080	18,193,920
....	3.56	1.75	259,920	1,039,680	2,339,280	4,158,720	75	1,223,400	5,217,600	11,010,600	19,574,400
....	4.07	2.00	272,640	1,090,560	2,453,760	4,362,240	90	1,304,400	5,217,600	11,739,600	20,870,400
....	4.57	2.25	294,600	1,178,400	2,651,400	4,713,600	100	1,336,920	5,347,680	12,032,280	21,390,720
....	5.08	2.50	310,800	1,243,200	2,797,200	4,972,800					

Flow of Gas in Pipes—Low Pressure.

The following formulae are intended for low pressure distribution of gas, with comparatively small differences between the initial and final pressures:

Pole's Formula $Q = 1350 \sqrt{\frac{d^5h}{sl}}$

Molesworth's Formula $Q = 1000 \sqrt{\frac{d^5h}{sl}}$

Gill's Formula $Q = 1291 \sqrt{\frac{d^5h}{s\ (1 + d)}}$

Where Q = quantity of gas discharged in cubic feet per hour.
d = inside diameter of pipe in inches.
h = pressure in inches of water.
s = specific gravity of gas, air being 1.
l = length of main in yards.

Oliphant's Formula. A formula determined by F. H. Oliphant for the discharge of gas when the specific gravity is 0.60 is

$$Q = 42a \sqrt{\frac{P_1^2 - P_2^2}{L}}$$

Where Q = discharge in cubic feet per hour at atmospheric pressure.
P_1 = initial pressure in pounds per square inch (absolute)
P_2 = final pressure in pounds per square inch (absolute).
L = length of main in miles.
a = coefficient (see table below).

For gas of any other specific gravity, s, multiply the discharge by $\sqrt{\frac{0.60}{s}}$, for temperature of flowing gas when observed above 60°F deduct 1 per cent for each 5° and add a like amount for temperatures less than 60°F.

According to Oliphant, the discharge is not strictly proportional to $\sqrt{\frac{1}{d^5}}$. Using a coefficient of unity for 1-inch pipe he gives

$$a = \sqrt{\frac{1}{d^5}} + \frac{d^3}{30}$$

Values of Coefficient "a"

Inside diameter inches	a	Inside diameter inches	a	Inside diameter inches	a
¼	.0317	3	16.5	12	556
½	.1810	4	34.1	16	1160
¾	.5012	5	60	18	1570
1	1.00	5⅝	81	20	2055
1½	2.93	6	95	24	3285
2	5.92	8	198	30	5830
2½	10.37	10	350	36	9330

For 15 inch outside diameter pipe, 14½ inches inside dia. a = 863
For 16 inch outside diameter pipe, 15¼ inches inside dia. a = 1025
For 18 inch outside diameter pipe, 17¼ inches inside dia. a = 1410
For 20 inch outside diameter pipe, 19¼ inches inside dia. a = 1860

Capacity of Pipe Lines.

(Metric Metal Works.)

Tables to Find the Cubic Feet, Per Day of 24 Hours, of Gas of .6 Specific Gravity at Certain Pressure in Pipe Lines of Various Diameter and Lengths.

Select in table A the number opposite the gauge pressures, in pounds, then from table B select the number opposite the length of line in miles. Multiply these two numbers together and result is the cubic feet that a 1-inch line will discharge for the pressures and length named in twenty-four hours. If the diameter of the pipe is other than one inch, select the number in table C which corresponds with the diameter and multiply this number by the discharge for one inch already secured. The result is the quantity in cubic feet in twenty-four hours discharged by a line whose diameter was selected.

If there are other pressures and lengths not given in the table they can be secured by interpolation. Example—Suppose it is required to find the discharge per day of twenty-four hours of a pipe line having an intake of 200-pound gauge pressure and 25 pounds at the discharge end, the length being 20 miles, and the diameter 8 inches. In table A we find opposite 200 and 25 the number 211.25, and in table B opposite 20 miles, 22.5, multiplying these two numbers the result being 47,637 cubic feet that under the above condition of pressure and length a 1-inch pipe would convey, but the required diameter is 8 inches. Under this number in table C it will be found that 198 corresponds; therefore 47,637 × 198 = 9,433,126, which is the cubic feet discharged in 24 hours.

If the pressure were twenty pounds instead of twenty-five at the discharge end it would be found very closely by adding the figures opposite 15 and 25 and dividing by 2, the result would be 9,469,151.

TABLE A.

Intake, Lbs.	Discharge, Lbs.	Resultant	Intake, Lbs.	Discharge, Lbs.	Resultant	Intake, Lbs.	Discharge, Lbs.	Resultant
1	¼	4.7	40	5	51.2	110	75	86.8
1	½	3.9	40	10	49.0	110	85	75.0
2	½	6.9	40	15	46.1	110	100	49.0
2	1	4.7	40	20	42.4	125	5	138.6
2	1½	4.0	40	25	37.8	125	15	136.8
3	1	8.1	40	30	31.6	125	25	134.2
3	2	5.8	40	35	22.9	125	35	130.8
4	1	10.1	50	5	61.8	125	50	124.0
4	2	8.4	50	10	60.0	125	75	107.2
4	3	6.0	50	15	57.7	125	100	79.8
5	1	11.8	50	20	54.8	125	110	63.1
5	2	10.4	50	25	51.2	135	5	148.7
5	3	8.6	50	30	46.9	135	15	147.0
5	4	6.2	50	35	41.5	135	25	144.6
6	1	13.4	50	40	34.6	135	35	141.4
6	3	10.6	50	45	25.0	135	50	135.2
6	5	6.3	60	5	72.3	135	75	120.0
7	1	14.9	60	10	70.7	135	100	96.3
7	3	12.5	60	15	68.8	150	5	168.3
7	5	9.0	60	20	66.3	150	15	163.3
7	6	6.5	60	25	63.4	150	25	160.1
8	1	16.3	60	30	60.0	150	40	155.6
8	3	14.1	60	40	51.0	150	50	151.7
8	5	11.2	60	50	37.4	150	75	138.3
8	7	6.6	60	55	26.9	150	100	118.3
9	1	17.6	70	5	82.6	150	120	94.9
9	3	15.6	70	10	81.2	175	5	188.9
9	5	13.1	70	20	77.5	175	15	187.6
9	8	6.8	70	30	72.1	175	25	185.7
10	1	19.2	70	40	64.8	175	35	183.3
10	2	18.3	70	50	54.7	175	50	178.5
10	4	16.3	70	60	40.0	175	75	167.3
10	6	13.6	80	5	92.8	175	100	151.2
10	8	9.8	80	10	91.6	175	150	94.2
10	9	7.0	80	20	88.3	200	5	214.1
12	1	21.8	80	30	83.7	200	15	212.9
12	3	20.1	80	40	77.5	200	25	211.3
12	6	17.0	80	50	69.2	200	35	209.1
12	8	14.1	80	60	58.3	200	50	204.9
12	10	10.2	80	70	42.4	200	75	195.3
15	1	25.4	90	5	103.1	200	100	181.7
15	3	24.0	90	10	102.0	200	125	163.2
15	6	21.4	90	20	99.0	200	150	137.9
15	9	18.0	90	30	94.9	200	175	100.6
15	12	13.1	90	40	89.4	200	190	64.8
20	1	31.1	90	50	82.5	220	5	234.2
20	4	29.4	90	60	73.5	220	15	233.1
20	8	26.4	90	70	61.6	220	25	231.6
20	10	24.5	90	80	44.7	220	35	229.6
20	15	18.0	100	5	113.3	220	50	225.8
20	18	11.7	100	10	112.3	220	75	217.1
25	1	36.7	100	15	111.0	220	100	204.9
25	3	35.7	100	20	109.5	220	125	188.8
25	6	34.0	100	25	107.8	220	150	167.3
25	10	31.2	100	35	103.6	220	175	138.3
25	15	26.5	100	50	94.9	220	200	94.9
25	18	22.6	100	75	71.6	230	5	244.1
30	1	42.1	100	85	56.8	230	15	243.2
30	3	41.2	100	95	33.5	230	25	241.7
30	6	39.8	110	5	123.4	230	35	239.8
30	10	37.4	110	15	121.4	230	50	236.2
30	15	33.5	110	25	118.4	230	75	227.9
30	20	28.3	110	35	114.6	230	100	216.3
30	25	20.0	110	50	106.8	230	150	181.5

TABLE A—Continued.

Intake, Lbs.	Dis-charge, Lbs.	Re-sultant	Intake, Lbs.	Dis-charge, Lbs.	Re-sultant	Intake, Lbs.	Dis-charge, Lbs.	Re-sultant
230	200	117.5	325	250	213.0	400	225	338.6
230	215	84.4	325	275	177.5	400	250	319.4
250	5	264.2	325	285	160.0	400	275	296.9
250	15	263.3	325	300	128.0	400	300	270.2
250	25	262.0	350	5	364.5	400	325	238.0
250	35	269.2	350	15	363.8	400	350	197.5
250	50	256.9	350	25	362.8	400	375	141.9
250	75	249.3	350	35	361.6	425	5	439.6
250	100	238.8	350	50	359.2	425	15	439.0
250	125	225.0	350	75	353.7	425	25	438.2
250	150	207.4	350	100	346.4	425	35	437.2
250	175	184.7	350	125	337.1	425	50	435.2
250	200	154.9	350	150	325.6	425	75	430.7
250	230	101.0	350	175	311.7	425	100	424.7
275	5	289.3	350	200	295.0	425	125	417.1
275	15	288.4	350	225	275.0	425	150	407.9
275	25	287.2	350	250	251.0	425	175	396.9
275	35	285.7	350	275	221.6	425	200	383.9
275	50	282.6	350	300	184.4	425	225	368.8
275	75	275.7	350	325	132.8	425	250	351.3
275	100	266.2	375	5	389.5	425	275	330.9
275	150	238.5	375	15	388.8	425	300	307.2
275	200	194.6	375	25	387.9	425	325	279.3
275	250	117.8	375	35	286.8	425	350	245.7
300	5	314.4	375	50	384.6	425	375	203.7
300	15	313.6	375	75	379.5	425	400	146.2
300	25	312.5	375	100	372.7	450	5	464.6
300	35	311.0	375	125	364.0	450	15	464.0
300	50	308.2	375	150	353.4	450	25	463.3
300	75	301.9	375	175	340.6	450	35	462.3
300	100	293.8	375	200	325.4	450	50	460.4
300	125	282.2	375	225	307.4	450	75	456.2
300	150	268.3	375	250	286.1	450	100	450.5
300	175	251.3	375	275	260.8	450	135	443.4
300	200	230.2	375	300	230.0	450	150	434.7
300	250	170.3	375	325	191.1	450	175	424.4
300	275	123.0	375	350	137.4	450	200	412.3
325	5	339.4	400	5	414.5	450	225	398.3
325	15	338.7	400	15	413.9	450	250	382.1
325	25	337.6	400	25	413.1	450	275	363.5
325	35	336.3	400	35	412.0	450	300	342.1
325	50	333.7	400	50	409.9	450	325	317.2
325	75	327.9	400	75	405.1	450	350	288.1
325	100	320.0	400	100	398.8	450	375	253.2
325	125	309.8	400	125	390.2	450	400	209.8
325	150	297.3	400	150	380.8	450	425	150.4
325	175	281.9	400	175	369.0	475	50	485.7
325	200	263.4	400	200	355.0	500	50	510.0

TABLE B.

Miles	Multipliers	Miles	Multipliers	Miles	Multipliers
⅛	2880.	19	231.2	61	129.1
¼	2016.	20	225.5	62	128.1
⅜	1652.4	21	220.1	63	126.9
½	1419.7	22	214.9	64	126.0
⅝	1275.9	23	210.0	65	125.1
¾	1158.6	24	205.7	66	124.1
⅞	1083.7	25	201.6	67	123.1
1	1008.0	26	197.6	68	122.2
1½	826.2	27	193.8	69	121.3
1¾	763.6	28	190.5	70	120.4
2	714.9	29	187.0	72	118.7
2½	638.0	30	183.9	74	117.2
2¾	607.2	31	181.0	76	115.6
3	582.7	32	178.0	78	114.2
3½	539.0	33	175.6	80	112.7
4	504.0	34	172.9	82	111.2
4½	475.5	35	170.3	84	109.9
5	450.0	36	168.0	86	108.7
5½	428.9	37	165.8	88	107.5
6	411.4	38	163.6	90	106.2
6½	395.3	39	161.3	92	105.1
7	380.4	40	159.5	94	103.9
7½	367.9	41	157.5	96	102.9
	356.2	42	155.6	98	101.8
8½	345.2	43	153.7	100	100.8
9	336.0	44	152.0	102	99.8
9½	327.3	45	150.2	105	98.3
10	319.0	46	148.7	107	97.5
10½	311.1	47	146.9	110	96.0
11	303.6	48	145.4	112	95.3
11½	297.3	49	144.0	115	93.9
12	291.3	50	142.6	118	92.8
12½	284.7	51	141.2	120	92.0
13	276.4	52	139.8	122	91.2
13½	274.6	53	138.5	125	90.2
14	269.5	54	137.1	130	88.4
14½	264.6	55	135.8	135	86.8
15	260.5	56	134.8	140	85.2
15½	255.8	57	133.5	145	83.7
16	252.0	58	132.3	150	82.3
17	244.7	59	131.2	....	....
18	237.5	60	130.1	....	....

TABLE C.

Multipliers for diameters other than 1 inch.

¼ inch = .0317	3 inch = 16.50	12 inch = 556
½ inch = .1810	4 inch = 34.10	16 inch = 1160
¾ inch = .5012	5 inch = 60.00	18 inch = 1570
1 inch = 1.0000	5⅝ inch = 81.00	20 inch = 2055
1½ inch = 2.9300	6 inch = 95.00	24 inch = 3285
2 inch = 5.9200	8 inch = 198.00	30 inch = 5830
2½ inch = 10.3700	10 inch = 350.00	36 inch = 9330

For wrought iron pipes greater than 12 inches in diameter the measure is taken from outside, and for pipes of ordinary thickness the corresponding inside diameters and multipliers are as follows:

Outside dia. of 15-inch pipe gives 14¼ in. inside dia. = 863
Outside dia. of 16-inch pipe gives 15¼ in. inside dia. = 1025
Outside dia. of 18-inch pipe gives 17¼ in. inside dia. = 1410
Outside dia. of 20-inch pipe gives 19¼ in. inside dia. = 1860

Measuring the Flow of Natural Gas.

ORIFICE METER.

An instrument known as the orifice meter, for testing small flows of natural gas, is shown in the figure. This instrument is simple in construction, consisting of a short 2-inch nipple, b, with pipe thread on one end and a thin plate disk on the other. The disk carries a 1-inch orifice, a, and a hose connection, c, for taking the pressure. The meter is especially intended for testing small gas wells and "casinghead" gas from oil wells. As a rule the flow of gas from an oil well is rather small, and it is not advisable to test the flow with a Pitot tube such as is used in testing large gas wells. In using the orifice tester, it is necessary to know the specific gravity of the gas in order to obtain the flow.

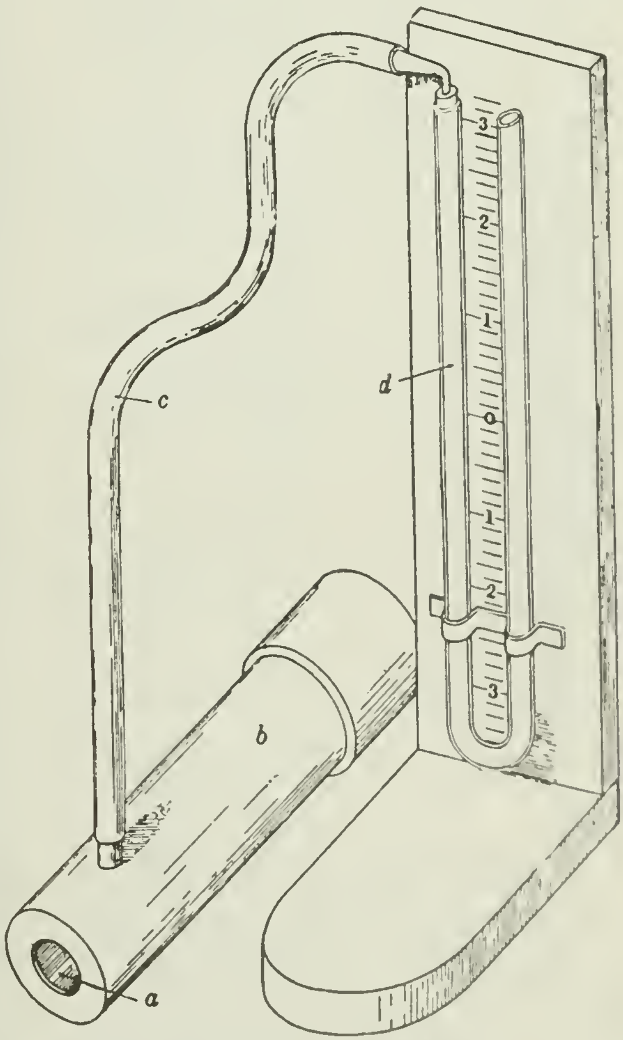


Fig. 86—Orifice Meter.
(U. S. Bureau of Standards.)

Before the orifice well tester is attached to the casinghead the well should be permitted to blow into the atmosphere until the head of the gas is reduced and the flow has become normal. Then the tester is attached by simply screwing it into the end of a 3-foot length of 2-inch pipe and the pressure is read in inches of water on the siphon gage, d. In the tables * on pages 420-21, the flow of the well with values for the gas of different gravities is opposite the gage reading. The orifice in the instrument should be kept dry and uninjured; otherwise the page reading will not be correct.

*Westcott H. P.: Handbook of Natural Gas, 1915, pp. 545-548.

Capacities of Orifices for Testing Flows of Natural Gas From Small Gas Wells and Casinghead Gas From Oil Wells.

(Temperature, 60° F.; atmospheric pressure, 14.4 pounds per square inch.)
ONE-INCH ORIFICE IN PLATE ⅛ INCH THICK.

Pressure	Capacity in Cubic Feet per 24 Hours, at Specific Gravity of—														
	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1	1.05	1.1	1.15	1.2	1.3	1.4	1.5
Inches of Water																
1	26,400	25,440	24,500	23,660	22,920	22,220	21,600	21,020	20,520	20,010	19,560	19,120	18,720	18,000	17,320	16,750
2	37,510	36,040	34,750	33,600	32,520	31,530	30,640	29,800	29,080	28,360	27,720	27,120	26,540	25,480	24,570	23,760
3	46,440	44,640	43,000	41,540	30,240	39,020	37,940	36,880	36,000	35,130	34,320	33,550	32,850	31,560	30,400	29,370
4	52,630	50,590	48,740	47,060	45,600	44,200	42,980	41,800	40,800	39,790	38,880	38,040	37,220	35,760	34,460	33,310
5	57,880	55,630	53,610	51,790	50,160	48,640	47,280	45,980	44,880	43,770	42,760	41,830	40,940	39,360	37,920	36,620
6	63,140	60,720	58,480	56,490	54,720	53,060	51,600	50,180	48,960	47,760	46,650	45,640	44,680	42,960	41,370	39,960
7	68,110	65,470	63,090	60,910	59,040	57,210	55,630	54,120	52,800	51,500	50,320	49,220	48,190	46,320	44,610	43,100
8	73,050	70,220	67,680	65,350	63,310	61,390	59,680	58,050	56,640	55,240	54,000	52,800	51,690	49,690	47,850	46,220
9	77,680	74,680	72,000	69,500	67,340	65,280	63,480	61,720	60,240	58,800	57,430	56,160	54,960	52,800	50,880	49,170
10	82,340	79,150	76,270	73,650	71,370	69,190	67,270	65,420	63,840	62,280	60,860	59,520	58,240	55,900	53,920	52,100
11	86,680	83,320	80,300	77,540	75,120	72,840	70,800	68,880	67,200	65,560	64,080	62,660	61,320	58,920	56,780	54,860
12	90,720	87,190	84,000	81,140	78,600	76,220	74,110	72,000	70,320	68,610	67,030	65,560	64,170	61,680	59,400	57,400
Inches of Mercury																
½	67,200	64,600	62,300	60,100	58,200	56,500	54,900	53,400	52,100	50,800	49,600	48,600	47,500	45,700	41,000	42,500
1	95,200	91,500	88,200	85,100	82,500	80,000	77,800	75,600	73,800	72,000	70,300	68,800	67,300	64,700	62,300	60,200
1½	116,600	112,000	108,000	104,300	101,000	97,900	95,300	92,600	90,400	88,200	86,200	84,300	82,500	79,200	76,300	73,800
2	134,600	129,400	124,700	120,400	116,700	113,100	110,000	107,000	104,400	101,800	99,500	97,300	95,300	91,500	88,200	85,200
2½	145,600	139,900	134,900	130,200	126,200	122,400	118,900	115,700	112,900	110,100	107,600	105,300	103,000	99,000	95,400	92,200
3	164,900	158,500	152,700	147,500	142,900	138,600	134,700	131,000	127,800	124,700	121,800	119,200	116,600	112,000	108,000	104,300
3½	178,200	171,300	165,100	159,400	154,500	149,800	145,600	141,600	138,200	134,800	131,700	128,800	126,100	121,200	116,700	112,800
4	190,400	183,000	176,400	170,300	165,000	160,000	155,600	151,300	147,600	144,000	140,700	137,600	134,700	129,400	124,700	120,500
5	212,900	204,600	197,200	190,400	184,500	178,900	174,000	169,200	165,000	161,000	157,300	153,900	150,600	144,700	139,400	134,700
6	233,200	224,100	216,000	208,600	202,100	195,900	190,500	185,300	180,800	176,400	172,300	168,600	165,000	158,500	152,700	147,600
7	251,900	242,100	233,400	225,300	218,300	211,700	205,800	200,200	195,300	190,000	186,200	182,100	178,200	171,200	165,000	159,400
8	269,400	258,900	249,500	240,900	233,400	226,400	220,100	214,000	208,800	203,700	199,100	194,700	190,600	183,100	176,400	170,560
9	285,700	274,600	264,700	255,600	247,600	240,100	233,500	227,000	221,500	216,100	211,200	206,500	202,100	194,200	187,100	180,800
10	301,200	289,500	279,000	269,400	261,000	253,100	246,100	239,300	233,500	227,800	222,600	217,700	213,100	204,700	197,300	190,600
11	315,800	303,600	292,500	282,500	273,700	265,400	258,000	250,900	244,800	238,900	233,400	228,300	223,400	214,700	206,800	199,900
12	328,400	315,700	304,200	293,800	284,600	276,000	268,400	261,000	254,600	248,400	242,700	237,400	232,400	223,300	215,100	207,900

Capacities of Orifices for Testing Flows of Natural Gas From Small Gas Wells and Casinghead Gas From Oil Wells.—Continued.

ONE-HALF INCH ORIFICE IN PLATE ⅛ INCH THICK.

Pressure	Capacity in Cubic Feet per 24 Hours, at Specific Gravity of—															
	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1	1.05	1.1	1.15	1.2	1.3	1.4	1.5
Inches of Water ½	4,490	4,320	4,160	4,020	3,890	3,7[illegible]0	3,670	3,570	3,480	3,400	3,320	3,250	3,180	3,050	2,910	2,810
1	6,260	6,010	5,790	5,000	5,440	5,2[illegible]0	5,110	4,970	4,850	4,730	4,620	4,520	4,420	4,250	4,100	3,960
1½	7,900	7,590	7,310	7,070	6,840	6,6[illegible]0	6,450	6,280	6,120	5,970	5,830	5,710	5,590	5,370	5,170	5,000
2	9,140	8,780	8,460	8,170	7,910	7,6[illegible]0	7,460	7,260	7,080	6,910	6,750	6,600	6,460	6,210	5,980	5,780
2½	10,220	9,820	9,470	9,140	8,850	8,5[illegible]0	8,350	8,120	7,920	7,730	7,550	7,380	7,230	6,950	6,690	6,470
3	11,150	10,720	10,330	9,980	9,660	9,[illegible]70	9,110	8,860	8,640	8,130	8,210	8,060	7,890	7,580	7,390	7,050
3½	12,020	11,550	11,130	10,750	10,410	10,100	9,810	9,550	9,310	9,090	8,880	8,680	8,500	8,170	7,870	7,600
4	12,800	12,290	11,850	11,440	11,080	10,750	10,450	10,170	9,910	9,670	9,450	9,210	9,050	8,690	8,380	8,090
4½	13,480	12,950	12,480	12,050	11,670	11,320	11,000	10,710	10,440	10,190	9,950	9,730	9,530	9,160	8,820	8,520
5	14,130	13,570	13,080	12,640	12,230	11,870	11,530	11,230	10,940	10,680	10,430	10,200	9,990	9,600	9,250	8,930
5½	14,690	14,110	13,600	13,130	12,720	12,310	11,990	11,670	11,380	11,100	10,850	10,610	10,380	9,989	9,610	9,290
6	15,210	14,620	14,080	13,610	13,170	12,730	12,420	12,090	11,780	11,500	11,230	10,990	10,760	10,330	9,960	9,620

THREE-EIGHTHS INCH ORIFICE IN PLATE ⅛ INCH THICK.

Pressure	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1	1.05	1.1	1.15	1.2	1.3	1.4	1.5
½	2,270	2,180	2,100	2,030	1,970	1,910	1,850	1,810	1,760	1,720	1,680	1,610	1,610	1,540	1,490	1,440
1	3,460	3,320	3,200	3,090	3,000	2,910	2,820	2,750	2,680	2,670	2,550	2,500	2,450	2,350	2,260	2,190
1½	4,310	4,140	3,999	3,860	3,730	3,620	3,520	3,420	3,339	3,260	3,180	3,110	3,050	2,430	2,820	2,730
2	4,830	4,640	4,470	4,320	4,180	4,060	3,910	3,810	3,740	3,650	3,560	3,490	3,410	3,280	3,160	3,950
2½	5,400	5,190	5,000	4,830	4,680	4,540	4,410	4,290	4,186	4,080	3,990	3,900	3,820	3,670	3,540	3,120
3	5,770	5,550	5,350	5,170	5,000	4,850	4,720	4,590	4,474	4,370	4,260	4,170	4,080	3,920	3,780	3,650
3½	6,290	6,050	5,830	5,630	5,450	5,290	5,140	5,000	4,875	4,760	4,650	4,550	4,450	4,270	4,120	3,980
4	6,650	6,390	6,160	5,950	5,670	5,590	5,430	5,280	5,152	5,030	4,910	4,800	4,700	4,520	4,350	,4210
4½	7,210	6,930	6,680	6,450	6,240	6,060	5,890	5,730	5,585	5,450	5,330	5,210	5,100	4,900	4,720	4,560
5	7,680	7,380	7,110	6,870	6,650	,6450	6,270	6,100	5,916	5,800	5,670	5,510	5,430	5,210	5,020	4,850
5½	8,100	7,790	7,500	7,250	7,020	6,810	6,620	6,140	6,278	6,130	5,980	5,850	5,730	5,510	5,310	5,130
6	8,290	7,970	7,680	7,420	7,180	6,970	6,770	6,590	6,423	6,270	6,120	5,990	5,860	5,630	5,430	5,240

Orifice Capacity.

Diameter, Inches		Area	Morse Drill Gage Size	Cubic Feet per Hour		
Frac.	Decimal	Square Inch		Coal Gas, 0.32 sp. gr. 2″ Press	Water Gas, 0.62 sp. gr. 2″ Press	Natural Gas 0.62 sp. gr. 4½-oz. Press
	0.0135	0.000143	80	1.04	0.86	1.67
	0.0145	0.000165	79	1.16	0.97	1.89
1/64	0.0156	0.00019	....	1.26	1.05	2.05
	0.016	0.00020	78	1.32	1.10	2.14
	0.018	0.00025	77	1.35	1.13	2.20
	0.020	0.00031	76	1.62	1.35	2.63
	0.021	0.00035	75	1.80	1.52	2.96
	0.0225	0.00040	74	2.16	1.80	3.51
	0.024	0.000.45	73	2.29	1.90	3.70
	0.025	0.00049	72	2.46	2.05	4.00
	0.026	0.00053	71	2.70	2.25	4.38
	0.028	0.00062	70	2.79	2.33	4.54
	0.0292	0.00067	69	3.08	2.57	4.97
	0.031	0.00075	68	2.23	2.70	5.26
1/32	0.031	0.00076	....	3.26	2.73	5.32
	0.032	0.00080	67	3.42	2.85	5.56
	0.033	0.00086	66	3.53	2.94	5.73
	0.035	0.00096	65	3.69	3.08	6.00
	0.036	0.00102	64	3.86	3.23	6.30
	0.038	0.00108	63	4.05	3.38	6.60
	0.038	0.00113	62	4.11	3.51	6.84
	0.039	0.00119	61	4.50	3.75	7.31
	0.040	0.00126	60	4.95	4.12	8.04
	0.041	0.00132	59	5.22	4.35	8.48
	0.042	0.00138	58	5.40	4.50	8.67
	0.043	0.00145	57	5.67	4.71	9.2
	0.0465	0.00170	56	6.57	5.47	10.6
3/64	0.0469	0.00173	....	6.75	5.63	11.0
	0.0520	0.0021	55	8.9	6.75	13.2
	0.0550	0.0023	54	9.0	7.50	14.6
	0.0595	0.0028	53	10.8	9.0	17.5
1/16	0.0625	0.0031	....	11.7	7.7	19.0
	0.0635	0.0032	52	11.9	9.9	19.3
	0.0670	0.0035	51	12.6	10.5	20.5
	0.070	0.0038	50	13.5	11.2	21.8
	0.0730	0.0042	49	14.4	12.0	23.4
	0.076	0.0043	48	15.3	12.7	24.8
6/64	0.0781	0.0048	....	15.7	13.1	25.5
	0.0785	0.0018	47	15.8	13.2	25.7
	0.081	0.0051	46	16	13.5	26
	0.082	0.0053	45	17	14.3	28
	0.086	0.0058	44	18	15	29
	0.089	0.0062	43	19	16.5	32
	0.0935	0.0069	42	20	17	33
3/32	0.0937	0.0069	....	21	18	35
	0.096	0.0072	41	22	19	37
	0.098	0.0075	40	23	20	39
	0.0995	0.0078	39	24	20.5	40
	0.1015	0.0081	38	25	21	41
	0.104	0.0085	37	26	22	43
	0.1065	0.0090	36	27	22.5	44
7/64	0.1093	0.0094	....	28	23	45
	0.110	0.0095	35	29	24	47
	0.111	0.0097	34	30	25	49
	0.113	0.0100	33	31	26	51
	0.116	0.0106	32	32	27	53

ORIFICE CAPACITY—Continued.

Diameter, Inches		Area, Square Inch	Morse Drill Gage Size	Cubic Feet per Hour		
Frac.	Decimal			Coal Gas, 0.43 sp. gr. 2″ Press	Water Gas. 0.62 sp. gr. 2″ Press	Natural Gas, 0.62 sp. gr. 4½-oz. Press
	0.120	0.0113	31	33	28	55
1/8	0.125	0.0123	....	36	30	58
	0.1285	0.0130	30	39	32	62
	0.136	0.0145	29	43	35	68
	0.1405	0.0155	28	44	37	72
9/64	0.1406	0.0155	....	45	38	74
	0.144	0.0163	27	47	39	76
	0.147	0.0174	26	48	40	78
	0.1495	0.0175	25	51	42	82
	0.152	0.0181	24	52	43	84
	0.154	0.0186	23	53	44	86
5/32	0.156	0.0192	....	54	45	88
	0.157	0.0192	22	55	46	90
	0.159	0.0198	21	57	47	91
	0.161	0.0203	20	58	48	95
	0.166	0.0216	19	60	50	97
	0.1695	0.0226	18	62	52	101
11/64	0.1719	0.0232	....	63	53	103
	0.173	0.0235	17	65	54	105
	0.177	0.0246	16	68	56	109
	0.180	0.0254	15	69	58	113
	0.182	0.0260	14	71	59	115
	0.185	0.0269	13	72	61	119
3/16	0.1875	0.0276	....	75	62	121
	0.189	0.0280	12	76	63	123
	0.191	0.0286	11	77	64	125
	0.1935	0.0294	10	79	66	129
	0.196	0.0302	9	80	67	131
	0.199	0.0311	8	83	69	134
	0.201	0.0317	7	84	70	136
13/64	0.203	0.0324	....	86	71	138
	0.204	0.0327	6	87	72	140
	0.205	0.0332	5	89	74	144
	0.209	0.0343	4	93	77	150
	0.213	0.0356	3	95	79	154
7/32	0.2187	0.0375	....	97	80	156
	0.221	0.0384	2	99	82	160
	0.228	0.0408	1	104	86	168
15/64	0.2344	0.0442	....	108	90	175
1/4	0.250	0.0491	....	119	99	193
17/64	0.2656	0.0554	....	131	109	212
9/32	0.2812	0.0621	....	142	119	232
19/64	0.2969	0.0692	....	153	128	250
5/16	0.3125	0.0767	....	164	136	165
21/64	0.3281	0.0845	....	176	146	285
11/32	0.3437	0.0928	....	187	155	302
23/64	0.3594	0.1014	....	198	165	322
3/8	0.375	0.1104	....	209	174	340
25/64	0.3906	0.1198	....	221	184	360
13/32	0.4062	0.1296	....	231	193	376
27/64	0.4219	0.1398	....	241	201	392
7/16	0.4375	0.1503	....	254	211	412
29/64	0.4531	0.1612	....	264	220	430
15/32	0.4687	0.1725	....	277	230	448
31/64	0.4844	0.1843	....	286	239	466
1/2	0.500	0.1963	....	299	249	485
33/64	0.5156	0.2088	....	309	257	500
17/32	0.5312	0.2216	....	320	267	520
35/64	0.5469	0.2349	....	331	276	539
9/16	0.5625	0.2485	....	340	285	556
37/64	0.5781	0.2625	....	353	295	576
19/32	0.5937	0.2769	....	365	303	590

ORIFICE CAPACITY—Continued.

Diameter, Inches		Area, Square Inch	Morse Drill Gage Size	Cubic Feet per Hour		
Frac.	Decimal			Coal Gas, 0.43 sp. gr. 2″ Press	Water Gas 0.62 sp. gr. 2″ Press	Natural Gas, 0.62 sp. gr. 4½-oz. Press
39/69	0.6094	0.2917	....	376	313	610
5/8	0.625	0.3068	....	387	323	630
41/64	0.6406	0.3223	....	399	333	650
21/32	0.6562	0.3382	....	410	341	665
43/64	0.0719	0.3546	....	421	350	682
11/16	0.6875	0.3712	....	431	369	720
45/64	0.7031	0.3883	....	443	370	722
23/32	0.7187	0.4057	....	454	378	737
47/64	0.7344	0.4236	....	466	387	755
3/4	0.750	0.4418	....	476	397	774
49/64	0.7656	0.4604	....	488	406	792
25/32	0.7812	0.4794	....	499	415	810
51/64	0.7969	0.4988	....	510	424	827
13/16	0.8125	0.5185	....	520	433	845
53/64	0.8281	0.5386	....	532	443	865
27/32	0.8438	0.5591	....	543	453	884
25/64	0.8594	0.5801	....	554	461	900
7/8	0.875	0.6013	....	565	472	920
57/64	0.8906	0.6229	....	576	480	938
29/32	0.9062	0.6450	....	588	490	955
59/64	0.9219	0.6675	....	599	500	976
15/16	0.9375	0.6903	....	510	507	985
61/64	0.9531	0.7134	....	620	517	1010
31/32	0.9687	0.7371	....	632	526	1025
63/64	9.9844	0.7611	....	644	536	1047
1	1.0000	0.7854	....	655	545	1062

NOTE:—The above table is based upon data obtained from gas orifices that are ordinarily used in gas appliances such as the ones used in Hale Gas Mixers.

ARTIFICIAL GAS:—The above figures are based upon 2-inch pressure; for higher pressures these figures should be increased by a percentage as shown below:

3-inch = 25 %	
4-inch = 50	10-inch = 120 %
5-inch = 62.5	12-inch = 140
6-inch = 75	16-inch = 180
7-inch = 87.5	20-inch = 210

NATURAL GAS:—The above figures for natural gas are based on a gas under 4½ oz. pressure having a specific gravity of 0.62, which is the ordinary gravity of natural gas sold in cities supplied by gas from the Mid-Continent, Pennsylvania and West Virginia fields. When the pressure is greater than 4½ oz. the figures in the table should be increased as shown below:

5 oz. = 10%	8 oz. = 39 %
6 oz. = 20	9 oz. = 47.5
7 oz. = 30	10 oz. = 60

Outline of Methods of Analysis of Petroleum Products.

1. Specific Gravity and Baume' Gravity.
   - (a) With hydrometer.
   - (b) With picnometer.
   - (c) With Westphal balance.
   - (d) By fluid suspension.
   - (e) By displacement.
   - (f) Asphaltic Cement.
2. Color of Petroleum.
   - (a) Saybolt Chromometer.
   - (b) Lovibond Tintometer.
   - (c) Potassium Bichromate.
   - (d) Iodimetric.
   - (e) Union Colorimeter.
3. Odor of Oil.
4. Transparency.
5. Viscosity or Fluidity.
   - (a) Saybolt Universal, Engler and Redwood Viscosimeters.
   - (b) Furol Viscosity for fuel oil and road oil.
   - (c) Ubbelohde Viscosimeter for thin petroleum products.
   - (d) MacMichael Disk Friction Viscosimeter.
   - (e) Float test for viscosity of road oils.
   - (f) Zero Viscosity for semi-solid petroleum products.
   - (g) Petrolatum.
6. Melting Point.
   - (a) Ring and Ball.
   - (b) Cube method.
   - (c) "General Electric" method.
   - (d) Wax.
7. Cold Test.
   - (a) Cloud test.
   - (b) Pour test.
   - (c) Cold test.
8. Water and Bottom Settlings.
   - (a) By centrifuge.
   - (b) By distillation.
9. Distillation Tests for Petroleum.
   - (a) End point distillation.
   - (b) Fractional—Gravity distillation analysis.
   - (c) Proximate distillation for water, gasoline, kerosene and residuum.
   - (d) Fractional—Sample distillation.
10. Flash and Burning Points.
    - (a) Illuminating oils with closed tester (Tag.).
    - (b) All types of petroleum products with the Elliott or New York closed tester.
    - (c) Lubricants and asphalt with Cleveland open cup.
    - (d) Fuel oil with Pensky-Martens.
11. Pressure—Heat Tests.
    - (a) Cracking test under high pressure and temperature.
    - (b) Vapor pressure test at high pressure.
    - (c) Motor oil lubricant test for stability under heat and pressure.
    - (d) Vapor pressure of light gasoline.
12. Carbon residue.
    - (a) Conradson carbon test.
    - (b) Fixed carbon and ash in asphalt.
    - (c) Asphaltic carbon in lubricating oils.

13. Emulsification test of lubricating oils.
14. Heat of combustion.
    (a) By bomb calorimeter.
    (b) By calculation from gravity.
15. Sulphur in Petroleum Products.
    (a) By bomb calorimeter.
    (b) By Eschka method.
    (c) By chemical bomb.
    (d) In illuminating oils by lamp method.
    (e) For Naphtha and turpentine substitute, white lead test.
16. Ultimate Analysis.
    (a) Carbon and Hydrogen.
    (b) Nitrogen.
17. Doctor Test for Refined Distillates.
18. Olefins, Ethylenes or Unsaturated Hydrocarbons.
    (a) Babcock method.
    (b) Cylinder method.
    (c) Refining loss.
19. Aromatic and Paraffin Hydrocarbons in Petroleum.
    (a) Nitrating method.
    (b) Distillation method.
20. Acid.
    (a) Free acid in petroleum products.
    (b) Combined fatty acid.
21. Floc Test.
22. Corrosion and Gumming Test of Gasoline.
23. Penetration or Consistency of Asphalt.
24. Ductility of Asphalt.
25. Resistance of Asphalt and Oil to Evaporation.
26. Determination of Natural Asphalt or Semi-Solid Hydrocarbons in Petroleum. Oxidation of Lubricating Oils.
27. Solubility of Petroleum and Asphalts.
    (a) In petroleum ether—
        (1) A.S.T.M. precipitation number of lubricating oils.
        (2) Tar in lubricating oils, asphaltenes in asphaltic cement.
    (b) In carbon bisulphide—total bitumen.
    (c) In carbon tetrachloride—carbene free bitumen.
28. Resistance of asphalt to oxidation.
29. Paraffin wax or scale determination.
30. Bitumen and Grading of Asphalt-Mineral Mixtures.
    (a) By burning.
    (b) By extraction.
31. Tensile and Cementing Strength of Asphaltic Surface Mixtures.
32. Specific Gravity of Gas.
    (a) Effusion or viscosity method.
33. Gasoline Determination in Gas.
    (a) By absorption test.
    (b) Freezing test.
34. Complete Chemical Analysis of Gas with Preparation of Reagents.
35. Heat of Combustion of Gas.
    (a) By the calorimeter.
    (b) By oxygen consumption.
    (c) By calculation from chemical analysis.

Index to Applications of Methods of Analysis.

PRODUCT	Routine Test	Occasional Test	Rarely Used
A. Crude Petroleum....	1A, 2D, 3, 4, 8, 9B, 9C, 15	7C, 9D, 10, 5A, 9C, 14, 26, 29	2D, 7B, 9D, 12, 16, 18
B. Gasoline, Benzine and Naphtha.........	1, 2, 3, 4, 9A, 17, 18, 22	9B, 14, 19, 20, 11D	5B, 7A, 15, 16 20
C. Kerosene and Illuminating Oils.......	1, 2ABC, 3, 4, 5B, 7, 9B, 10A, 15, 17, 21	10B, 14, 18, 20, 22	9C, 11B, 16, 19
D. Gas Oil, Straw Oil, Absorption Oil....	1, 2, 3, 4, 7, 9C, 10, 14, 15	5, 11A, 12A, 13, 17, 18	16, 19, 20, 21
E. Lubricants, Paraffin Oils.............	1, 2, 3, 4, 5A, 7, 10, 12A, 13, 15, 20, 27A	14, 17, 18, 11C, 12C	16, 19, 21
F. Fuel Oil, Diesel Engine Oil..........	1, 5C, 7, 8, 10, 14, 15	5, 11, 26, 27A, 29	2D, 3, 9, 12, 16 18, 19
G. Road Oil, Flux Oil..	1AB, 5AD, 8, 10, 12, 25, 26, 27	7B, 14, 15, 29	2D, 11, 16
H. Asphalt and Pitch...	1DF, 5F, 6ABC, 10C, 12, 23, 24, 27	8B, 15, 28. 29	2D, 3, 14, 16, 25
I. Wax..............	1, 2, 3, 6D	4, 25	11A, 12A, 14, 15, 16, 17, 18, 19, 20
J. Grease............	1, 2, 3, 4, 5DE, 8, 12B, 27	20, 25	16
K. Asphalt Surface Mix.	1E, 30, 31		
L. Gas...............	32, 33, 34, 35		16

Note—See special specifications for other tests of Petroleum Products.

1. Specific Gravity and Baume' Gravity (General Discussion).

Specific gravity is the relation by weight of the same volume of oil and of water. Unless some other temperature is specifically mentioned the gravity refers to 60°F. Specific gravity is determined by means of the hydrometer, the Westphal balance, the picnometer and by displacement methods. The absolute specific gravity scale is not commonly used in the oil industry. Instead, the Baume' gravity scale, an entirely arbitrary standard is used. Two Baume' gravity scales are in use in the oil industry; one is that adopted by the U. S. Bureau of Standards and its relation to specific gravity is indicated by the following formula:

$$\text{Specific Gravity} = \frac{140}{130 + \text{Baume}'} \text{ for liquids lighter than water.}$$

Another scale possibly more commonly used is that of the American Petroleum Association, which is based upon the following relation to specific gravity:

$$\text{Specific Gravity} = \frac{141.5}{131.5 + \text{Baume}'} \text{ for liquids lighter than water.}$$

The difference between the two readings varies from nothing with very heavy oils to as much as 0.5°Be' for ordinary gasoline. When the oil is heavier than water a different formula is used for calculating the Baume' gravity, the following being in general use:

$$\text{Degrees Baume}' = 145 - \frac{145}{\text{Specific Gravity}} \text{ for liquids heavier than water.}$$

Oils heavier than water are not commonly encountered. The method of using the hydrometer is the same in all cases whether its reading is in terms of the U..S. Bureau of Standards Baume' Scale, the Petroleum Association Baume' Scale, Baume' Scale for liquids heavier than water, or for direct specific gravity. The ideal instrument for all purposes is, of course, that reading directly in specific gravity. By the use of tables these readings can be converted into the Baume' reading desired and without any misunderstanding as to which scale is intended.

Tables for the correction of the specific gravity of oils are to be found on pages 538 to 542. Tables for the correction of the Baume' gravity of oils to the basis of 60°F are to be found on pages 529 to 537. Baume' values are extended to lower than 10° on page 529.

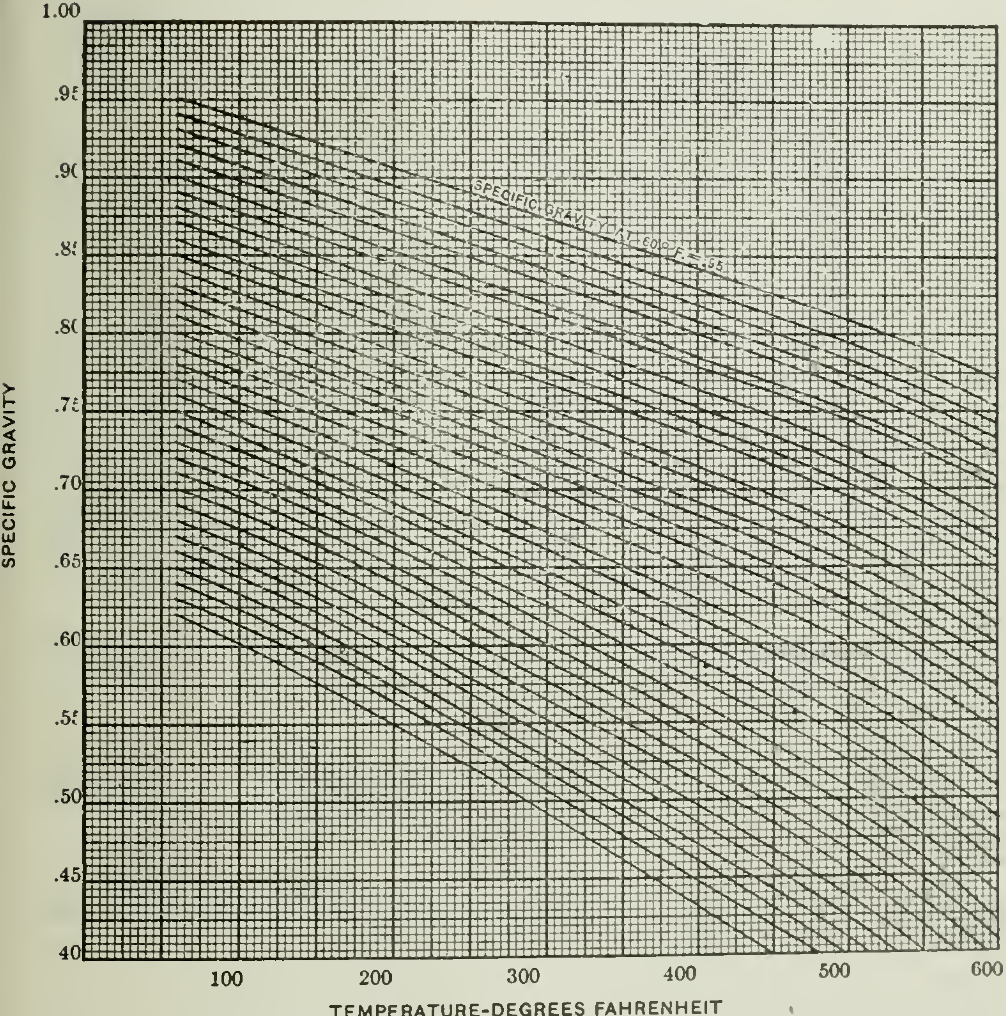


Fig. 87—Effect of High Temperatures on the Specific Gravity of Oil.

1A. Specific Gravity and Baume' Gravity With the Hydrometer.

The correct method of reading the hydrometer is illustrated in Fig. 88, page 432. The sample of oil is placed in a clear jar or cylinder and the hydrometer carefully immersed in it to a point slightly below that to which it naturally sinks and is then allowed to float freely. The reading should not be taken until the oil and the hydrometer are free from air bubbles and are at rest.

In taking the reading the eye should be placed slightly below the plane of the surface of the oil and then raised slowly until this surface, seen as an ellipse, becomes a straight line. The point at which this line cuts the hydrometer scale should be taken as the reading of the instrument.

In case the oil is not sufficiently clear to allow the reading to be made as above described, it will be necessary to read from above the oil surface and to estimate as accurately as possible the point to which the oil rises on the hydrometer stem. It should be remembered, however, that the instrument is calibrated to give correct indications when read at the principal surface of the liquid. It will be necessary, therefore, to correct the reading at the upper meniscus by an amount equal to the height to which the oil creeps up on the stem of the hydrometer. The amount of this correction may be determined with sufficient accuracy for most purposes by taking a few readings on the upper and the lower meniscus in a clear oil and noting the differences.

In the case of thick viscous oils after the hydrometer has apparently sunk to a stationary position it is well to determine if it will rise to the same position when pushed down into the oil.

A specific gravity hydrometer will read too low and a Baume' hydrometer too high when read at the upper edge of the meniscus. The correction for meniscus height should therefore be added to a specific gravity reading and subtracted from a Baume' reading.

The magnitude of the correction will obviously depend upon the length and value of the subdivisions of the hydrometer scale and must be determined in each case for the particular hydrometer in question.

Specific gravity and Baume' gravity readings of oils are conveniently taken at room temperature and these readings must be converted to the gravity at 60°F. As a general rule it may be said that petroleum oil expands with heat so that 0.0004 must be added as a correction to the specific gravity readings for each degree Fahr. that the oil is above 60°F or must be subtracted for each degree Fahr. below 60°F. On the Baume' scale 0.1°Be' may be subtracted for each degree Fahr. above 60°F or added for each degree Fahr. below 60°F. For exact temperature corrections for specific gravity, see pages 538 to 542. For exact temperature corrections for Baume' gravity, see pages 529-537. For conversions of Baume' to and from specific gravity, see pages 523-528.

The following table is based on the data contained in Bureau of Standards Technologic Paper No. 77 and upon which are based the tables contained in Bureau of Standards Circular No. 57, United States Standard Tables for Petroleum Oils. It differs from Table 3 of Circular No. 57 in that the specific gravity of the oil is known as 60°/60°F instead of at the temperature at which the volume measurements are made.

Volume at 60 F Occupied by Unit Volume of Oil at Various Temperatures.

Observed Temperature, Degrees Fahr.	Specific Gravity at 60°/60° F.								
	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
	0.00097[1]	0.00081[1]	0.00069[1]	0.00059[1]	0.00051[1]	0.00045[1]	0.00041[1]	0.00038[1]	0.00037[1]
30	1.0288	1.0240	1.0208	1.0178	1.0151	1.0135	1.0123	1.0116	1.0111
32	1.0269	1.0224	1.0194	1.0166	1.0141	1.0126	1.0115	1.0108	1.0103
34	1.0251	1.0208	1.0180	1.0154	1.0131	1.0117	1.0107	1.0100	1.0095
36	1.0232	1.0193	1.0167	1.0142	1.0121	1.0108	1.0099	1.0092	1.0088
38	1.0213	1.0177	1.0153	1.0130	1.0111	1.0099	1.0091	1.0085	1.0080
40	1.0194	1.0161	1.0139	1.0118	1.0101	1.0090	1.0082	1.0077	1.0073
42	1.0174	1.0145	1.0125	1.0106	1.0091	1.0081	1.0074	1.0069	1.0066
44	1.0155	1.0129	1.0111	1.0095	1.0080	1.0072	1.0066	1.0062	1.0059
46	1.0136	1.0113	1.0097	1.0083	1.0070	1.0063	1.0058	1.0054	1.0051
48	1.0116	1.0098	1.0084	1.0071	1.0060	1.0054	1.0050	1.0046	1.0044
50	1.0097	1.0082	1.0070	1.0059	1.0050	1.0045	1.0041	1.0038	1.0037
52	1.0078	1.0065	1.0056	1.0048	1.0040	1.0036	1.0033	1.0031	1.0029
54	1.0059	1.0048	1.0042	1.0036	1.0030	1.0027	1.0025	1.0023	1.0021
56	1.0040	1.0032	1.0028	1.0024	1.0020	1.0018	1.0017	1.0015	1.0014
58	1.0020	1.0016	1.0014	1.0012	1.0010	1.0009	1.0009	1.0008	1.0007
60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
62	0.9981	0.9984	0.9986	0.9988	0.9990	0.9991	0.9992	0.9992	0.9992
64	0.9962	0.9968	0.9972	0.9976	0.9980	0.9982	0.9984	0.9985	0.9985
66	0.9942	0.9952	0.9958	0.9964	0.9970	0.9973	0.9976	0.9977	0.9978
68	0.9923	0.9936	0.9944	0.9952	0.9960	0.9964	0.9967	0.9970	0.9971
70	0.9903	0.9919	0.9930	0.9940	0.9950	0.9955	0.9959	0.9962	0.9963
72	0.9884	0.9903	0.9916	0.9928	0.9940	0.9946	0.9951	0.9954	0.9956
74	0.9864	0.9887	0.9902	0.9917	0.9930	0.9937	0.9943	0.9947	0.9948
76	0.9845	0.9871	0.9888	0.9905	0.9920	0.9928	0.9935	0.9939	0.9941
78	0.9825	0.9855	0.9875	0.9893	0.9909	0.9919	0.9927	0.9931	0.9934
80	0.9806	0.9839	0.9861	0.9881	0.9899	0.9910	0.9918	0.9923	0.9927
82	0.9786	0.9823	0.9847	0.9869	0.9889	0.9901	0.9910	0.9915	0.9920
84	0.9767	0.9807	0.9833	0.9857	0.9879	0.9892	0.9902	0.9908	0.9912
86	0.9748	0.9790	0.9819	0.9845	0.9868	0.9883	0.9893	0.9900	0.9905
88	0.9728	0.9774	0.9805	0.9833	0.9856	0.9875	0.9855	0.9893	0.9898
90	0.9708	0.9758	0.9791	0.9821	0.9848	0.9865	0.9877	0.9885	0.9891
92	0.9688	0.9741	0.9777	0.9809	0.9838	0.9856	0.9869	0.9878	0.9884
94	0.9669	0.9725	0.9763	0.9798	0.9828	0.9847	0.9860	0.9870	0.9877
96	0.9649	0.9708	0.9749	0.9786	0.9818	0.9838	0.9852	0.9863	0.9870
98	0.9629	0.9692	0.9735	0.9774	0.9808	0.9829	0.9841	0.9856	0.9862
100	0.9610	0.9676	0.9721	0.9762	0.9797	0.9820	0.9836	0.9848	0.9855
102	0.9591	0.9660	0.9707	0.9750	0.9787	0.9811	0.9828	0.9841	0.9848
104	0.9572	0.9643	0.9693	0.9738	0.9777	0.9802	0.9820	0.9833	0.9841
106	0.9552	0.9626	0.9679	0.9726	0.9767	0.9793	0.9812	0.9826	0.9834
108	0.9533	0.9610	0.9665	0.9714	0.9757	0.9784	0.9804	0.9819	0.9827
110	0.9514	0.9594	0.9651	0.9702	0.9747	0.9776	0.9796	0.9811	0.9819
112	0.9495	0.9578	0.9637	0.9690	0.9736	0.9767	0.9788	0.9804	0.9812
114	0.9476	0.9562	0.9623	0.9678	0.9726	0.9758	0.9780	0.9796	0.9805
116	0.9456	0.9545	0.9609	0.9666	0.9716	0.9749	0.9772	0.9788	0.9798
118	0.9437	0.9529	0.9595	0.9654	0.9706	0.9740	0.9764	0.9781	0.9791
120	0.9418	0.9513	0.9581	0.9642	0.9696	0.9731	0.9756	0.9774	0.9781

[1] These approximate volume co-efficients are derived from Table 11 of Technologic Paper No. 77, by using the A term only. The table as given above has been computed by using both the A and B terms and therefore differs slightly from the values that would be obtained by using the co-efficients as given in the column headings.

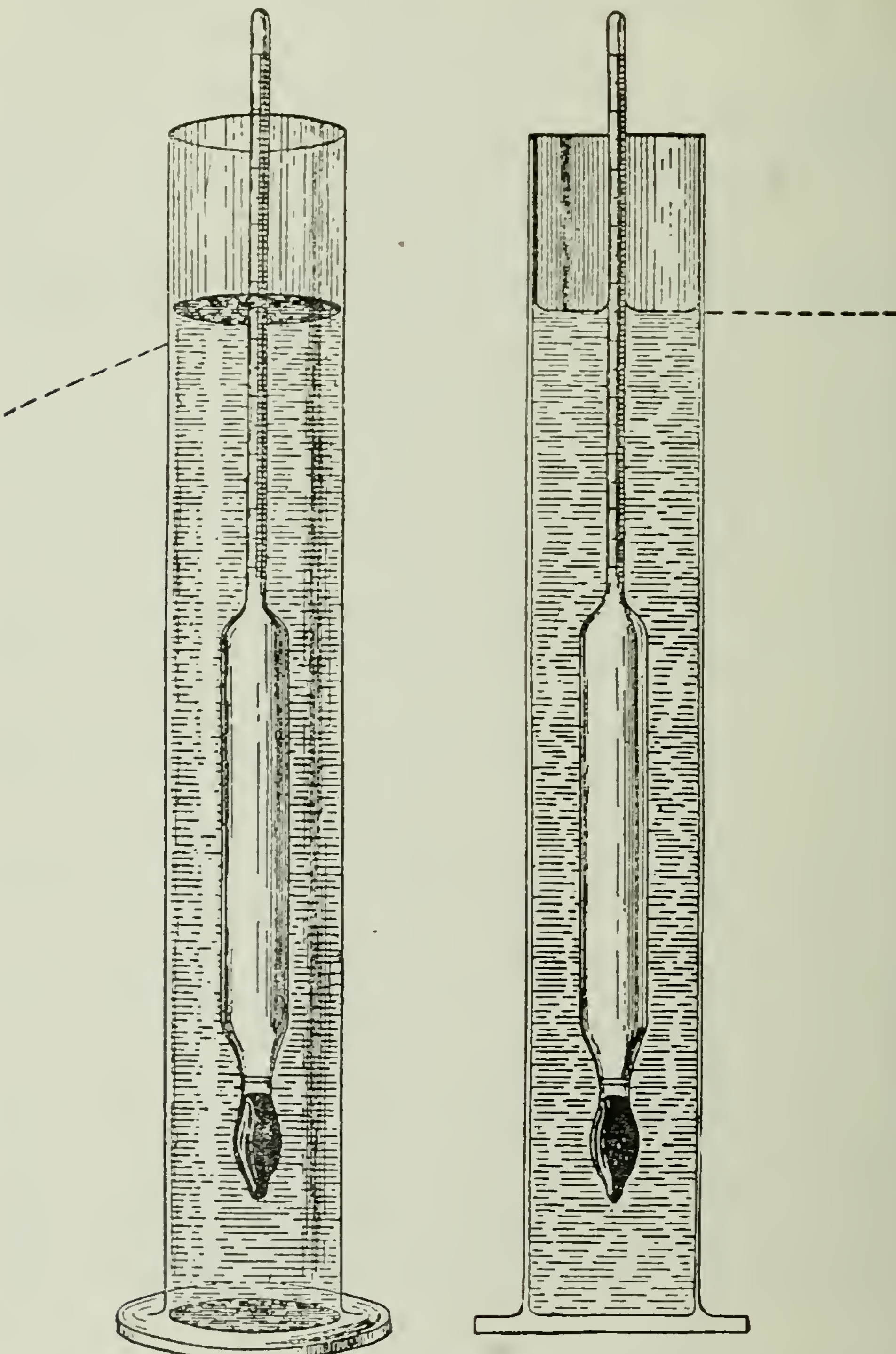


Fig. 88—Method of Reading the Hydrometer.

Fig. 89—Baume' Hydrometer

1B. Specific Gravity With the Picnometer.

Various types of picnometers may be used for this purpose, each of which has special advantages. Some are plain bottles with capillary openings in a well made ground glass stopper; others have graduated tubes in the stoppers, vacuum walls and inserted thermometers. The Sprengel picnometer is particularly adapted to the handling of very viscous oils as it prevents including air bubbles in the instrument. With any of the various types the perfectly dry and clean picnometer is weighed at 60°F to the nearest 0.0001 gram. It is filled with distilled water at 60°F and weighed. It is then dried completely and filled with the oil to be tested at 60°F. The net weight of the oil divided by the net weight of the distilled water gives the specific gravity of the oil. For conversion into degrees Baume' the formulae given on page 428 or the tables given on pages 523 to 528 are used.

Fig. 90—Picnometer Without Thermometer.

Fig. 91—Picnometer With Thermometer.

1C. Specific Gravity With the Westphal Balance.

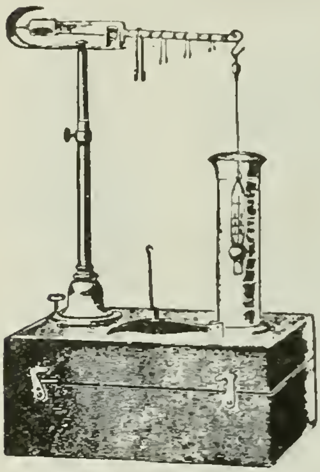


Fig. 92 — Westphal Ballance.

This is a very convenient instrument where a great variety of petroleum products are to be tested as it covers any range of specific gravity and can be used for practically any type of liquid. Its character is shown by the figure 92. The oil is put into the jar and the weights or riders are adjusted on the beam until the pointer is in exact poise. The readings are in specific gravity based on a water temperature of 60°F at which temperature the instrument is standardized. The specific gravity may be converted to Baume' scale with the tables.

1D. Specific Gravity of Semi-Solid Petroleum Materials.

A convenient method of taking the specific gravity of asphaltic cement and similar semi-solid petroleum materials is the following. (See Fig. 93.) Roll up a ball of the asphalt about 1 cm. in diameter, being careful that no water or air is inclosed. Place this in a cylinder of cold distilled water from which the air has been removed by previous boiling. If the ball of asphalt floats, denatured alcohol is added until it shows no tendency to go either up or down when placed in the middle of the cylinder. The specific gravity of the liquid is then taken with the Westphal balance or with the hydrometer. If the ball of asphalt sinks a saturated solution of sodium chloride or common salt is added until the asphalt when placed in the center of the cylinder shows no tendency to go either up or down. The specific gravity is taken with a hydrometer for liquids heavier than water or with the Westphal balance. It is necessary in performing this test that the bubbles of air which tend to adhere to the surface of the asphalt be occasionally removed, and that the solution be thoroughly mixed. All air bubbles and water must be thoroughly kneaded out of the asphalt. The usual temperature required for the gravity of this material is 77°F or 25°C.

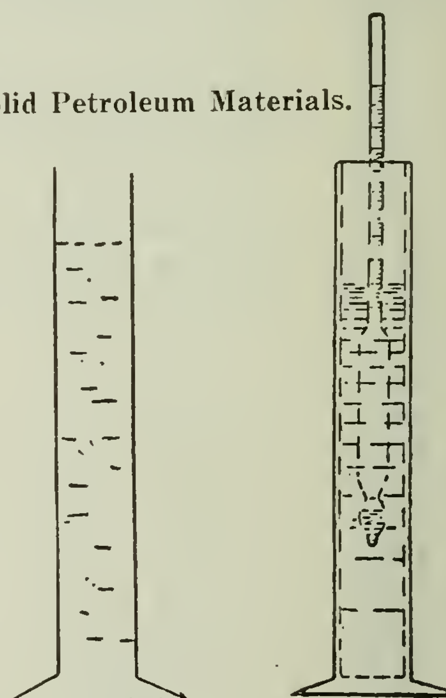


Fig. 93—Specific Gravity of Asphaltic Cement by Fluid Suspension.

1E. Specific Gravity of Solid Asphaltic Materials.

A fragment of bituminous material is suspended by means of a thread from a hook of one pan support of the balance and about one-half inch above the pan and weighed. This weight is "a." It is then immersed in water at 25°C and suspended, the water container not being allowed to touch the balance and is weighed again. This weight is "b."

The specific gravity is $\frac{a}{a-b}$. (See Fig. 94.)

The sample of asphaltic surface mixture for this test should be cut out of the street after the pavement has been rolled and cooled. This test is a very good measure of the all around quality of the work. The sample is weighed in the air and in water, the weight in air divided by the loss of weight in water gives the specific gravity. This times 62.4 gives the weight per cubic foot and times 93.6 gives the weight per square yard of 2-inch surface.

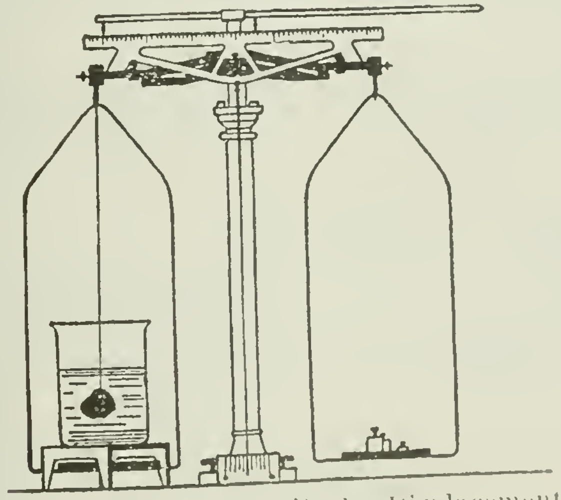


Fig. 94—Specific Gravity by Displacement.

1F. Method of Determining the Specific Gravity of Asphaltic Cement.

Fig. 95—Capsule for Specific Gravity of Asphaltic Cement.

When considerable accuracy is required, the specific gravity of asphaltic cement may be done in the following manner:

For a receptacle, use a short glass tube as shown in the accompanying figure. This may be a half-inch test tube that has been cut off to a length of about two inches.

Enough of the dry asphalt is put in the tube to fill it about one-half full. The tube is placed in an air oven at a temperature of from 105° to 150°C so that the asphalt melts down compactly in the tube.

The record for determining specific gravity is as follows:

C_1 = Weight of the tube in air.
C_2 = Weight of the tube in water.
A_1 = Weight of the tube + the asphaltic cement in air.
A_2 = Weight of the tube + asphaltic cement in water.

These weighings are carried out with the water at a temperature of 77°F. The specific gravity then is equal to:

$$\frac{A_1 - C_1}{(A_1 - C_1) - (A_2 - C_2)}$$

2A. THE COLOR OF REFINED PETROLEUM (KEROSENE, NAPHTHA, GASOLINE).

The Saybolt apparatus consists of two color comparison tubes, one being arranged for insertion of a standard yellow glass in the bottom, the other being graduated for different lengths of oil column. (See Fig. 96.)

The yellow glass discs are supplied with each Chromometer.

Two glasses are used to determine color shades up to and including +15, and only one glass from +16 to +25.

An excess of oil is filled into the graduated tube so that in drawing off the excess the color of the oil becomes lighter.

The apparatus should be set at a window having a one-light sash so that a good light is reflected from the mirror, but not in the direct rays of the sun, and care should be taken that no colored light is reflected toward the instrument from surrounding buildings, tanks or other objects.

Fig. 96—Saybolt Chromometer.

Clean the Chromometer before making a new test, by allowing some of the oil to be tested to run through the graduated tube.

After using, do not let the instrument stand with the light reflecting up the tubes.

When not in use, put the color glasses in the pockets prepared for them on the back of the upright stand.

For the purpose of most easily determining color shades, the color of the column of oil when nearing the color of the standard glass discs, is lowered shade by shade by use of the pet cock.

Now lower the column of oil one shade more and if it appears whiter than the standard glass disc, the color of the oil is recorded one shade above this last whiter point.

It is evident that no oils are to be compared with one disc unless they positively show whiter at 10 4/8 inches with two discs.

Moreover, a full tube (20 inches) of white oil that shows whiter than one (1) disc must rate over +25.

ONE DISC

Inches of Oil in Tube	Color Shades	
20	+25	Water white
18	+24	
16	+23	
14	+22	
12	+21	
10 6/8	+20	
9 4/8	+19	
8 2/8	+18	
7 2/8	+17	
6 2/8	+16	

TWO DISCS

Inches of Oil in Tube	Color Shades	
10 4/8	+15	Standard white
9 6/8	+14	
9	+13	
8 2/8	+12	
7 6/8	+11	
7 2/8	+10	
6 6/8	+ 9	
6 4/8	+ 8	
6 2/8	+ 7	
6	+ 6	
5 6/8	+ 5	
5 4/8	+ 4	Standard white
5 2/8	+ 3	
5	+ 2	
4 6/8	+ 1	
4 4/8	0	
4 2/8	— 1	
4	— 2	
3 6/8	— 3	
3 5/8	— 4	
3 4/8	— 5	
3 3/8	— 6	
3 2/8	— 7	
3 1/8	— 8	
3	— 9	

2-B. Color by Lovibond Tintometer.

The Lovibond color units and divisions are shown below, together with the color, series and number of each glass. These slides are used for determining the color of the refined products—gasoline, naphtha and kerosene.

Lovibond color units with specifications for the slides

Slide	Color	Series	Number
Water white	Yellow	510	2.3
	Red	200	1.6
1 to 12.0	Amber	500	0.1 to 12.0

If the oil is darker than the water white glass, slides are added to the slot containing the standard water white until the color of the oil is matched. When the .2 slide is added in this manner, the color is reported as W.W.—0.2 the minus sign indicating that the oil is darker than the standard water white. If the color of the oil is lighter than that of the water white glass, additional slides are placed in the slots in front of the oil and should the color be matched in this manner with, say the .5 slide and the .2 slide, the color is reported W.W.+0.70.

The color equivalent of water white, the standard color for gasoline and naphtha, has been defined as the equivalent of a column 404.6 mm. long of a 0.00027% acidulated solution of potassium chromate.

The most practical adaptation of the tintometer for the color of lubricating oils is in the Union Colorimeter covering the National Petroleum Association standards as shown in paragraph 2-E.

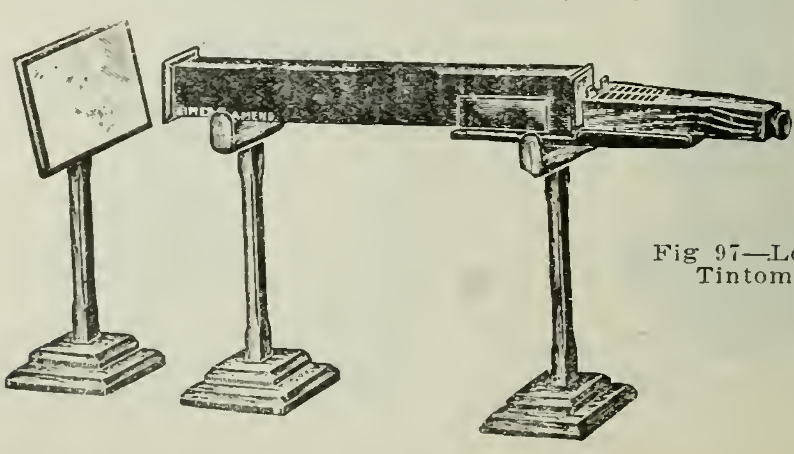


Fig 97—Lovibond Tintometer.

2-C. Color With Potassium Bichromate Solutions.

In the absence of an instrument, standard acidulated solutions may be prepared to correspond with the solutions indicated in the following table. Each of these solutions when placed in four-ounce sample bottles and marked with the equivalent Saybolt value may be used to match samples. Solutions prepared in four-ounce bottles as indicated below are much more convenient and more easily read than in the case of using the Saybolt Chromometer.

Saybolt Color	Milligrams of potassium bichromate per 100cc of 1% sulphuric acid solution	Saybolt Color	Milligrams of potassium bichromate per 100cc of 1% sulphuric acid solution
25	0.20	9	1.95
24	0.30	8	2.05
23	0.37	7	2.17
22	0.45	6	2.30
21	0.55	5	2.40
20	0.65		
19	0.75	4	2.55
18	0.85	3	2.65
17	0.95	2	2.75
16	1.10	1	2.85
15	1.25	0	3.00
14	1.35		
13	1.50		
12	1.65		
11	1.75		
10	1.85		

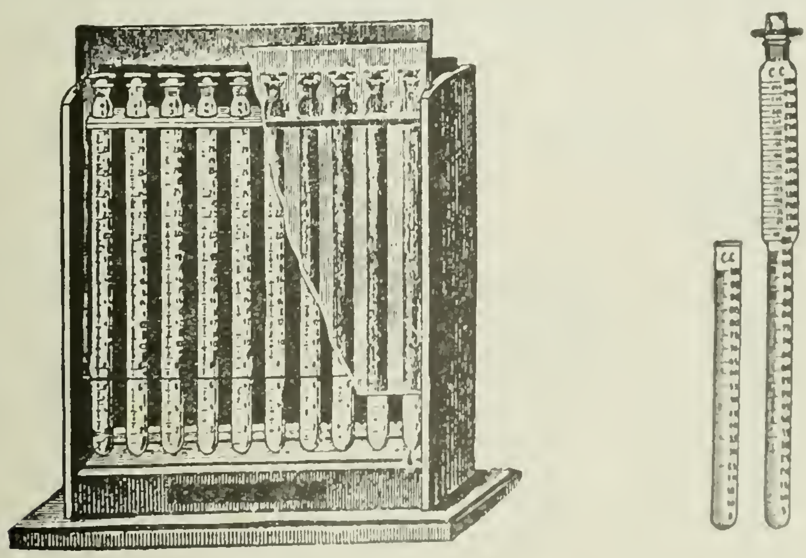


Fig. 98—Color Tubes.

2-D. Color of Oil by Iodine Method.

This method may be applied to all dark colored petroleum products. In determining the color by the iodine method a solution is made containing in one liter of very pure distilled water, ten grams of iodine and twenty grams of potassium iodide. This is kept in a glass stoppered bottle. The apparatus necessary is that indicated in Fig. 98 which may be a set of carbon color tubes or two tubes such as are required in the determination of manganese in steel. For crude oil, road oil, fuel oil and other black oils a dilution of 1/1000 in colorless benzol is made by diluting 1cc to 10cc of benzol and then 1cc of this to 100cc with benzol. This is thoroughly mixed in one of the glass stoppered color tubes. 1 cc of the standard iodine solution is put into the large color tube which holds 250cc. It is diluted with distilled water until its color matches that of the oil under test. The color is calculated as follows: I = milligrams of iodine in 100cc of water in the tube containing the diluted iodine.

d = The number of cc of benzol to 1cc of oil.
Color = I (d + 1).

For gas oil, lubricating oils and yellow oils, a dilution of 1/100 with benzol is sufficient. For gasoline, naphtha, kerosene and illuminating oils there is no dilution with benzol, the comparison being made directly. The union colorimeter may be used for comparison purposes.

The descriptive terms applied in the color of crude oil are black, brownish black, blackish brown, brown, reddish brown, green, greenish brown, brownish green and bluish green. The kerosene is spoken of as being water white, superfine white, prime white, standard white, prime light straw, light straw, and straw. Other colors are designated by yellow, dark yellow, reddish yellow, brownish yellow, yellowish brown, brown red, blood red, and yellowish red.

2-E. Color of Lubrication Oils.
(Union Colorimeter)

The color of lubricating oils is determined by placing a 4-ounce bottle of the oil under examination in the right-hand circular compartment of the instrument. In the compartment behind the slot place a 4-ounce bottle of water white gasoline or distilled water. Then place one of the standard glasses in the slot and close the slide. The instrument should be directed toward a window so that the observer can compare the color of the oil with the standard glass

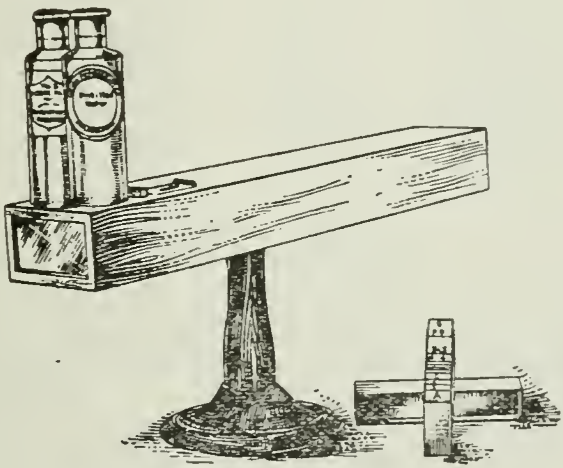


Fig. 99—Union Colorimeter.

In the case of cylinder stocks (filtered) fifteen cubic centimeters are mixed with 85cc of water white gasoline or benzol and the color is determined as in the case of lighter lubricating oils. (For dark cylinder stocks use method 2D.)

The following are the NATIONAL PETROLEUM ASSOCIATION STANDARDS for Engine, Machinery and Cylinder Oils:

			Tagliabue-Robinson Colorimeter Equivalent
A	Cylinder—Extra Light Filtered.		
D	Cylinder—Light Filtered.		
E	Cylinder—Medium Filtered.		
G	Lily white	N. P. A. No. 1	20¾
H	Cream white	N. P. A. No. 1½	17½
I	Extra Pale	N. P. A. No. 2	12¼
J	Extra lemon pale		10
K	Lemon pale	N. P. A. No. 3	9½
L	Extra orange pale		9
M	Orange pale	N. P. A. No. 4	8½
N	Pale	N. P.	5½
O	Light red	N. P. A. No. 5	3¼
P	Dark red	N. P. A. No. 6	2
Q	Claret red		1¼

Equivalents of the above colors in Lovibond slides and in iodine colors expressed in milligrams of iodine per 100cc of solution are as follows:

N. P. A. Standard	Lovibond Red	Yellow	Blue	Iodimetric
A	10.2	29.0	0	50 (diluted)
D	21.0	31.0	0	100 (diluted)
E	89.0	56.0	0	500 (diluted)
G	0.12	2.4	0	2.8
H	0.6	8.0	0	5.7
I	2.5	26.0	0	10.8
J	4.6	27.0	0	20.1
K	6.9	32.0	0	32.1
L	7.8	39.0	0	38.4
M	14.0	50.0	0.55	70.7
N	21.0	56.0	0.55	112.0
O	35.0	93.0	0	195.0
P	60.0	60.0	0.55	300.0
Q	60.0	106.0	1.8	460.0

3. Odor of Oil.

The odor of oil may be spoken of as sweet, ethereal, aromatic, tarry, fatty, creosotic, acid, sour, sulphurous, sulphuretted hydrogen, pyridine and pungent.

The sour or cracked odor is characteristic of benzine or incompletely refined gasoline. The aromatic odor or odor of benzene (benzol) is characteristic of high temperature cracking or aluminum chloride refining. Sweet ethereal odors are characteristic of naphthas made from low sulphur paraffin base crude oils. Tarry and creosotic odors are characteristic of cracked residues. Fatty odors are often noticed in illuminating oils. Acid and sulphurous odors are found in sludge oils from agitator treatment. Sulphuretted hydrogen and pungent odors come from high sulphur crude oils, such as Mexican. Pyridine odors come from oils containing a large amount of nitrogen (California) and from shale oils.

Odors may be intensified in some cases by mild treatment of the oil with acid or with caustic.

4. Transparency of Oil.

Transparency may be expressed by the thickness of oil in centimeters through which the filament of a fifty watt Mazda electric lamp is visible. It may be also noted whether the oil is fluorescent and the character of the fluorescence, whether bluish, greenish or yellowish by reflected light; also whether any turbidity is of a smoky, granular or flocculent character.

Transparency is usually closely related to color. Transparency is often affected by the blending of oils, the mixing of light crude with heavy crude oil or of paraffin base with asphaltic base crude oil often produces a turbidity.

5-A. Viscosity of Liquid Petroleum Products.

(SAYBOLT UNIVERSAL.) (A. S. T. M.)

The apparatus is shown in figure 100.

To make the test, heat the bath to the necessary temperature and clean out the standard oil tube with the plunger, using some of he oil to be tested. Place the cork stopper into the lower end of the air chamber at the bottom of the standard oil tube. The stopper should be sufficiently inserted to prevent the escape of air, but should not touch the small outlet tube of the standard oil tube. Heat the oil to be tested, outside the viscosimeter, to slightly below the temperature at which the viscosity is to be determined and pour it into the standard oil tube until it ceases to overflow into the overflow cup.

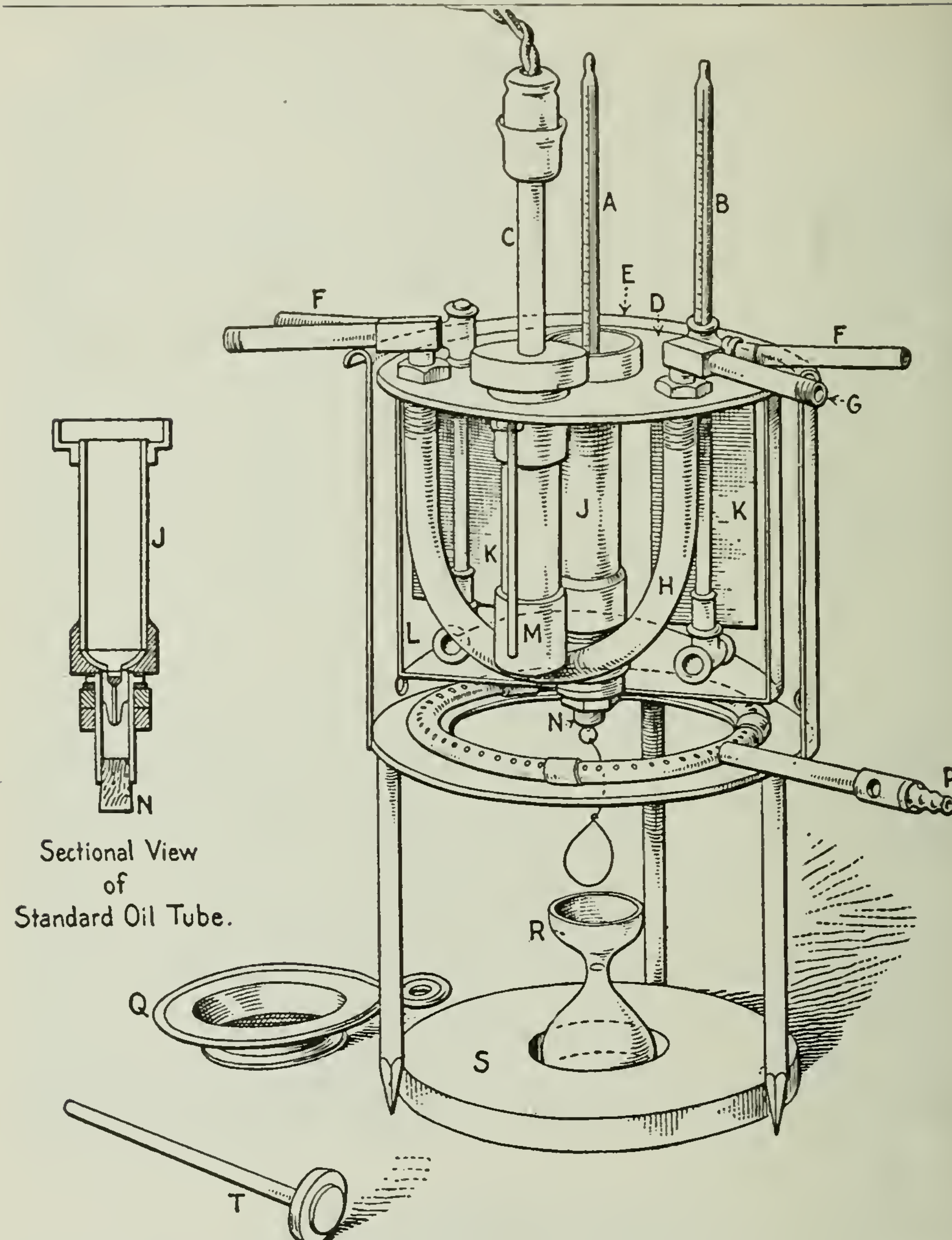
By means of the oil tube thermometer keep the oil in the standard oil tube well stirred and also stir well the oil in the bath. It is extremely important that the temperature of the oil in the bath be maintained constant during the entire time consumed in making the test. When the temperature of the oil in the bath and in the standard oil tube are constant and the oil in the standard oil tube is at the desired temperature, withdraw the oil tube thermometer; quickly remove the surplus oil from the overflow cup by means of a pipette so that the level of the oil in the overflow cup is below the level of the oil in the tube proper; place the 60-cc. flask in position so that the oil from the outlet tube will flow into the flask without making bubbles; snap the cork from its position, and at the same instant start the stop watch. Stir the liquid in the bath during the run and carefully maintain it at the previously determined proper temperature. Stop the watch when the bottom of the meniscus of the oil reaches the mark on the neck of the receiving flask.

The time in seconds for the delivery of 60-cc. of oil is the Saybolt viscosity of the oil at the temperature at which the test was made.

Viscosity is commonly determined at 100°F, 150°F or 210°F. The bath is held constant within .25°F at such a temperature as will maintain the desired temperature in the standard oil tube. Oil or water is used as the bath liquid. The oil for the bath should be a pale engine oil of at least 350°F flash point (open cup). Viscosity determinations should be made in a room free from draughts, and from rapid changes in temperature. All oil introduced into the standard oil tube, either for cleaning or for test, shall first be passed through the strainer.

This is the test for the viscosity of lubricants adopted by the American Society for Testing Materials.

The Saybolt standard universal viscosimeter is made entirely of metal. The standard oil tube is fitted at the top with an overflow cup and the tube is surrounded by a bath. At the bottom of the standard oil tube is a small outlet tube through which the oil to be tested flows into a receiving flask, whose capacity to a mark on its neck is 60 (+0.15) cc. The lower end of the outlet tube is enclosed by a larger tube, which when stoppered by a cork acts as a closed air chamber and prevents the flow of oil through the outlet tube until the cork is removed and the test started. A looped wire is attached to the lower end of the cork as an aid to its rapid removal. The bath is provided with two stirring paddles and operated by two turn-table



A Oil Tube Thermometer.	*K* Stirring Paddles.
B Bath Thermometer.	*L* Bath Vessel.
C Electric Heater.	*M* Electric Heater Receptacle.
D Turntable Cover.	*N* Outlet Cork Stopper.
E Overflow Cup.	*P* Gas Burner.
F Turntable Handles.	*Q* Strainer.
G Steam Inlet or Outlet	*R* Receiving Flask.
H Steam U-Tube.	*S* Base Block.
J Standard Oil Tube.	*T* Tube Cleaning Plunger.

Fig. 100—Saybolt Universal Viscosimeter.

handles. The temperatures in the standard oil tube and in the bath are shown by thermometers. The bath may be heated by a gas ring burner, steam U-tube, or electric heater. The standard oil tube is cleaned by means of a tube cleaning plunger, and all oil entering the standard oil tube shall be strained through a 30-mesh brass wire strainer. A stop watch is used for taking the time of flow of the oil and a pipette, fitted with a rubber suction bulb, is used for draining the overflow cup of the standard oil tube.

The standard oil tube should be standardized by the United States Bureau of Standards, Washington, and conforms to the following dimensions:

Dimensions	Minimum, Cm.	Normal, Cm.	Maximum, Cm.
Inside diameter of outlet tube	0.1750	0.1765	0.1780
Length of outlet tube	1.215	1.225	1.235
Height of overflow rim above bottom of outlet tube	12.40	12.50	12.60
Diameter of container of standard oil tube	2.955	2.975	2.995
Outer diameter of outlet tube at lower end	0.28	0.30	0.32

The approximate factors for conversion of readings of the Saybolt Universal to other instruments are as follows: (for the usual range of use):

To Saybolt Furol	.101	to	.113
To MacMichael	.50		.65
To Saybolt "A"	0.5		1.0
To Saybolt "C"	0.46		.72
To Engler	0.027		.035
To Tagliabue	0.25		.51
To Penn. R. R. Pipet	0.30		.94
To Scott	0.13		......
To Redwood	0.83		.90
To Magruder Plunger	1.25		2.0
To Ostwald	1.30		1.90

These values are not exact as they vary greatly with the actual viscosity readings. For exact conversion to Engler and Redwood values, see the following pages.

70°F may be used for light oils, gas oils, "straw" oils, engine oils, dynamo oils, auto oils, cottonseed oils and the like.

100°F may be used for Engine oils, machine oils and occasionally cylinder oils.

210°F may be used for cylinder oils, road oils, other heavy oils and asphaltic fluxes.

338°F may be used for asphalt, fluxes, paraffin wax and residues.

Other viscosimeters in use are the Engler, Tagliabue, Scott, Redwood, Penn. Ry. pipet, MacMichael, Lamansky-Nobel, Ostwald, Martens, Stormer, Ubbelohde, Lepenau, Kuenkler, Albrecht, Arvine, Barbey, Cockrell, Doolittle, Gibbs, Mason, Napier, Nasmyth, Phillips, Reischauer, Magruder.

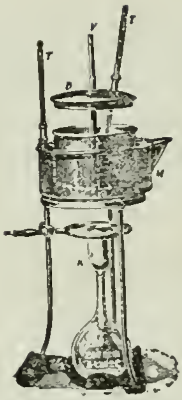


Fig. 101—Engler Viscosimeter.

The Engler viscosimeter is used most extensively in Germany and its dimensions are as follows:

Width of jet	4.5 mm
Inside diameter of the inside vessel for oil	106 mm
Height of vessel below overflow	25 mm
Length of the oil jet	20 mm
Inside diameter of the oil jet upper end	2.9 mm
Inside diameter of the oil jet lower end	2.8 mm
Length of jet projecting from lower part of outer vessel	3.0 mm

The quotient of the time of outflow of 200 cc. of oil divided by the time of outflow of 200 cc. of water is taken as a measure of the viscosity or is the so-called Engler degree.* ("Specific Viscosity.")

The Redwood viscosity is used extensively in England and its value may be calculated from the Engler or the Saybolt.

*Tables for the interchange of readings on the Saybolt, Engler and Redwood Viscosimeters are on the following pages.

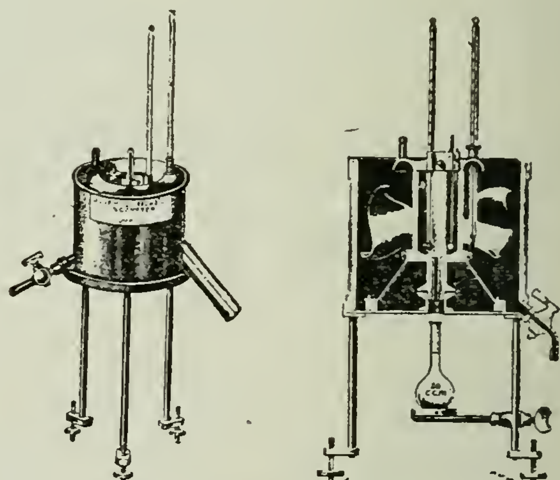


Fig. 102—Redwood Viscosimeter.

Bureau of Standards—Viscosimeter Comparisons.

Calculated Time Ratios from Equations:

$$\text{Kinematic Viscosity} = .00147\,t - \frac{3.74}{t}$$ for Engler No. 2204 U (See Tech. Paper No. 112, p. 14, 1919)

$$\text{Kinematic Viscosity} = .00220\,t - \frac{1.80}{t}$$ for Standard Saybolt Universal (See Tech. Paper 112, p. 19, 1919)

$$\text{Kinematic Viscosity} = .00260\,t - \frac{1.715}{t}$$ for Redwood (See W. F. Higgins Collected Researches, National.

Physical Lab., Vol. 11, p. 18, 1914: quoted in Tech. Paper 112, p. 25, 1919.

Time Engler Second	Time Engler Time, Saybolt	Time Engler Time, Redwood
58	1.72	1.93
60	1.71	1.93
62	1.70	1.92
64	1.69	1.91
66	1.68	1.91
68	1.68	1.90
70	1.67	1.90
75	1.65	1.88
80	1.63	1.87
85	1.62	1.86
90	1.61	1.86
95	1.60	1.85
100	1.59	1.84
110	1.58	1.83
120	1.56	1.82
130	1.56	1.81
140	1.55	1.81
150	1.54	1.80
160	1.53	1.80
180	1.52	1.80
200	1.52	1.79
225	1.51	1.79
250	1.51	1.78
275	1.51	1.78
300	1.51	1.78
325	1.51	1.78
350	1.50	1.78
375	1.50	1.77
400	1.50	1.77
500	1.50	1.77
600	1.50*	1.77*

Multiplying factors to reduce Saybolt times to Engler numbers or Redwood times.

Engler Degrees.	Saybolt Time. Engler Degrees.	Redwood Time. Engler Degrees.
1.15	29.9	26.5
1.20	30.1	26.7
1.25	30.3	26.8
1.30	30.5	26.9
1.35	30.7	27.0
1.40	30.9	27.1
1.45	31.1	27.2
1.50	31.3	27.3
1.60	31.5	27.4
1.70	31.7	27.5
1.80	31.9	27.6
1.90	32.1	27.7
2.00	32.3	27.9
2.10	32.5	28.0
2.20	32.6	28.1
2.30	32.8	28.2
2.40	32.9	28.2
2.50	33.0	28.3
2.60	33.1	28.3
2.70	33.2	28.4
2.80	33.3	28.4
2.90	33.4	28.5
3.00	33.5	28.5
3.50	33.6	28.6
4.00	33.7	28.7
4.50	33.9	28.8
5.00	33.9	28.8
6.00	34.0	28.9
7.00	34.1	28.9
8.00	34.1	28.9
9.00	34.2*	29.0*

*This value holds good for all higher viscosities. (Bureau of Standards.)

Viscosimeter Comparisons.

Multiplying factors to reduce Engler degrees to Saybolt or Redwood times.

Saybolt Time.	Engler Degrees. Saybolt Time.	Redwood Times. Saybolt Time.
34	.0335	.890
36	.0332	.886
38	.0330	.884
40	.0328	.882
42	.0326	.879
44	.0324	.877
46	.0322	.875
48	.0319	.873
50	.0317	.871
55	.0315	.869
60	.0313	.866
65	.0312	.864
70	.0310	.861
75	.0308	.859
80	.0307	.858
85	.0305	.857
90	.0304	.856
95	.0303	.855
100	.0302	.854
110	.0301	.853
120	.0300	.852
130	.0299	.851
140	.0299	.850
160	.0298	.849
180	.0297	.848
200	.0296	.848
225	.0295	.848
250	.0294	.847
300	.0293	.847
350	.0293	.847
400	.0292*	.846*

Redwood to Saybolt and Engler.

Redwood Time. Seconds.	Saybolt Time. Redwood Time.	Engler Degrees. Redwood Time.
30	1.12	.0377
32	1.13	.0375
34	1.13	.0372
36	1.14	.0370
38	1.14	.0369
40	1.14	.0368
42	1.15	.0366
44	1.15	.0365
46	1.15	.0363
48	1.15	.0362
50	1.16	.0361
55	1.16	.0359
60	1.16	.0357
65	1.16	.0355
70	1.17	.0354
75	1.17	.0353
80	1.17	.0352
85	1.17	.0351
90	1.17	.0350
95	1.17	.0350
100	1.17	.0350
110	1.18	.0349
120	1.18	.0348
130	1.18	.0347
140	1.18	.0347
150	1.18	.0347
160	1.18	.0347
180	1.18	.0347
200	1.18	.0347
225	1.18	.0346
250	1.18*	.0345*

*This value holds good for all higher viscosities. (Bureau of Standards.)

5-B. VISCOSITY OF FUEL OILS AND ROAD OILS.

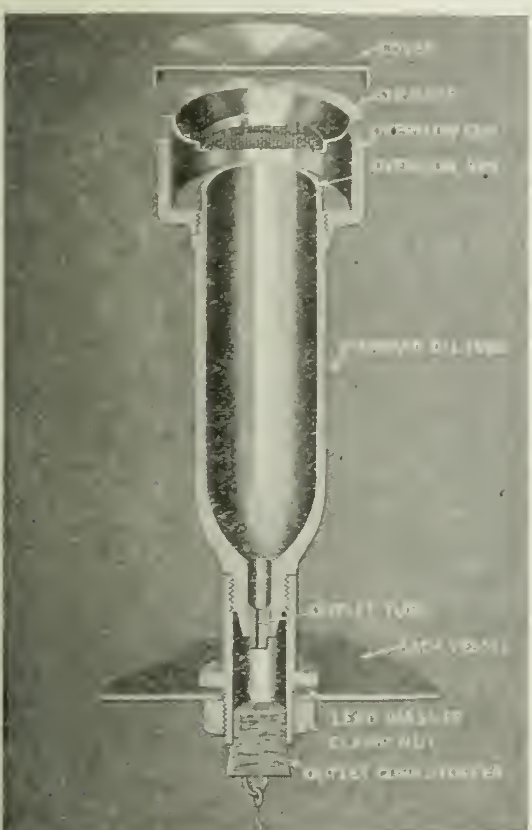


Fig. 103—Furol Viscosity Tube. (Cameragraph Co. of Kansas City.)

Viscosity is determined by means of the Saybolt Furol Viscosimeter.

The apparatus and method of operation is the same as for the Standard Saybolt Universal Viscosimeter, all dimensions being the same except the diameter of the outlet tube which shall be as follows:

Inside diameter of outlet tube, cm.—

Minimum	Normal	Maximum
0.313	0.315	0.317

Outside diameter at lower end, cm.—

Minimum	Normal	Maximum
0.40	0.43	0.46

Viscosity may be determined at 104°F (40°C), 122°F (50°C) or 70°F and is expressed as—seconds, Saybolt Furol, being the time in seconds for the delivery of 60 cc. of oil.

Oil showing a time of less than 25 seconds, Saybolt Furol, at 122°F, should be tested on the Saybolt Universal at 122°F. Oil showing a time of less than 32 seconds Saybolt Universal, at 122°F should be measured in the Saybolt Universal at 100°F (37°8C).

5-C. METHOD FOR DETERMINING THE VISCOSITY OF KEROSENE AND GASOLINE.

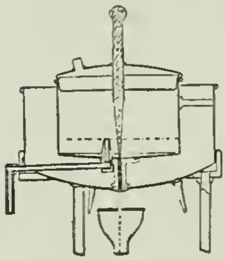


Fig. 104—Ubbelohde Viscosimeter.

The apparatus used for this test is essentially that described on pages 55, 56 and 57 of Holde's "Examination of Hydrocarbon Oils." A diagram of the apparatus is shown in figure 104. The instrument is known as the Ubbelohde viscosimeter.

The dimensions are as follows:

	Normal Instrument	
Inner diameter of outlet tube at top	0.125	centimeters
Inner diameter of outlet tube at bottom	0.125	"
Outside diam. of outlet tube at bottom, d_1	1.0	"
Length of outlet tube, l	3.0	"
Diameter of container, D	10.5	"
Outside diameter of overflow pipe, d_2	......	
Initial head on bottom of outlet tube, h_1	4.6	"
Average head, h (calculated)	3.992	"
Water rate	200	seconds
Capacity of container	132	cubic centimeters

The apparatus is placed in a horizontal position by means of the plummet, the outflow tube is examined by looking through from the top with a sheet of white paper underneath to determine if there are any obstructions or dirt. If dirty, the outflow tube is cleaned by drawing a silk thread back and forth through it. Water or cracked ice, depending upon the temperature desired, is placed in the outer vessel, the plug is put in place and an excess of kerosene or gasoline introduced. The excess runs out of the overflow pipe. The plug is loosened sufficiently to allow just a drop of liquid to pass out to the jet. When the proper temperature has been maintained for 15 minutes the plug is withdrawn and the time required to fill the 100 cc. flask is determined with the stop watch. The time divided by the time required for water gives the viscosity. For example, if the time of outflow of kerosene is 320 seconds and the water is 200 seconds, the viscosity is 1.6.

5-D. VISCOSITY WITH THE MacMICHAEL VISCOSIMETER.

In the MacMichael Viscosimeter a disk is suspended in a cup of fluid. The force exerted by the rotation of the fluid on the plunger is measured.

The cup is oil jacketed, being formed of two pieces of heavy spun brass. Within the oil jacket is immersed an electric heating coil. This coil draws current from the same line as the motor, only one connection being necessary. The fluid to be tested is heated in place, no other heating device being required. Stirring is effected by a slight vertical movement of the plunger. For low temperature work, the fluid and the adjacent parts are chilled in an ice bath or brine solution.

The speed control is of the phonograph type. The motor is adapted for ordinary lighting circuits. Variations in voltage do not affect the accuracy of the determinations.

In operating, the cup is filled to the mark on the side with the material to be tested. This requires about 100 cc. The temperature is raised or lowered by means of the heating coils. The deflection noted on the dial is the viscosity of the fluid.

The operation is very rapid, so that the drop in temperature on ordinary work is entirely negligible. For extreme accuracy, the temperature may be raised slightly above the desired point, and an allowance made for the drop up to the moment of reading. This will seldom be found necessary in actual practice. The readings are in degrees of angular deflection, 300° to the circle, designated as °M. The practical working unit is 1/1000 of the absolute unit. As water at 20°C or 68°F has exactly 1/100 of the absolute unit of viscosity, water at this temperature reads 10°M. Thus by shifting the decimal point practical units, absolute units and specific viscosity may be obtained at one reading. Readings are taken directly from the dial, no intermediate calculations being required.

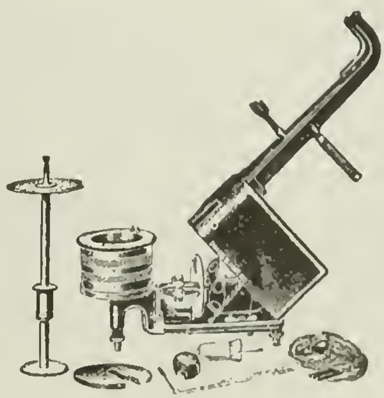


Fig. 105—MacMichael Viscosimeter.

5-E. FLOAT TEST (VISCOSITY) OF PETROLEUM RESIDUES.

The special apparatus for the float test consists of an aluminum saucer having a diameter of 8.89 centimeters and a depth of 2.54 cm. and a radius of curvature of 5.16 cm. At the bottom there is an opening into which a collar may be screwed. This conical collar is 2.22 cm. long, is 0.95 cm. in diameter at the small end, 1.27 cm. in diameter at the large end and has a wall 0.13 cm. thick. This apparatus and method of operating is shown in Fig. 107.

In making the test the brass conical collar is placed with the small end down on a brass plate which has been previously amalgamated with mercuric chloride. A small quantity of the material to be tested is carefully heated until quite fluid. It is then poured into the collar until slightly more than level with the top. The collar and plate are placed in ice water until rigid. The excess of material protruding from the collar is cut off with a warm knife. A pan of water is now heated to the desired temperature. The material should be kept in the ice water at least 15 minutes at a temperature of 5°C. The collar with the material is quickly screwed into the aluminum float which is immediately placed in the warm bath. As the plug of material becomes warm and fluid it is forced upward and out of the collar until the water gains entrance to the saucer and causes it to sink. The time in seconds between placing the apparatus on the water and when the water breaks through the residue is determined with the stop watch and is recorded as the measure of the consistency of the material. Unless otherwise specified, the float test is made at 50°C, but it would necessarily be higher with the more viscous materials.

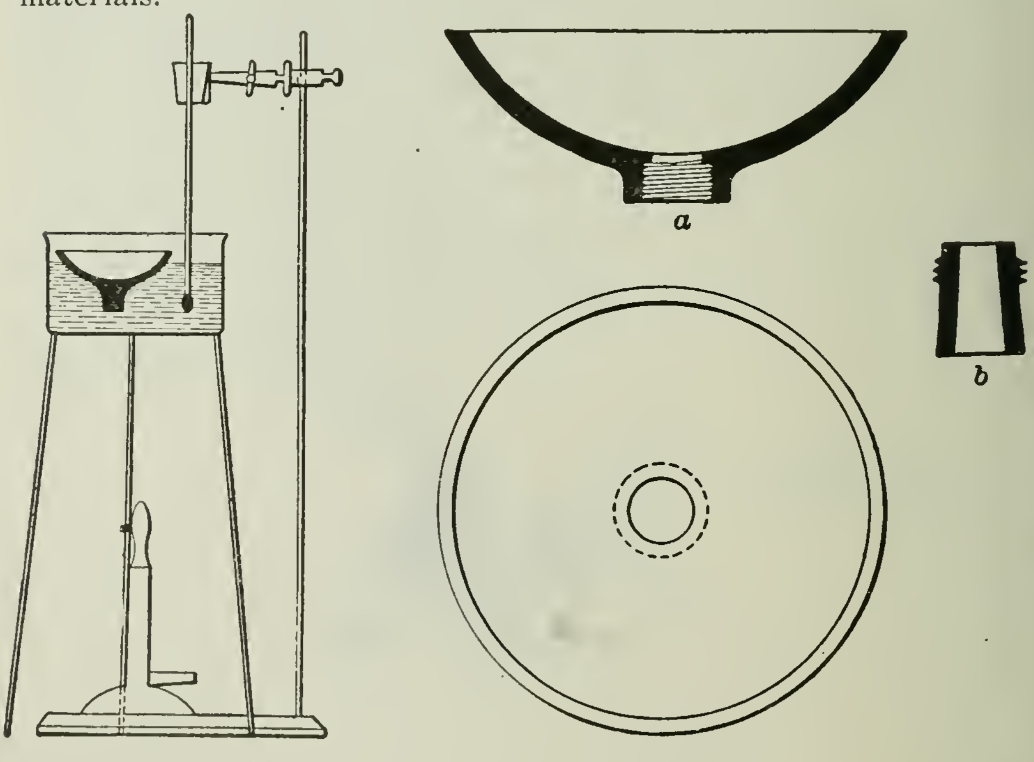


Fig. 107—Float Test Apparatus.

5-F. ZERO VISCOSITY FOR SEMI-SOLID PETROLEUM PRODUCTS.

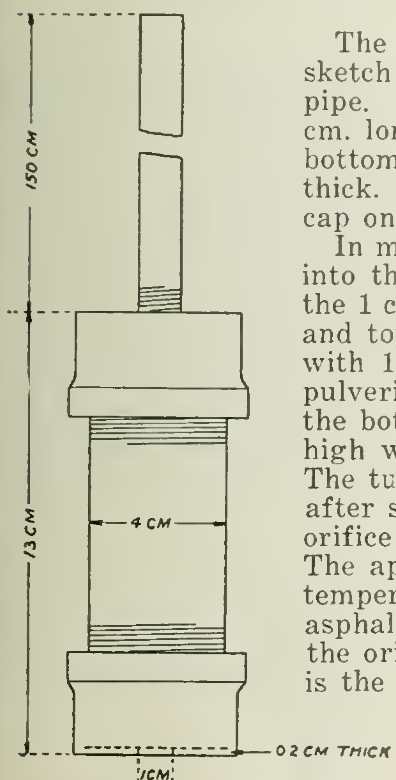


Fig. 106—Zero Viscosimeter.

The apparatus used is a cylinder shown in the sketch and may be constructed from ordinary iron pipe. The cylinder is 4 cm. in diameter and 13 cm. long with an opening centrally located in the bottom 1 cm. in diameter and with lips 2 mm. thick. A tube 150 cm. long is screwed into the cap on the top.

In making the test the melted asphalt is poured into the cylinder with the cap off of the top and the 1 cm. opening on the flat surface. It is cooled and topped with more asphalt, the cap is put on with 150 cm. tube and the cylinder is packed in pulverized ice and supported horizontally so that the bottom rests on a circular ring at least 1 cm. high which keeps the ice away from the orifice. The tube when ice cold is filled with mercury and after some of the asphalt has protruded from the orifice it is trimmed off flush with the outer edge. The apparatus is now supported vertically at the temperature of 0°C for 5 hours. The weight of asphalt or bituminous material protruding from the orifice after this time expressed in decigrams is the zero viscosity.

5-G. VISCOSITY OF PETROLATUM.

Obtain a sample that exactly represents batch under inspection. Melt slowly and heat to a temperature 15°F above its probable melting point. Chill the thermometer bulb to 40°F, wipe dry, thrust into melted petrolatum, remove immediately, hold vertically until surface dulls, and suspend at room temperature for 60 minutes.

Suspend thermometer in the test tube with lowest end of bulb 15 mm. from the bottom. While the glass ring above the bulb is expected to prevent rubbing of coating of petrolatum, care should be exercised in inserting thermometer into the test tube.

Surround this assembly with water bath at 60°F. Raise temperature of bath 2°F per minute to 100°F then 1°F to end of test. Read thermometer when first drop leaves it and record. An average of three such tests, if the variation does not exceed 2°F, may be given as the melting point of the sample under test. If a greater variation, take the average of five determinations. (From page 359, 1921 Proc. of A. S. T. M.)

6-A. MELTING POINT OF BITUMINOUS MATERIALS. (SOFTENING POINT.) (Ring and Ball Method.)

The apparatus consists of a brass ring ⅝-inch in diameter, ¼-inch deep, 3/32-inch wall suspended 1 inch above the bottom of the beaker; a steel ball ⅜-inch in diameter weighing between 3.45 and 3.50 grams, a standardized thermometer and a 600 cc. glass beaker.

Carefully melt the sample and fill the ring with the material to be tested, removing any excess. Place the ball in the center of the ring and suspend in the beaker containing 400 cc. of water at a temperature of 5°C. Set the thermometer bulb within ½ inch of the sample and at the same level. Apply heat uniformly, preferably with a 200 watt electric hot plate over the bottom of the beaker sufficiently to raise the temperature of the water 5°C per minute. Record the temperature at starting the test and every minute thereafter until the test is completed. The softening point is the temperature at which the specimen touches the bottom of the beaker. For temperatures above 99°C glycerin should be used instead of water. Tests should check within 3°C.

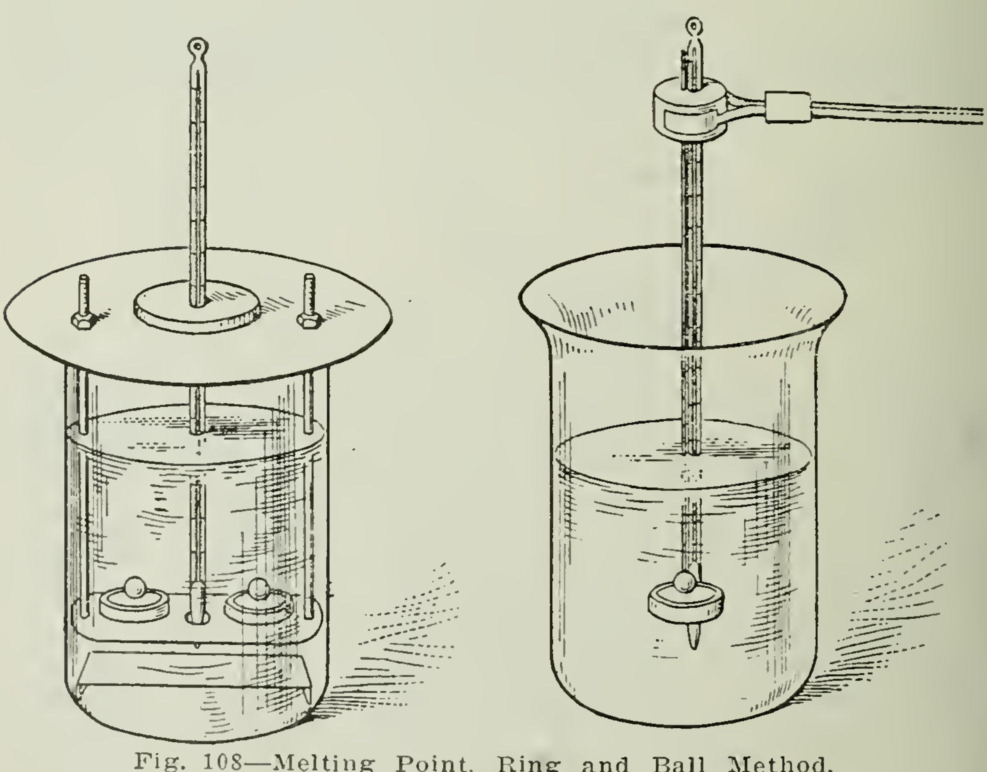


Fig. 108—Melting Point, Ring and Ball Method.

6-B. MELTING POINT OF BITUMINOUS MATERIALS. (Cube Method.)

The bituminous material is carefully melted and poured into the ½-inch brass cubical mold which has been amalgamated with mercury and which is set on an amalgamated brass plate. The hot material should slightly more than fill the mold and when cold the excess may be cut off with a hot spatula. The cube is removed from the mold and fastened upon the lower arm of a No. 12 wire B. & S. gauge bent at right angles and suspended beside a thermometer in a tall covered beaker of 400 cc. capacity.

This tall form beaker is set in an 800 cc. low form beaker which is arranged for the application of heat. The wire is passed through the center of the two opposite faces of the cube which is suspended with its base one inch above the bottom of the inside beaker. The inner beaker cover has two openings, one for the wire and one for the thermometer. The wire is held in place by a cork in the cover. The bulb of the thermometer is level with the cube and at an equal distance from the sides of the beaker. Heat is applied to the liquid in the outer vessel in such manner that the thermometer registers an increase of 5°C per minute and the temperature at which the bitumen touches a piece of paper placed in the bottom of the beaker is taken as the melting point. Determinations should check within 2°. The temperature at the beginning of the test should be approximately room temperature.

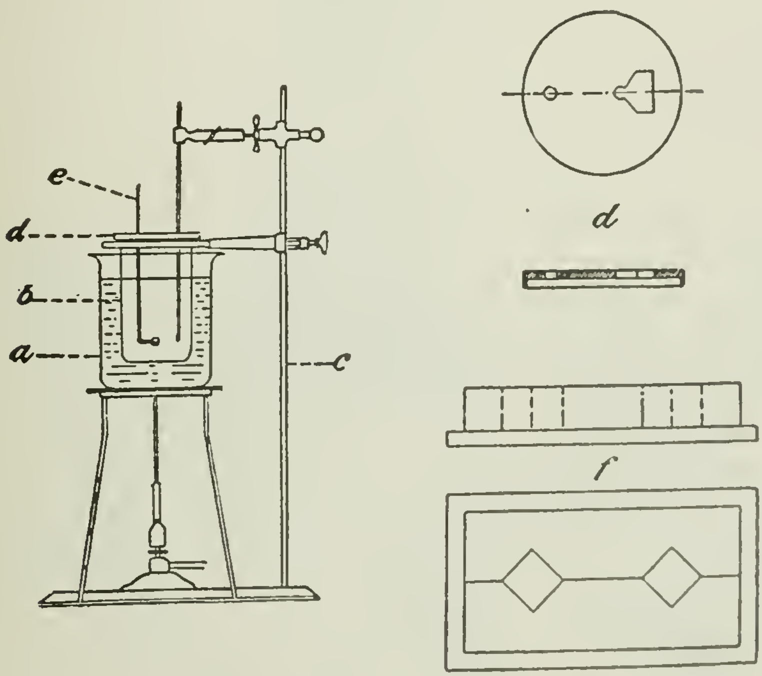


Fig. 109—Melting Point, Cube Method.

6-C. MELTING POINT OF BITUMINOUS MATERIALS.
(General Electric Method.)

Mold one gram of the bituminous material so that it completely and uniformly covers the short bulb of a thermometer graduated to at least 500°F. Fit this thermometer with a cork into a ⅝x6-inch test tube with a side tubulation or air vent so that the bulb of the thermometer is ¾-inch from the bottom of the tube. Support the thermometer and tube with a clamp and immerse the tube to a depth of four inches in 400 cc. of commercial concentrated sulphuric acid in a 600 cc. beaker. The beaker of sulphuric acid is heated by direct contact with an electric hot plate of 220 watt capacity and 4½ inches in diameter.

The melting point is taken from readings of the thermometer when the bituminous material flows sufficiently that a tear strikes the bottom of the tube.

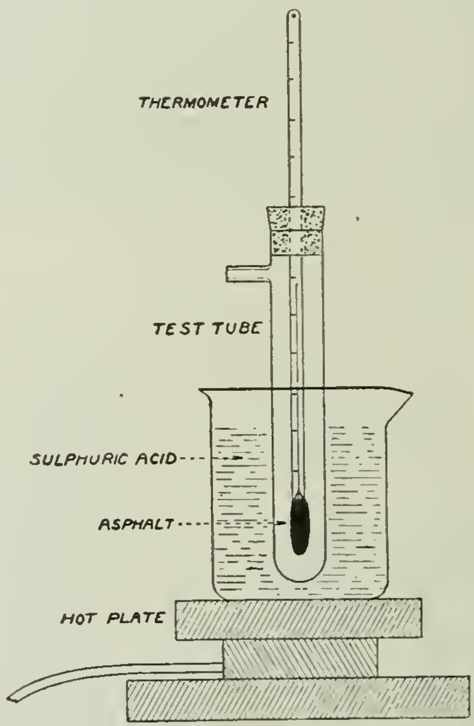


Fig. 110—Melting Point, General Electric Method.

Comparison of General Electric and Ball and Ring methods for melting point:

B. & R.	G. E.
246°F	270°F
220	240
185	200
140	150

6-D. WAX MELTING POINT. (SO CALLED "ENGLISH" METHOD.)

The apparatus is shown in figures 111 and 112.

An average sample of the wax to be tested is melted in a suitable container in a water bath whose temperature is not more than 35°F above the approximate melting point of the wax sample. Direct heat, such as a flame or hot plate, must not be used and the wax sample must not be held in the melted condition any longer than necessary.

The test tube is filled with melted wax to a height of 2 in. The test tube cork, carrying the stirrer and the melting point thermometer, with the 3⅛-in. immersion line at the under surface of the cork, is inserted into the test tube for a distance of ½-in. The lower end of the thermometer bulb is then ⅜-in. from the bottom of the test tube.

The air bath being in its proper position in the water bath, the latter is filled to within ½ in. of the top with water at a temperature 15 to 20°F below the approximate melting point of the wax sample.

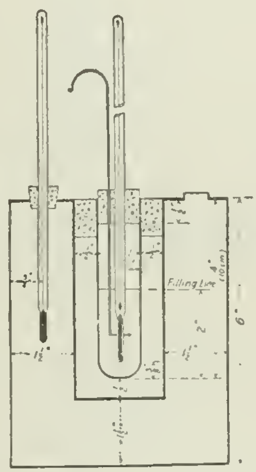


Fig. 111—Melting Point of Wax.

The test tube containing the melted wax, with wax stirrer and thermometer in place is inserted into the air bath in a central vertical position so that the bottom of the test tube is ½ in. from the bottom of the air bath. The temperature of the water bath is adjusted by stirring if necessary, so that it is lower than the temperature of the wax sample by not more than 30°F and not less than 25°F, when the wax sample has cooled to a temperature 10°F above its approximate melting point.

When these conditions have been obtained, temperature adjustment and stirring of the water bath are discontinued. The wax is stirred continuously during the remainder of the test, the stirring loop being moved up and down throughout the entire length of the test tube in a steady motion at the rate of 20 complete cycles per minute. The melting point thermometer reading, estimated to 1°F is observed and recorded every 30 seconds. The temperature of the wax will fall gradually at first, will then become almost constant and will then again fall gradually.

The melting point thermometer reading, estimated to .1°F, is observed and recorded every 30 seconds, for at least three minutes after the temperature again begins to fall after remaining almost constant. The record of temperature readings is then inspected and the average of the first four readings that lie within a range of .2°F is the uncorrected melting point.

The A. S. T. M. wax test thermometer should be used (approx. 37 cm. long 3 in. immersion).

The titer test apparatus shown in Fig. 112 gives practically the same results as the above and is very simple and inexpensive.

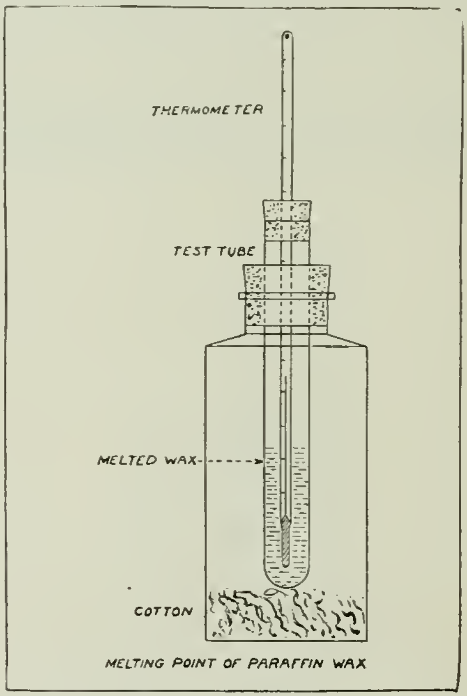


Fig. 112—Melting Point of Wax (Titer Method).

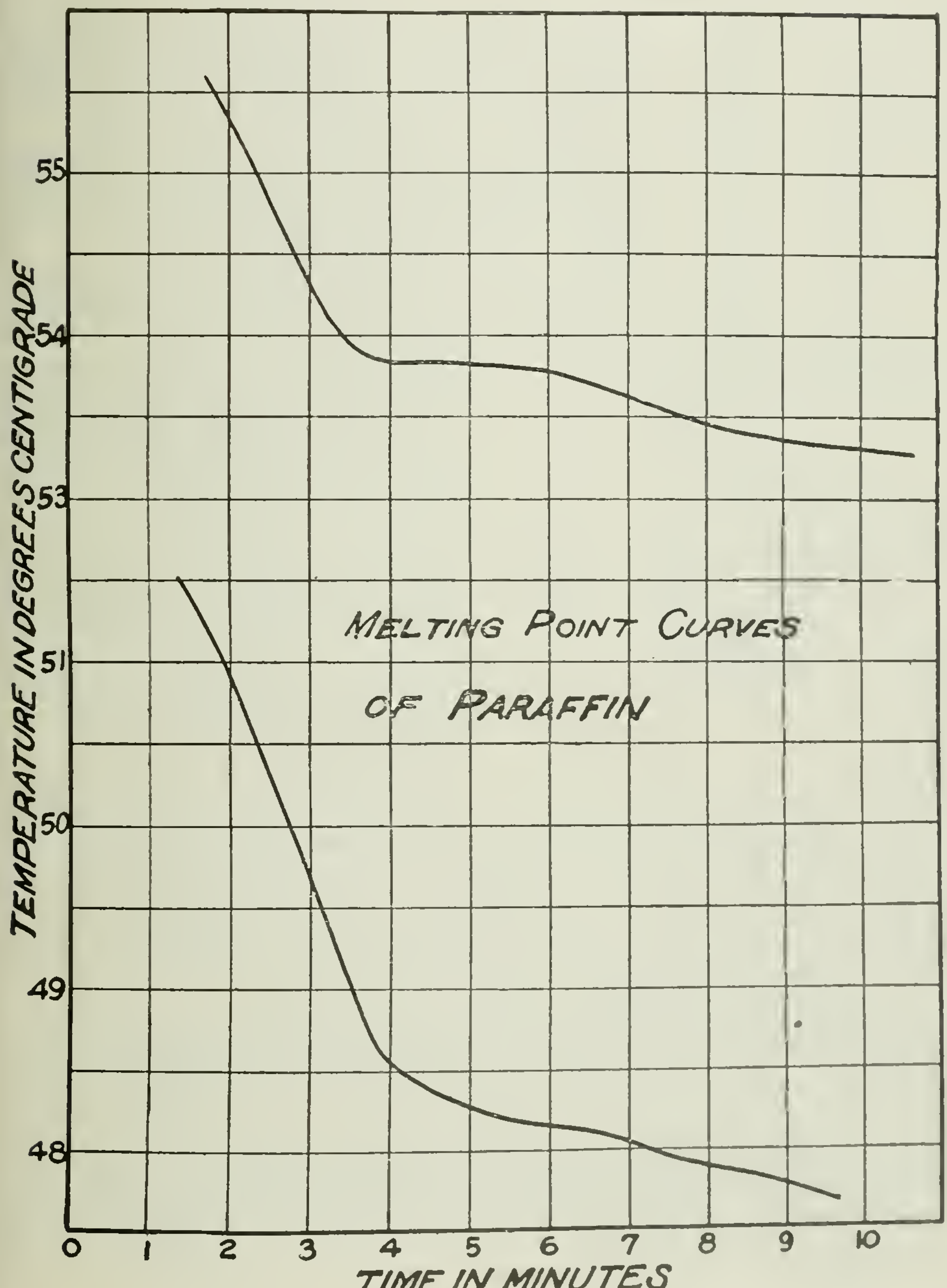


Fig. 113—Freezing Point Curve of Wax.

7-A. CLOUD, POUR AND COLD TESTS.

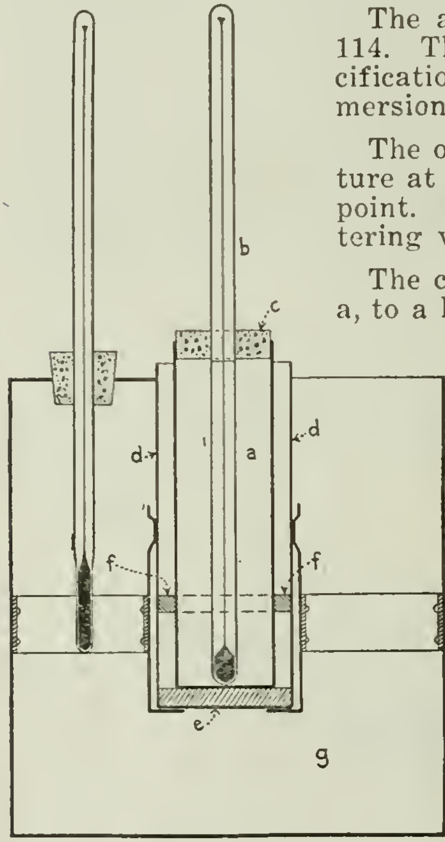


Fig. 114—Cloud and Pour Test Apparatus.

The apparatus is set up as shown in figure 114. The thermometer is per A. S. T. M. specification, 22.2 cm. long scaled for 4¼-in. immersion, —36° to +120°F.

The oil to be tested is brought to a temperature at least 25°F above the approximate cloud point. Moisture, if present, is removed by filtering while warm and thin.

The clear oil is poured into the cold test jar, a, to a height of not less than 1 nor more than 1¼ in.

The cold test jar is tightly closed by the cork, c, carrying the cold test thermometer, b, in a vertical position in the center of the jar with the thermometer bulb resting on the bottom of the jar.

The disk, e, is placed in the bottom of the jacket, d, and the cold test jar with the ring gasket, f, 1 in. above the bottom shall be inserted into the jacket. The disk, jacket and inside of jacket shall be clean and dry.

The temperature of the cooling bath, g, shall be adjusted so that it is below the cloud point of the oil by not less than 15° nor more than 30°F and this temperature is maintained throughout the test. The jacket, containing the cold test jar, is supported firmly in a vertical position in the cooling bath so that not more than 1 in. of the jacket projects out of the cooling medium.

At each cold test thermometer reading which is a multiple of 2°F the cold test jar is removed from the jacket, quickly but without disturbing the oil, inspected for cloud and replaced in the jacket. This complete operation must be done in not more than three seconds.

When the bottom of the oil has become opaque, to a height of not less than ⅛ nor more than $\frac{3}{16}$ in., the reading of the cold test thermometer, corrected for error if necessary, shall be recorded as the cloud point. The required height of cloud is approximately at the middle of the thermometer bulb. The cold test jar may be marked to indicate the proper level.

Oils having a viscosity greater than 600 seconds, Saybolt Universal at 100°F, are allowed to stand in the cold test jar at a temperature of 60° to 85°F for at least five hours prior to making the test for pour point. A viscous oil which has been stored in a warm place is liable to show an abnormally low, fictitious pour point unless this precaution is observed. Oils having a viscosity not greater than 600 seconds, Saybolt Universal at 100°F, may be tested without such preliminary standing.

After preliminary standing, if necessary, the oil to be tested is brought to a temperature of 90°F, or to a temperature 15°F higher than its pour point, if this pour point is above 75°F, and is poured into the cold test jar, a, to a height of not less than 2 nor more than 2¼ in. The jar may be marked to indicate the proper level.

The cold test jar shall be tightly closed by the cork, c, carrying the cold test thermometer, b, in a vertical position in the center of the jar with the thermometer bulb immersed so that the beginning of the capillary shall be ⅛ in. below the surface of the oil.

The disk, e, shall be placed in the bottom of the jacket, d, and the cold test jar, with the ring gasket, f, 1 in. above the bottom is inserted into the jacket. The disk, gasket and inside of jacket shall be clean and dry.

The temperature of the cooling bath, g, shall be adjusted so that it is below the pour point of the oil by not less than 15 nor more than 30°F and this temperature shall be maintained throughout the test. The jacket, containing the cold test jar, shall be supported firmly in a vertical position in the cooling bath so that not more than 1 in. of the jacket projects out of the cooling medium.

At each cold test thermometer reading which is a multiple of 5°F, the cold test jar shall be removed from the jacket carefully and shall be tilted just sufficiently to ascertain whether the oil around the thermometer remains liquid. As long as the oil around the thermometer flows when the jar is tilted slightly, the cold test jar shall be replaced in the jacket. The complete operation of removal and replacement shall require not more than three seconds. As soon as the oil around the thermometer does not flow when the jar is tilted slightly, the cold test jar shall be held in a horizontal position for exactly five seconds, and observed carefully. If the oil around the thermometer shows any movement under these conditions, the cold test jar shall be immediately replaced in the jacket and the same procedure shall be repeated at the next temperature reading 5°F lower. As soon as a temperature is reached at which the oil around the thermometer shows no movement when the cold test jar is held in a horizontal position for exactly five seconds, the test shall be stopped.

The lowest reading of the cold test thermometer, corrected for error if necessary, at which the oil around the thermometer shows any movement when the cold test jar is held in a horizontal position for exactly five seconds, shall be recorded as the pour point.

8-A. SEDIMENT AND WATER IN PETROLEUM (CENTIFUGE METHOD).

The apparatus is shown in Figs. 115 and 116.

Exactly 50 cc. of 90 per cent benzol are measured into each of two centrifuge tubes and exactly 50 cc. of the oil to be tested are then added to each. The centrifuge tubes are tightly stoppered and shaken vigorously until the contents are thoroughly mixed. The temperature of the bath is maintained at 100°F and the centrifuge tubes are immersed therein to the 100 cc. mark for 10 minutes.

The two centrifuge tubes are then placed in the centrifuge on opposite sides and are whirled at a rate of 1400 to 1500 r. p. m. or the equivalent for 10 minutes. The combined volume of water and sediment at the bottom of each tube is read and recorded, estimating to 0.1 cc. if necessary. The centrifuge tubes are then replaced in the centrifuge, again whirled for 10 minutes as before and removed for reading the volume of water and sediment as before. This operation is repeated until the combined volume of water and sediment in each tube remains constant for two consecutive readings.

The preferred form of centrifuge has a diameter of swing (tip to tip of whirling tubes) of 15 to 17 in. and a speed of at least 1500 r. p. m. or the equivalent. If the available centrifuge has a diameter of swing varying from these limits, it is run at the proper speed to give the same centrifugal force at the tips of the tubes as that obtained with the preferred form of centrifuge. The proper speed may be calculated from the following formula in which d represents diameter of swing (tip to tip of whirling tubes) of the centrifuge used:

$$\text{R. p. m.} = 1500 \sqrt{\frac{16}{d}}$$

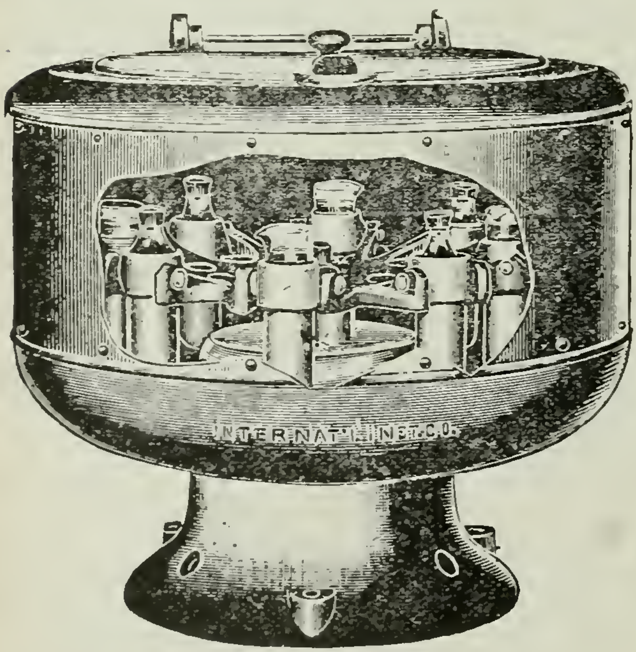


Fig. 115—Centrifuge for B. S.

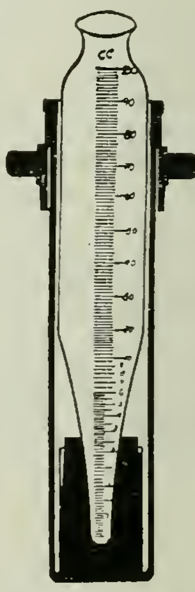


Fig. 116—Sedimentation Tubes.

8-B. WATER IN PETROLEUM PRODUCTS (DISTILLATION METHOD).

100 cc. of the oil to be tested are measured in an accurate 100-cc. graduated cylinder at room temperature and poured into the distillation flask. The oil adhering to the walls of the 100-cc. graduated cylinder is transferred to the distillation flask by rinsing with two successive 25 cc. portions of gasoline, the cylinder being allowed to drain each time. The sample is taken with great care to see that the water and the oil are uniformly mixed, insuring a representative sample. The apparatus used is that by Dean and Stark (J. of I. and E. Chem. 12-486) a figure of which is shown herewith. The oil and gasoline in the distillation flask is thoroughly mixed by swirling the flask with proper care to avoid any loss of material. A boiling stone, such as a piece of unglazed porcelain, may be introduced for the purpose of preventing bumping during the subsequent distillation.

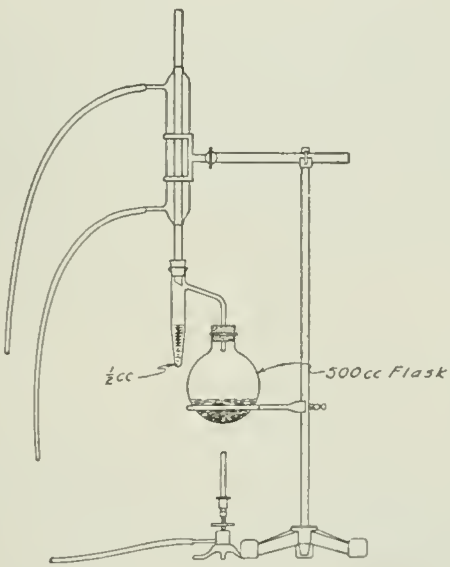


Fig. 117—Water Determination Apparatus.

The flask should be of pyrex glass.

Heat is best applied without danger of bumping or foaming by immersing the flask in a bath of glycerin. It may be applied with care using an electric heater or a gas flame. The graduated receiving tube should be kept cool. Distill until no further increase in the volume of the recovered water is observed.

9-A. END POINT DISTILLATION TESTS OF GASOLINE, NAPHTHA, BENZINE, PRESSURE DISTILLATE, TURPENTINE SUBSTITUTES AND KEROSENE.

The apparatus is shown in Figs. 118 and 119.

The condenser bath is filled with cracked ice or other convenient cooling medium and enough water is added to cover the condenser tube.

The temperature is maintained between 32°F and 40°F.

The condenser tube is swabbed out to remove any liquid remaining from a previous test.

A piece of unstarched absorbent cloth attached to a cord or copper wire may be used for this purpose.

The bulb of the distillation thermometer is covered uniformly with long fiber absorbent cotton weighing between 3 and 5 milligrams.

Fresh cotton is used for each distillation.

One hundred (100) cc. of the naphtha are measured into the 100 cc. graduated cylinder, the naphtha and cylinder being both cooled to a temperature between 55°F and 65°F and is transferred direct to the Engler flask using a long stemmed funnel with a small flare so that no liquid is permitted to flow into the vapor tube.

The Engler flask has previously been rinsed with the naphtha under test and has been allowed to drain vertically inverted for at least five minutes.

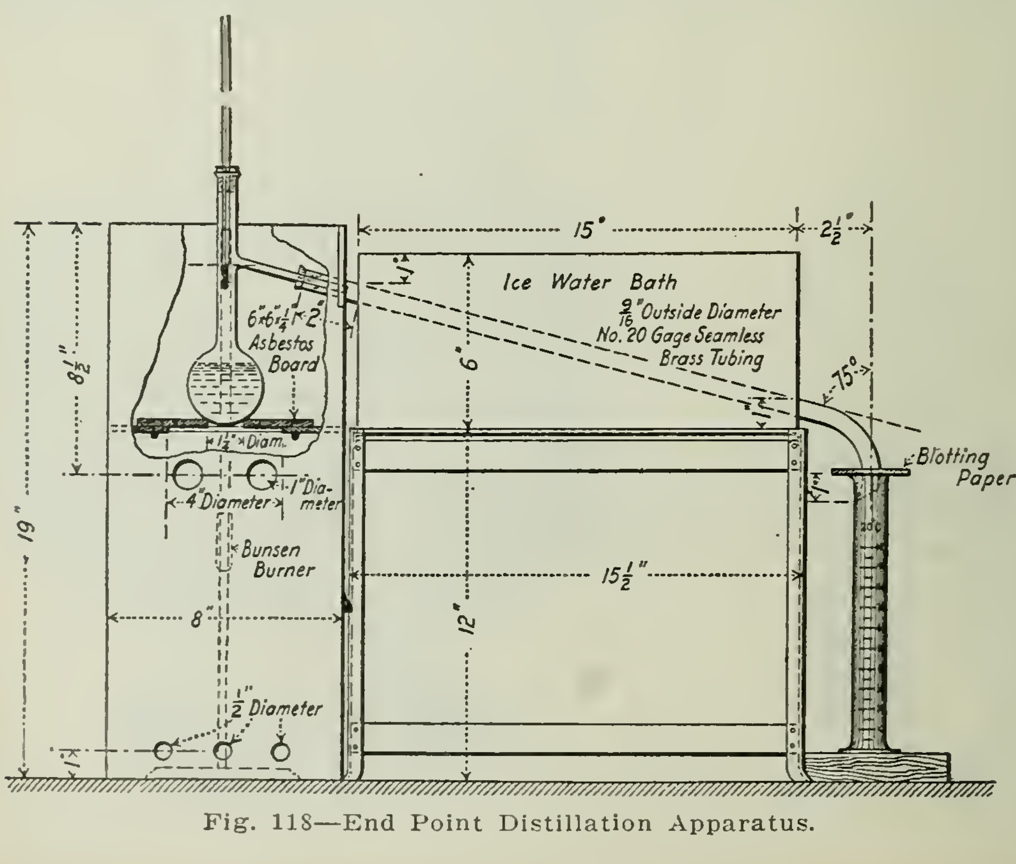


Fig. 118—End Point Distillation Apparatus.

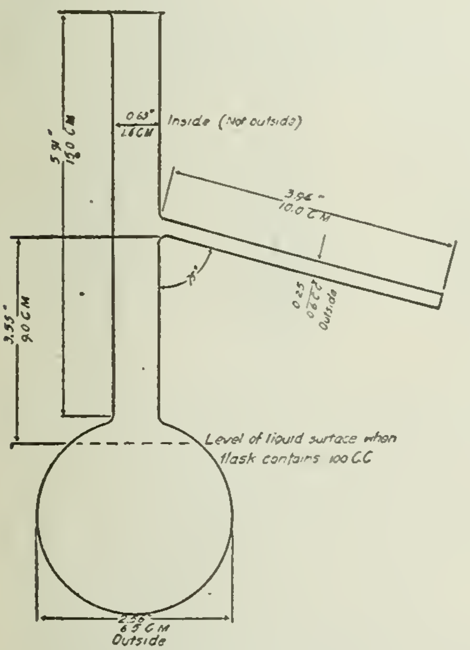
The thermometer provided with a cork is fitted tightly into the flask so that it will be in the middle of the neck and so that the lower end of the capillary tube is on a level with the inside of the bottom of the vapor outlet at its junction with the neck of the flask.

The charged flask is placed over the 1¼-inch opening in the 6x6-inch asbestos board with the vapor outlet tube inserted into the condenser tube.

A tight connection is made by means of a cork.

The position of the flask shall be so adjusted that the vapor tube extends into the condenser tube not less than one inch nor more than two inches.

The graduated cylinder which has previously been used in measuring the charge, is placed without further draining at the outlet of the condenser tube in such a position that the condenser tube shall extend into the graduate at least one inch but not below the 100 cc. mark.



Standard 100 c. c. Engler flask for use in making distillation test of gasoline.

Fig. 119—End Point Flask.

If the room temperature is above 65°F, the cylindrical graduate shall be immersed up to the 100 cc. mark in a glass water bath maintained at a temperature between 55°F and 65°F.

The top of the graduate is closely covered with a piece of fiber blotting paper or similar material so that it fits the condenser tube tightly.

Heat is applied at a uniform rate so that the first drop falls from the condenser in not less than five nor more than ten minutes.

When the first drop falls from the end of the condenser, the reading of the distillation thermometer is recorded as the *Initial Boiling Point*.

The receiving cylinder is then moved so that the end of the condenser tube shall touch the side of the cylinder.

Heat is then regulated so that distillation proceeds at a uniform rate of not less than four or more than five cubic centimeters per minute.

The reading of the distillation thermometer is recorded when the bottom of the meniscus of the distillate in the receiving graduate is at each 10 cc. mark or if desired, also at each 5 cc. mark.

After the 90 per cent point has been recorded, the heat may be increased sufficiently to bring over the heavy ends.

There should be no further increase after this adjustment and it is not necessary to maintain the rate as this cannot conveniently be done.

However, the time required between 90 per cent and the end point should not be more than 5 minutes.

The heating shall be continued until the mercury reaches a maximum and then starts to fall consistently.

The highest temperature observed shall be recorded as the *end point* or maximum temperature.

This point will be reached when the bottom of the flask has become dry.

The total volume of distillate collected in the receiving flask is recorded as the *total recovery.*

The cooled residue in the Engler flask is poured into a cylindrical graduate and the volume is recorded as *residue.*

The difference between the 100 cc. taken and the sum of the recovery and the residue is calculated and recorded as *distillation loss.*

Description of Apparatus.

The Flask—The Standard 100 cc. Engler flask is shown in figure 119, the dimensions and allowable tolerance being as follows:

	Centimeters	Inches	Tolerances Cm.
Diameter of bulb, outside	6.5	2.56	0.2
Diameter of neck, inside	1.6	0.63	0.1
Length of neck	15.0	5.91	0.4
Length of vapor tube	10.0	3.94	0.3
Diameter of vapor tube, outside	0.6	0.24	0.05
Diameter of vapor tube, inside	0.4	0.16	0.05
Thickness of vapor tube wall	0.1	0.04	0.05

The position of the vapor tube shall be 9 cm. (3.55 in.) (+3 mm.) above the surface of the liquid when the flask contains its charge of 100 cc. The tube is approximately in the middle of the neck and set at an angle of 75° (tolerance + 3 deg.) with the vertical.

The Condenser.—The condenser (Fig. 118) consists of a $\frac{9}{16}$ inch (14.29 mm) OD No. 20 Stubbs Gage seamless brass tube, 22 in. (55.88 cm) long. It is set at an angle of 75° from the perpendicular and is surrounded with a cooling bath 15 inches long (38.1 cm.) approximately 4 in. (10.16 cm.) wide by 6 in. (15.24 cm.) high. The lower end of the condenser tube is cut off at an acute angle and curved downward for a length of 3 in. (7.62 cm.) and slightly backward so as to insure contact with the wall of the graduate at a point 1 to 1¼ in. (2.54-3.175 cm.) below the top of the graduate when it is in position to receive the distillate.

The Shield.—The shield (Fig. 118) is made of approximately 22 gage sheet metal and is 19 in. (48.26 cm.) high, 11 in. (27.94 cm.) long and 8 in. (20.32 cm.) wide, with a door on one narrow side, with two openings 1 in. (2.54 cm.) in diameter, equally spaced in each of two narrow sides, and with a slot cut in one side for the vapor tube. The centers of these four openings are 8½ in (21.59 cm.) below the top of the shield. There are also three ½ in. (1.27 cm.) holes in each of the four sides with their centers 1 in. (2.54 cm.) above the base of the shield.

Ring Support and Hard Asbestos Boards.—The ring support is the ordinary laboratory type, 4 in. (10.16 cm.) in diameter and is supported on a stand inside the shield. There are two hard asbestos boards: One 6x6x¼ inch (15.24 cm.x15.24.x6.35 mm) with a hole 1¼ in. (3.175 cm.) in diameter (1½ in. if end point is over 470°F) in its center, the sides of which shall be perpendicular to the surface; the other, an asbestos board to fit tightly inside the shield with an opening 4 in. (10.16 cm.) in diameter concentric with the ring support. These are arranged as follows: The second asbestos board is placed on the ring and the first or smaller asbestos board on top so that it may be moved in accordance with the directions for placing the distilling flask. Direct heat is applied to the flask only through the 1¼ in. (3.175 cm.) opening in the first asbestos board.

Gas Burner.—The burner is so constructed that sufficient heat can be obtained to distill the product at the uniform rate specified below. The flame should never be so large that it spreads over a circle of diameter greater than 3½ in. (8.89 cm.) on the under surface of the asbestos board. A sensitive regulating valve is a necessary adjunct as it gives complete control of heating.

Electric Heater.—The electric heater which may be used in place of the gas flame, shall be capable of bringing over the first drop within the time specified below when started cold, and of continuing the distillation at the uniform rate. The electric heater shall be fitted with an asbestos board top ⅛ to ¼ inch (3.175 to 6.35 mm) thick, having a hole 1¼ in. (3.175 cm.) in diameter in the center. When an electric heater is employed, the portion of the shield above the asbestos board shall be the same as with the gas burner.

Thermometer—Low distillation thermometer is a mercury, nitrogen filled total immersion glass engraved thermometer, length about 381 mm. diameter, 6 to 7 mm. made of pyrex glass with bulb length of 10 to 15 mm. bulb diameter 5 to 6 mm. range 30°F to 580°F. 30°F mark 100 to 110 mm. from bottom of bulb. The 580°F mark 35 to 45 mm. from top of stem. Graduated in 2°F. The allowable error not over 1°F at any point.

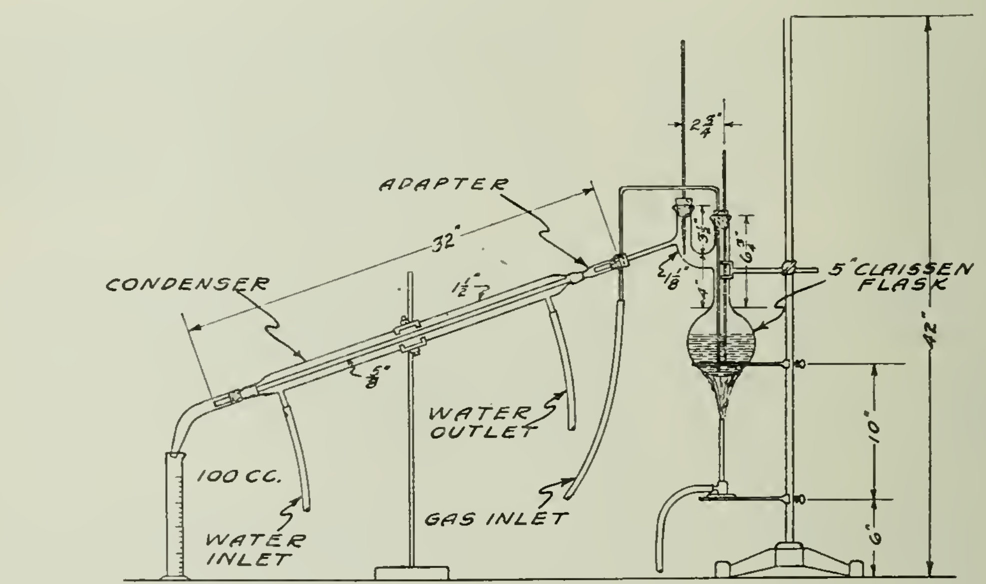
High distillation thermometer is a mercury, nitrogen filled total immersion glass engraved thermometer, length about 381 mm. diameter, 6 to 7 mm. made of pyrex glass with bulb length of 10 to 15 mm. bulb diameter 5 to 6 mm. range 30°F to 76°F. 30°F mark 25 to 35 mm. above bottom of bulb. 760°F mark 30 to 45 mm. below top of tube. The scale is graduated in 2°F. Accuracy within one small scale division.

Graduate.—The graduate shall be a cylindrical type of uniform diameter with a pressed or molded base and lipped top. It is graduated for 100 cc. so that the 10 cc. markings are clearly set out. The graduations must be corrected within ½ cc. at any point.

9-B. FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF CRUDE PETROLEUM AND PETROLEUM DISTILLATES.

The apparatus to be used is that shown in Fig. 120. This apparatus consists of a 1,000 cc. Claisen distilling flask of heavy pyrex glass having the dimensions shown in the figure. The distilling flask, the condenser and the condenser tube must be of pyrex glass or equally resistant glass. The tubulus and the condenser are set at an angle of 75° to the vertical.

The oil to be tested should be as nearly as possible free from water. Exactly 800 cubic centimeters at 60°F are poured into the distillation flask. The thermometer used in the vapor neck of the flask is scaled for 3-inch immersion and should read to 760°F. It is inserted so that the top of the mercury bulb is even with the bottom of the tubulus and is in the center of the neck of the flask. The other neck of the flask is fitted with a glass tube which goes to the bottom of the flask and also with a total immersion thermometer reading to 760°F and inserted into the oil.



FRACTIONAL GRAVITY DISTILLATION APPARATUS

Fig. 120—Fractional Gravity Distillation Apparatus.

The distillation is begun using a slightly luminous flame of a Tirrell burner. The flame must be protected from drafts. The flask may be blanketed with asbestos paper. The flame is controlled by a screw pinch cock on the rubber tubing or by a needle valve in the base of the burner.

The condenser water should be at or below 60°F. If the running water is not sufficiently cold, ice water should be used for circulation at the beginning of the distillation. The temperature at which the first drop falls from the lower end of the condenser tube is recorded as the initial boiling point. The rate of distillation after the first 5% is taken is 8 cubic centimeters or 1% per minute. Temperature readings are taken every 2½% or 20 cubic centimeters. Five per cent fractions are collected in a 100 cc. graduated cylinder. For smooth operation of the distillation, two 100 cc. cylinders and one 50 cc. cylinder should be available. The 40 cc. of distillate are poured into a 50 cc. graduate to allow the distillate to mix thoroughly. The specific gravity is taken preferably with special 4-inch hydrometers, each hydrometer having a range in specific gravity of 0.050. If the special small hydrometers are not available a Westphal balance should be used. The receiving cylinder should be kept cold during the beginning of the distillation.

The record of the distillation is conveniently made on a special form. The specific gravities with the temperatures of observation are recorded and later corrected to the basis of 60°F. All observations should be in terms of specific gravity and converted to Baume gravity.

The straight fire distillation is continued until a temperature of 572°F is reached. An even cut in the distillation should be made on the 5% fraction whose end point is first above 572°F. Beyond this temperature inert gas such as natural gas, coal gas or carbon dioxide is introduced in sufficient quantity to carry the rate of distillation without the temperature at any time exceeding 650°F in the oil. Gas is introduced at the rate of about 10 cu. ft. per hour when cracking begins to take place or at a temperature of 600°F in vapor. After a temperature of 572°F has been reached, the condenser water is turned off so that the condenser may be warmed up sufficiently to prevent any wax that may be present from occluding the condenser tube. *With ordinary light crude oil, 90% should be distilled without cracking. In asphaltic base oils, 70% should always be distilled without cracking. The residue in the flask while warm is poured out and weighed in a seamless tin box and its consistency determined either by use of the penetrometer if the petroleum is asphalt base or by the Saybolt viscosimeter at 210°F if paraffin base. If the residue is fluid, it may be suitable for cylinder stock.

In the case of distillates such as pressure distillate, gas oil, kerosene, gasoline, naphtha, turpentine substitutes, etc., it is not necessary to use the gas tube or the thermometer in the oil unless specially desired. In this case, a dry point can be reached usually without appreciable cracking. From the gravity of the 5% fractions the gravity of the total distillate at any per cent or temperature may be calculated as well as the gravity of the stream. This type of analysis is indispensable in calculation of the gravity of the product from the receiving house gravities in the refinery. (See page 241 for record form.)

*The rate of distillation cannot ordinarily be maintained for the heavy fractions.

9-C. PROXIMATE DISTILLATION OF PETROLEUM.

400 cc. of the petroleum are poured into a 1,000 cc. flask which is connected to a condenser (as shown in Fig. 120). The thermometer is inserted so that the top of the bulb is just below the outlet of the flask. The flame is gradually applied to the oil so that any foaming will tend to make itself evident. If there is foaming it will be necessary to heat the upper portion of the flask. Before the application of the flame to prevent foaming, it is necessary to get the temperature at which the first drop falls into the receiver. This is the initial boiling point. The distillate is collected until a temperature of 410°F is reached when distillation is proceeding at the rate of 5 cc. per minute. The fraction collected up to this temperature is the gasoline or naphtha, the gravity of which is determined. If the gravity is less than 57, it is classified as naphtha, if above this, it is classified as gasoline. Or if initial b. p. is over 160°F the distillate is classed as naphtha. The distillation is continued at the same rate until a temperature of 572°F is reached. This fraction is kerosene and its gravity is determined. The residue in the flask is fuel oil and is used for the determination of wax or asphalt, gas oil or lubricants. The information given by this distillation is:

Water			————%
Gasoline	(———410°F)	(Gr.=————=————Be°)	————%
Kerosene	(410—572°F)	(Gr.=————=————Be°)	————%
Fuel Oil—Residuum		(Gr.=————=————Be°)	————%
			100.0%

9-D. SAMPLE PREPARATION DISTILLATION OF CRUDE OIL.

The apparatus consists of a 5-gallon steel still, condenser, gas burner, water supply under pressure, steam producers, superheater gauges and connections.

Ten thousand cubic centimeters is a convenient charge, giving a 5% fraction of 500 cc., which is sufficient for special tests. The still is covered with chicken wire and asbestos cement for insulation. Direct firing is used until a temperature of slightly above 500°F is indicated in the vapor or a gravity of 40° Be′ (0.825 specific gravity) is shown in the distillate fraction. At this temperature superheated steam or gas is introduced.

10A. FLASH POINT OF KEROSENE AND OTHER VOLATILE INFLAMMABLE LIQUIDS.

(With Standard "TAG" Closed Tester.)

This is essentially in accordance with the method of the American Society for Testing Materials, Book of Standards, 1921, page 669.

The test must be performed in a dim light so as to see the flash plainly.

Surround the tester on three sides with an inclosure to keep away drafts. A shield about 18 inches square and 2 feet high, open in front, is satisfactory. See that tester sets firmly and level.

For accuracy, the flash point thermometers which are especially designed for the instrument should be used as the position of the bulb of the thermometer in the oil cup is essential.

Put the water-bath thermometer in place. Place a receptacle under the overflow spout to catch the overflow. Fill the water bath with water at such a temperature that when testing is started, the temperature of the water bath will be at least 10°C below the probable flash point of the oil to be tested.

Put the oil cup in place in the water bath. Measure 50 cc. of the oil to be tested in a pipet or a graduate and place in oil cup. The temperature of the oil must be at least 10°C below its probable flash point when testing is started. Destroy any bubbles on the surface of the oil. Put on cover with flash point thermometers in place and gas tube attached. Light pilot light on cover and adjust flame to size of the small white bead on cover.

Light and place the heating lamp, filled with alcohol in base of tester and see that it is centrally located. Adjust flame of alcohol lamp so that temperature of oil in cup rises at the rate of about 1°C (1.8°F) per minute or not faster than 1°C (1.8°F) nor slower than 0.9°C (1.6°F) per minute.

Record the "time of applying the heating lamp," record the "temperature of the water bath at start," record the "temperature of the oil sample at start."

When the temperature of the oil reaches about 5°C below the probable flash point of the oil, turn the knob on the cover so as to introduce the test flame into the cup and turn it promptly back again. Do not let it snap back. The time consumed in turning the knob down and back should be about one full second, or the time required to pronounce distinctly the words "one thousand and one."

Record the "time of making the first introduction of the test flame" and record the "temperature of the oil sample at time of first test."

Repeat the application of the test flame at every 0.5°C rise in temperature of the oil until there is a flash of the oil within the cup. Do not be misled by an enlargement of the test flame or halo around it when entered into the cup or by slight flickering of the flame; the true flash consumes the gas in the top of the cup and causes a very slight puff.

Record the "time at which the flash point is reached," and the "flash point."

If the rise in temperature of the oil from the "time of making the first introduction of the test flame" to the "time at which the flash point is reached" was faster than 1.1°C or slower than 0.9°C

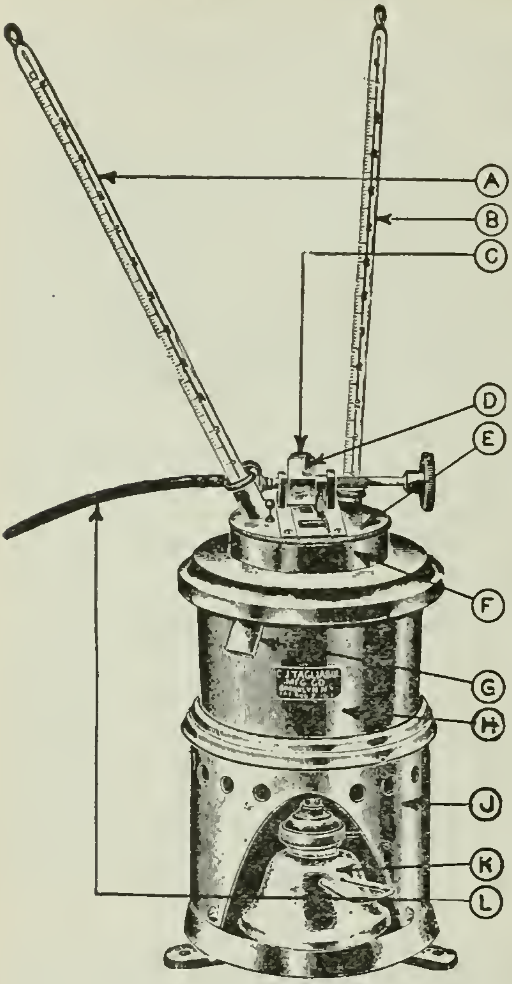


Fig. 122—A. S. T. M. Flash Tester.

per minute, the test should be questioned and the alcohol heating lamp adjusted so as to correct the rate of heating. It will be found that the wick of this lamp can be so accurately adjusted as to give a uniform rate of rise in temperature of 1°C per minute and remain so.

Repeat Tests.—It is not necessary to turn off the test flame with the small regulating valve on the cover, but leave it adjusted to give the proper size of flame.

Having completed the preliminary test, remove the heating lamp, lift up the oil cup cover and wipe off the thermometer bulb. Lift out the oil cup and empty and carefully wipe it. Throw away all oil samples after once using in making test.

Pour cold water into the water bath, allowing it to overflow into the receptacle until the temperature of the water in the bath is lowered to 8°C below the flash point of the oil as shown by the previous test. With cold water of nearly constant temperature it will be found that a uniform amount will be required to reduce the temperature of the water bath to the required point.

Place the oil cup back in the bath and measure into it a 50 cc. charge of fresh oil. Destroy any bubbles on the surface of the oil, put on the cover with its thermometer, put in the heating lamp, record time and temperature of oil and water and proceed to repeat test as described above. Introduce test flame for first time at a temperature 5°C below the flash point obtained on the previous test.

Precautions.—Be sure to record barometric pressure either from laboratory barometer or from nearest Weather Bureau station. Record temperature of room.

Note and record any flickering of the test flame or slight preliminary flashes when the test flame is introduced into the cup before the proper flash occurs. Record time and temperature of such flickers or slight flashes if they occur.

10B. FLASH AND BURNING POINTS OF ALL TYPES OF PETROLEUM OILS AND ASPHALTS.

(With New York or Elliott Closed Tester.)

The bath surrounding the oil cup is filled with very high flash fluid oil or is left unfilled if the oil to be tested has a very high flash point. The oil cup is filled with the material to be tested to within 3 millimeters of the flange joining the cup and the vapor chamber above. The glass cover is then placed on the oil cup and the thermometer adjusted so that its bulb is just covered by the oil or bitumen. The flame is applied to the bath in such manner that the temperature is raised at the rate of about 5°C per minute. Every half minute the testing flame is inserted in the opening in the cover and about halfway between the surface of the material and the cover. The first appearance of a faint bluish flame on the entire surface of the bitumen or oil shows that the flash point has been reached, and this temperature is recorded.

The burning point of the material is now obtained by removing the glass cover and replacing the thermometer in the frame. The temperature is raised at the same rate and material tested as before. The temperature at which the oil or bitumen ignites and burns is recorded as the burning point. The flame should be extinguished with the metal cover very promptly after the burning point is reached.

Fig. 123—Elliott Flash Tester.

Fig. 121—Foster Flash Tester.

10C. FLASH AND FIRE TESTS (CLEVELAND OPEN TESTER).

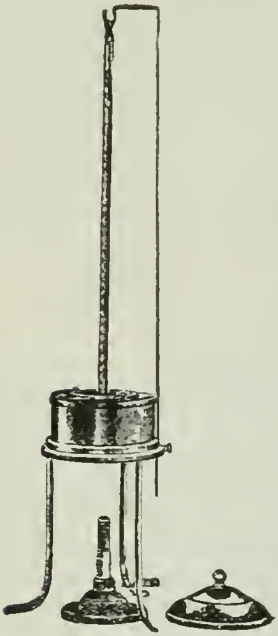


Fig. 125—Cleveland Flash Tester.

The apparatus is shown in Figs. 125 and 126.

The thermometer is suspended or held in a vertical position by any suitable device. The bottom of the bulb is placed ¼ in. (0.635 cm.) from the bottom of the cup, and above a point half way between the center and back of the cup.

The cup is filled with oil to be tested in such a manner that the top of the meniscus is exactly at the filling line at room temperature. The surface of the oil shall be free from bubbles. There shall be no oil above the filling line or on the outside of the apparatus.

The test flame shall be approximately $\frac{5}{32}$ in. (0.397 cm.) in diameter.

The test flame is applied as the temperature read on the thermometer reaches each successive 5°F mark. The flame is passed in a straight line across the center of the cup. The test flame shall be while passing across the surface of the oil, in the plane of the upper edge of the cup. The time for the passage of the test flame across the cup shall be approximately one second.

The rate of heating of the oil shall be such that the temperature read in the thermometer increases not less than 9 nor more than 11°F per miuute.

The flash point is taken as the temperature read on the thermometer when a flash appears at any point on the surface of the oil. The true flash must not be confused with a bluish halo that sometimes surrounds the test flame.

After determining the flash point the heating is continued at the specified rate, and application of the test flame is made at the specified intervals until the oil ignites and continues to burn for a period of at least five seconds. The temperature read when this occurs shall be taken as the fire point.

The flash point and fire point tests must be made in a room or compartment free from air drafts. It is desirable that the room or compartment be darkened sufficiently so that the flash may be readily discernible.

This method is suitable for lubricants, heavy fuel oils, road oils and asphalts. The A. S. T. M. flash point thermometer should be used. It is 38 cm. long and sealed for 1 inch immersion.

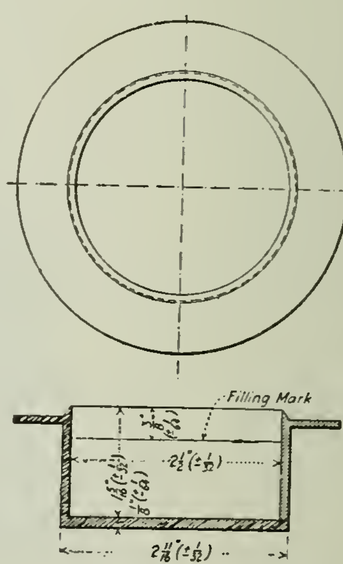


Fig. 126—Cleveland Flash Cup.

10D. FLASH POINT OF FUEL OIL (PENSKY-MARTENS).

The apparatus is the Pensky-Martens tester as described in tentative methods of A. S. T. M. for 1921, page 258. (See Fig. 127).

All parts of the cup and its accessories must be thoroughly clean and dry before starting the test. Particular care must be taken to avoid the presence of any gasoline or naphtha used to clean the apparatus after a previous test.

The cup is filled with the oil to be tested up to the level indicated by the filling mark.

The lid is placed on the cup and the latter set in the stove. Care shall be taken to have the locating devices properly engaged. The thermometer is inserted. If it is known that the oil will flash above 220°F the high temperature thermometer may be selected; otherwise, it is preferable to start with the low temperature thermometer and change in case a temperature of 220 to 230°F is reached.

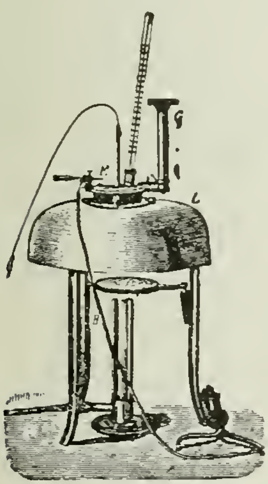


Fig. 127 — Pensky-Martens Flash Tester for Fuel Oil.

The test flame is lighted and adjusted so that it is of the size of a head $\frac{5}{32}$ in. (3.97 mm.) in diameter.

Heat is supplied at such a rate that the temperature read on the thermometer increases not less than 9 nor more than 11°F per minute. The stirrer is turned at a rate of from 1 to 2 revolutions per second.

Application of the test flame is made at each temperature reading which is a multiple of 2°F up to 220°F. For the temperature range above 220°F, application shall be made at each temperature reading which is a multiple of 5°F. Application of the test flame is made by operating the device controlling the shutter and test flame burner so that the flame is lowered in one-half second, left in its lowered position for one second, and quickly raised to its high position. Stirring is discontinued during the application of the test flame.

The flash point is taken as the temperature read on the thermometer at the time of the flame application that causes a distinct flash in the interior of the cup. The true flash must not be confused with the bluish halo that sometimes surrounds the test flame for the applications preceding the one that causes the actual flash.

The barometric pressure is observed and recorded. No corrections need be made except in case of dispute when the flash point figures may be corrected according to the following rule:

For each inch (25 mm.) below 29.92 in. (760 mm.) barometric reading add 1.6°F to the flash point.

For each inch (25 mm.) above 29.92 in. (760 mm.) barometric reading subtract 1.6°F from the flash point.

CORRECTIONS OF FLASH POINT FOR NORMAL BAROMETRIC PRESSURES.

To correct readings made at other pressures to the standard barometric pressure of 760 mm.

Barometer Millimeters	Correction Degrees C.
700	—2.1
705	—1.9
710	—1.7
715	—1.6
720	—1.4
725	—1.2
730	—1.0
735	— .9
740	— .7
745	— .5
750	— .3
755	— .2
760	0
765	+ .2

TYPICAL COMPARISON OF FLASH POINTS.

A. S.T. M. Closed (Tag)	100° F
Elliott or N. Y. Closed	100–105° F
Abel	102–106° F
Abel-Pensky	102–105° F
Pensky-Martens	102–106° F
Tag Open Cup	108–112° F
Cleveland Open Cup	110–115° F

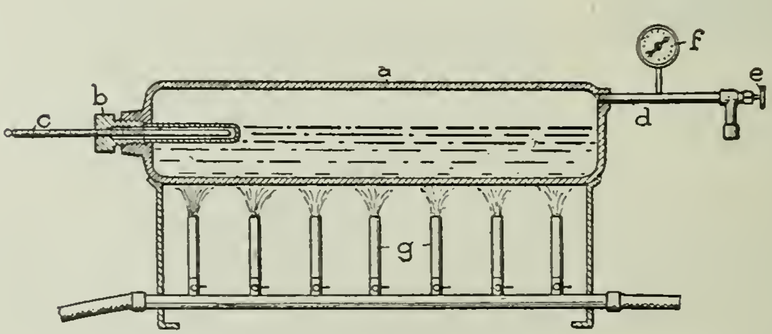


Fig. 128—Pressure Cracking Apparatus.

11A. CRACKING TEST FOR HEAVY PETROLEUM HYDROCARBONS.

The apparatus is set up as shown in figure 128. (a) is a cylindrical tube tested out to a pressure of 3,000 pounds such as is ordinarily used for dispensing oxygen gas. (b) is a thermometer well or plug with a tapered thread and of sufficient length that it protrudes well into the interior of the vessel (a). This plug has an opening from the outside into which the thermometer (c) is inserted. This mercury thermometer is graduated preferably in single degrees Centigrade and is of borosilicate glass, nitrogen filled and reading up to a temperature of 550°C. (d) is an extra heavy ammonia pipe fitting connected to a valve (e) and a pressure gauge (f). Pressure gauge (f) should read to at least 200 atmospheres or 200 kilograms per square centimeter. Heat is applied by gas burners (g) such as are used in combustion furnaces and the whole apparatus is supported on a stand with the end carrying the pressure gauge slightly elevated.

The capacity of the bomb is 1,500 to 1,600 cubic centimeters and 500 cc. of oil to be tested are poured into it at a temperature of approximately 20°C. The plug (b) is inserted and screwed in very tightly, using Stilson wrenches. An iron gasket should be used if necessary to give shoulder contact. The threads on the plug may be dressed with a mixture of equal parts of glycerin, litharge and copper oxide. The flame is applied so that it does not excessively heat the portion of the container not in contact with the oil. The total time consumed for the test after the beginning of the application of the heat should be between 55 minutes and 70 minutes. The heating is carried on until a pressure of 55 atmospheres is attained, based on a temperature of 400°C. It is desirable to keep the container covered with a sheet of asbestos during the operation. The temperature should not ordinarily exceed 425°C. The apparatus is cooled to about 20°C before opening.

The constants in this test are the dimensions of the apparatus, the amount of oil used, the rate of application of heat and maximum pressure at 400°C.

The variables are the percentage by volume of oil recovered after cracking, the amount of carbon formed, the amount of gas formed, the specific gravity of the gasoline and the total yield of gasoline. (See pages 235 and 237.)

Variations are due to the character of the oil treated, the specific gravity of the gasoline being higher, the recovery higher, the carbon and gas formation less and the total amount of oil recovered greater with paraffin base and with low specific gravity oils than with naphthene base and high specific gravity oils.

From one such equilibrium test it is possible to approximately estimate the amount of total gasoline which it would be possible to obtain from an oil. This may be calculated from one equilibrium test by taking into consideration the shrinkage or cracking and the increase in specific gravity of the residue above 210°C after cracking.

11B. VAPOR PRESSURE.

The vapor pressure of light petroleum hydrocarbons is determined with the same apparatus used for making the cracking test. The pressure readings with the corresponding temperature readings should be taken every 30 pounds and a curve plotted for intermediate points. The temperature should not be carried above 350°C as cracking will take place. (See curves on page 234.)

11C. HEAT-PRESSURE TEST FOR THE STABILITY OF MOTOR LUBRICANTS.

The apparatus used for this test is that shown in figure 128, being the same as that used for cracking test of heavy petroleum hydrocarbons.

Exactly 400 cubic centimeters of lubricating oil at a temperature of approximately 70°F is placed in the 1,600 cubic centimeter cylinder. The cylinder is tightly closed with the plug, using a soft iron gasket to prevent any leakage. The apparatus is set up on a suitable stand and with a row of Bunsen burners is brought up to a temperature of 425°C. It is maintained at exactly this temperature for 15 minutes. At the end of this time the pressure is recorded. The cylinder is now quickly cooled with water and the oil is emptied. The following notations are made:

The total amount of oil recovered by distilling 100 cubic centimeters according to method 9-A, the gravity of the fraction at a vapor temperature of 410°F. The amount of kerosene and its gravity. This is the fraction collected between vapor temperatures of 410°F and 572°F. The residue is collected and its gravity is taken. The amount of pitch in the recovered oil is obtained by evaporating the oil in an oven in accordance with method 26. The residue is heated at a temperature of 500°F until it ceases to lose weight. The residual pitch is calculated to the basis of the residual oil. The recovered oil is tested for acidity in accordance with method 20-A.

This test is of great value in determining the stability of motor oils in use. An oil having poor stability will have an increase in Baume' gravity of 7° or more and will have a acidity of 10 points or more expressed in terms of percentage tenth normal acid. Vegetable or animal oils by this test give an acid value approximately 200 times as great as mineral oils. This test serves as a very delicate means of detecting small quantities of animal or vegetable oil in mineral oils. The higher the pressure developed the more susceptible the oil is to decomposition by heat. (See pages 277 and 278.)

11D. VAPOR PRESSURE TESTS FOR LIGHT GASOLINE MADE FROM GAS.

(Westcott, Handbook of Casinghead Gasoline.)

Apparatus shown on page 466 consists of iron or steel pipe of 2 inch size, with caps screwed on ends. Upper cap has 0.25 inch nipple screwed in and is connected by a coupling to a 3 inch 30 lb. pressure gauge. Gauge is known as Inspector's Gas Gauge. All joints must be perfectly tight. Joints between large pipe and caps are best sealed with solder. Approximate external dimensions are indicated in Fig. 129. In addition to apparatus indicated, there is also required a tin cylinder for filling test tube, 12 by 3 inches, that can be slipped over outside of tube for convenience in carrying when not in use. The tin cylinder is provided with a lip for pouring. A small tin cover 0.75 inch deep, fitting over the bottom of the tin cylinder may be removed and used for measuring off one-tenth capacity of test tube. A small tin funnel 2.5 inches in diameter with stem 3 inches long and three-sixteenths inch in diameter should be used.

Remove the gauge from the tube and fill tube to 90 per cent of its capacity. Fill tube preferably by lowering it into the storage tank in upright position by means of a cord or wire. Leave the tube entirely immersed for several minutes, withdraw it and pour off sufficient liquid so that the tube will contain 90% of its capacity. A small measure having capacity of 10% of the test tube should be used for that purpose.

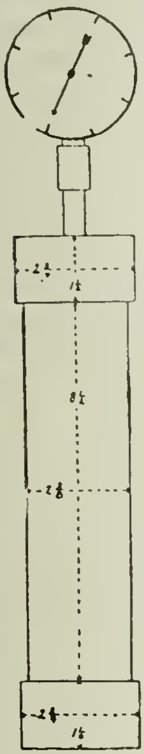


Fig. 129 Vapor Pressure Apparatus.

In case it is impracticable to lower the tube into the storage tank, draw the liquid off into the vessel of capacity about equal to the test tube. Pour liquid into the test tube until about half filled. Shake tube and contents gently in order to bring both to the same temperature. After standing for several minutes, pour out all the liquid from the tube. Draw another sample from the storage tank into the cylinder and pour through funnel into the tube until the latter is entirely full. Withdraw one-tenth as before. Screw gauge tightly into position, using a little liquid shellac or pyroxylin cement on joint to insure a tight fit.

Immerse the tube in water at a temperature of 70°F and allow it to remain for five minutes. Then remove it from the water and unscrew the gauge sufficiently to relieve the pressure indicated by the gauge for a period of 20 seconds and screw the gauge tightly into the tube again. Then place the tube in water at a temperature of 100°F (90°F from Nov. 1st to March 1st). The level of the water must be just below the lower edge of the pressure gauge. Stir the water continually and maintain the temperature exactly constant for ten minutes, then tap the gauge lightly with the finger and read the pressure.

A correction of pressure figures should be made according to the initial temperature of the gasoline. This correction should be as follows:

For tests on samples taken at a temperature of 50 to 59°F, inc., deduct 1 lb.

For tests on samples taken at a temperature of 40 to 49°F, inc., deduct 2 lbs.

For tests on samples taken at a temperature below 40°F, deduct 3 lbs.

The gravity of the liquid, the temperature of liquid gas placed in tube, the pressure at 70°F before venting tube, the corrected pressure at 100° F (90°F from Nov. 1st to March 1st) after venting at 70°F should all be recorded.

12A. CARBON RESIDUE IN LUBRICANTS AND DISTILLATES.
(Conradson Method.)

The apparatus consists of:

(a) Porcelain crucible, wide form, glazed throughout, 25 to 26cc capacity, 46 mm. in diameter.

(b) Skidmore iron crucible, 45cc (1½-oz.) capacity, 65 mm. in diameter, 37 to 39 mm. high with cover, without delivery tubes and one opening closed.

(c) Wrought iron crucible with cover, about 180cc capacity, 80 mm. diameter, 58 to 60 mm. high. At the bottom of this crucible a layer of sand is placed about 10 mm. deep, or enough to bring the Skidmore crucible with cover on nearly to the top of the wrought iron crucible.

(d) Triangle, pipe stem covered, projection on side so as to allow flame to reach the crucible on all sides.

(e) Sheet iron or asbestos hood provided with a chimney about 2 to 2½ inches high, 2⅛ to 2¼ inches in diameter to distribute the heat uniformly during the process.

(f) Asbestos or hollow sheet iron block, 6 to 7 inches square, 1¼ to 1½ inches high, provided with opening in center 3¼ inches in diameter at the bottom and 3½ inches in diameter at the top. The test shall be conducted as follows:

Ten grams of the oil to be tested are weighed in the porcelain crucible, which is placed in the Skidmore crucible and these two crucibles set in the larger iron crucible, being careful to have the Skidmore crucible set in the center of the iron crucible, covers being applied to the Skidmore and iron crucibles. Place on triangle and suitable stand with asbestos block and cover with sheet iron or asbestos hood in order to distribute the heat uniformly during the process.

Heat from a Bunsen burner or other burner is applied with a high flame surrounding the large crucible, as shown in Fig —, until vapors from the oil start to ignite over the crucible, when the heat is slowed down so that the vapor (flame) will come off at a uniform rate. The flame from the ignited vapors should not extend over two inches above the sheet iron hood. After the vapor ceases to come off, the heat is increased as at the start and kept so for five minutes, making the lower part of large crucible red hot, after which the apparatus is allowed to cool somewhat before uncovering the crucible. The porcelain crucible is removed, cooled in a dessicator and weighed.

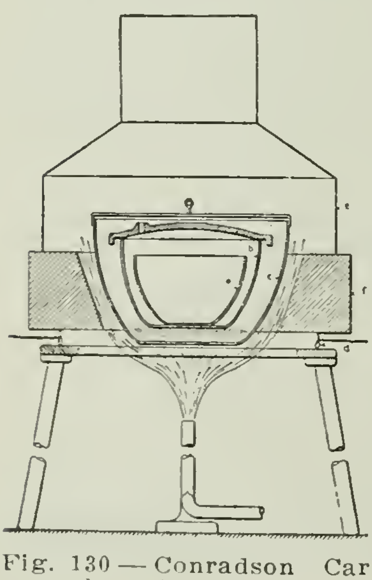


Fig. 130 — Conradson Carbon Apparatus.

The entire process should require about one-half hour to complete when heat is properly regulated. The time will depend somewhat upon the kind of oil tested, as a very thin, rather low flash-point oil will not take as long as a heavy, thick, high flash-point oil. (See A. S. T. M. 1918 Standards, page 620.)

12B. FIXED CARBON AND ASH IN OIL AND BITUMINOUS MATERIALS.

The apparatus used is that shown below, or the furnace shown on page—, such as is used for burning out mineral aggregates, is quite satisfactory.

Between .4500 and .5500 gram of the material is placed in a 20-gram platinum crucible having a tightly fitting cover. It is heated for seven minutes with the full flame of a Bunsen burner, as shown, or at 950°C in the electric furnace. With the open flame the crucible should be supported with its bottom 6 or 8 cm. above the top of the burner and the flame should be at least 20 cm. high when burning freely. A shield is used to protect from drafts. The crucible while remaining covered is placed in a dessicator, cooled and weighed, then ignited with lid removed until nothing but the ash remains. The loss is the fixed carbon and the residue is the ash.

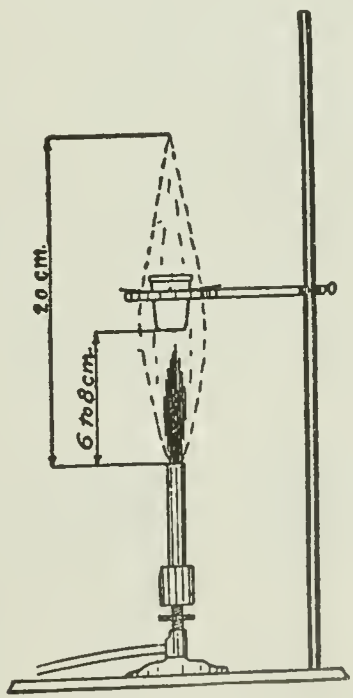


Fig. 131—Bunsen Burner for Fixed Carbon.

13. EMULSIFYING PROPERTIES OF LUBRICATING OILS.

The oil and water to be emulsified are contained in an ordinary commercial 100cc graduated cylinder, 1 1/16 to 1 2/16 inches inside diameter. An oil or water bath is provided for maintaining the contents of the cylinder at a temperature of 130°F, except when a different temperature is specified, both during the stirring and subsequent settling out of the oil from the emulsion. The paddle used in stirring is a copper plate 4¾ inches long, between three-fourths and seven-eighths inch wide and one-sixteenth inch thick. Means are provided for revolving this paddle about a verticle axis parallel to and midway between its two longer edges and for keeping the speed fairly constant at 1,500 r.p.m. A stop should be provided so that when the paddle is lowered into the cylinder (or bath raised) the distance from the bottom of the paddle to the bottom of the cylinder will be about one-fourth inch. To save time otherwise lost in waiting for the filled cylinders to come to the temperature of the bath it is desirable that the bath should be large enough to contain several cylinders.

Pour 27cc of the oil to be tested and 53cc of distilled water into a cylinder, place cylinder in bath and heat to 130°F. Submerge the paddle and run it for five minutes at a speed of 1,500 r.p.m. Stop the paddle, withdraw it from the cylinder, and use the finger to wipe off the emulsion clinging to the paddle and to return it to the cylinder. Wipe off the paddle with paper so that it will not contaminate the next sample. Keep the temperature of the cylinder constant at 130°F and take readings every minute of the position of the line of demarcation between the topmost layer of oil and the adjoining emulsion. The first reading is taken one minute after stopping the paddle. With oils which act normally the rate of settling out of the oil increases up to a maximum and then decreases and the maximum value in cc per hour is called the "demulsibility" and is recorded as the numerical result of the test. Each rate of settling is the average rate calculated from the time of stopping the paddle to the time of reading, as shown in the following condensed table:

TIME	Time Since Stopping Paddle, Minutes	Reading at Interface Between Oil and Emulsion	Oil Settled Out, c. c.	Rate of Settling, c. c. per Hour
9.50	0	80	0	0
9.55	5	77	3	36
10.02	12	67	13	65
10.05	15	63	17	68
10.10	20	61	19	57

The demulsibility in this case would be 68, the highest value in the last column. In cases where the maximum rate of settling has not been reached at the end of one hour, the test is discontinued and the demulsibility taken as the number of cc that settled out in the hour. (See page 34, Bulletin 5 of Bureau of Mines on Report of Committee for Standard of Petroleum Specifications.)

14. A HEAT OF COMBUSTION OR CALORIFIC VALUE.

The apparatus used for the heating value, calorific value or British thermal units of petroleum products is shown in figures 132, 133 and 134.

Any type of oxygen bomb calorimeter is satisfactory. Among these are the Atwater, Mahler, Parr and Kroeker bombs. The description of the operation of one bomb calorimeter is typical of all.

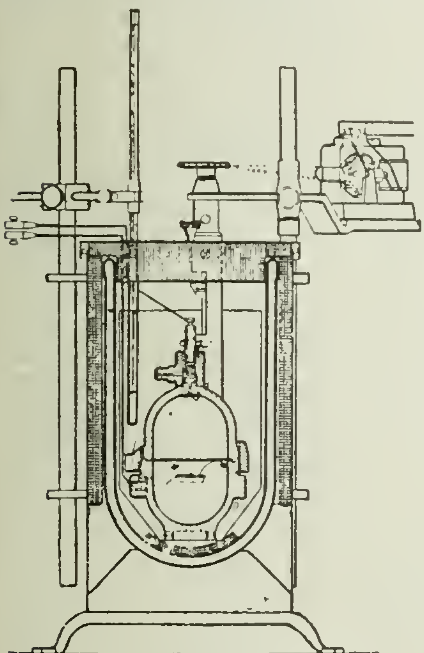


Fig. 132—Emerson Bomb Calorimeter.

The lower half of the bomb is placed in the cast iron holder. About one gram of the oil is weighed to the nearest 0.0001 gram into the fuel pan and is placed in the bomb on the fuel pan holder. If the oil is volatile it is not advisable to pour the fuel directly into the fuel pan. For this purpose, small gelatine capsules weighing .1 gm. are used and may be filled with ignited asbestos and into this the light oil is discharged from a weighing pipet. The capsule is immediately closed leaving a minimum amount of air space. A similar capsule has been previously weighed and its calorific value determined. A stock of standardized capsules should be kept on hand in an air tight receptacle. The platinum fuse wire is cut equal in length to the taper pin wrench which is connected to the terminal, being careful that it does not touch the pan. The wire is bent down so that it is covered by the oil or by the lips of the capsule. The upper half of the bomb is carefully fitted on the lead gasket to the lower half. The nut is screwed down over the upper half being careful not to cross the threads. The bomb nut is now tightened by the use of a long wrench, being careful to cause no sudden jerking or vibrating which will throw the oil from the pan. The bomb is now carefully lifted out and placed on the swivel table and connected with the oxygen piping. The valve in the top of the bomb is opened about one turn and the valve in the oxygen cylinder is carefully and slowly opened so that the pressure in the bomb as shown by the indicator rises to 300 pounds. The bomb valve is now closed and the oxygen cylinder is closed. Exactly 1900. grams of water at a temperature of about 4° below room temperature is weighed into the calorimeter water bucket. This is placed in the calorimeter container. The bomb is connected with the electric wire and is introduced into the water, being careful to place it in the center of the bucket. Two 100 watt lamps placed in parallel are in series with the fuse wire when a 110 volt circuit is used for firing. The spring motor is placed in series

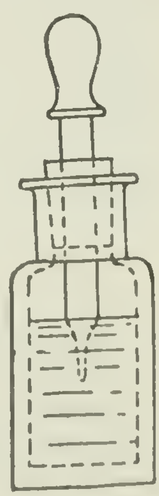


Fig. 133—Weighing Bottle for Liquid Fuels, Etc.

with a 60 watt lamp on a 110 volt circuit. The cover is put on, the connections to the bomb wire are made and the stirrer is introduced as far down as it will go. It should not touch the bomb. The thermometer is introduced and stirring is continued for about five minutes. The temperature is read and the stirring continued for exactly five minutes and the temperature is again read and the charge is fired by quickly throwing in the switch and withdrawing it. The stirring is continued for five minutes, the temperature being read at minute intervals or at the end of five minutes unless extreme accuracy is required. The stirrer is then run for an additional five minutes and the temperature is again read. The thermometer is corrected in accordance with the corrections furnished by the Bureau of Standards. The radiation corrections may be applied to each one minute interval but for ordinary purposes one-fifth of the radiation for the five minute period before firing is applied on the 5 minute period immediately after firing and four-fifths of the radiation in the third five minute period is applied on the five minute period immediately after firing. The calorimeter constant (usually about 2400) is determined by a blank test using exactly 1 gram of benzoic acid. This constant always remains the same with the same calorimeter but must be determined each time a change is made in the calorimeter. In the case of oil in which it has been necessary to use the capsule the correction made must be applied for the calorific value of the capsule. This is most conveniently applied to the corrected net rise in temperature of the thermometer. To convert British thermal units per pound to calories per gram, multiply by five-ninths. To obtain the water evaporative power, multiply the B. T. U. per pound by 1.035 and divide by 1000. To obtain the B. T. U. per gallon, multiply the B. T. U. per pound by the weight per gallon.

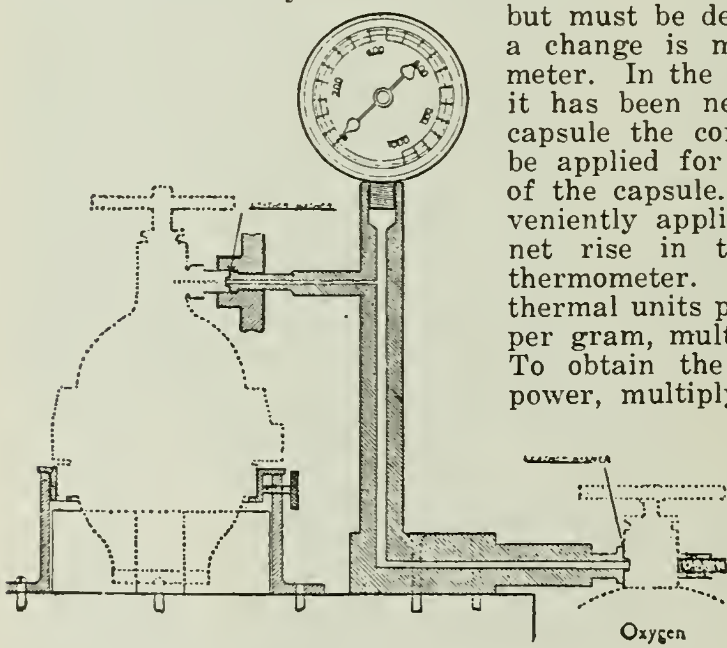


Fig. 134—Calorimeter Oxygen Connections.

14B. HEAT OF COMBUSTION FROM GRAVITY OF FUEL OILS.

An approximation of the heating value of fuel oil can be obtained by the following formula:

B. T. U. per lb. = 18700 + 40 (°Be′—10).

15A. TOTAL SULPHUR IN PETROLEUM PRODUCTS.

The apparatus is shown in Fig. 132 and may be any standard oxygen bomb calorimeter.

The determination may be made at the same time as a determination of calorific value.

Place 20cc of distilled water in the bottom of the bomb. Use 0.5 to 1.0 g. of oil, weighed into the sample cup of the bomb, when the material is not volatile. For volatile materials use either a small gelatine capsule or a very small glass bulb of the type used in the ultimate organic analysis of such liquids. If the latter is used, place a few drops of sulphur-free alcohol in the sample cup to start combustion. Arrange the ignition mechanism and close the bomb tightly. Admit oxygen until a pressure of 35 to 40 atmospheres is reached. The higher pressure is preferable. Ignite. Place the bomb in cold water for 20 minutes. Shake vigorously for 25 seconds and allow to drain for five minutes. Release the pressure rather slowly and open the bomb. Using distilled water in a wash bottle with a very fine jet, wash the wires and cover thoroughly, allowing the washings to collect in the bomb. In the same way wash the sample cup held by small tongs. Transfer the solution from the bomb to a 500cc beaker and wash the inside of the bomb thoroughly. The total volume of solution thus obtained need not exceed 350cc. Avoid any loss of material by spattering or otherwise in the various washings.

Filter the solution through a washed filter paper into another beaker, of smaller size if possible. Wash the filter thoroughly. Add 2cc of HCl (sp. gr. 1.20) and 10cc of saturated bromine water. To the hot solution add 10cc of a 10% barium chloride solution, as hot as possible, in a very fine stream or dropwise so that 30 to 45 seconds are required. Stir vigorously with a glass rod during this addition and for four minutes afterward. Allow the precipitate to settle for one hour on a steam bath. Cool and let stand for at least one hour at room temperature. Filter carefully through a suitable ashless filter paper and wash the precipitate with hot water, first by decantation and then on the filter till free from chloride. Transfer the wet filter paper and precipitate to a weighed platinum crucible. Dry carefully over a low flame. Allow the filter paper to burn away and then ignite until the precipitate is just burned white. Cool in a desiccator and weigh. From the increase in weight which is barium sulphate, calculate the percentage of sulphur as follows:

$$\text{Percentage of Sulphur} = \frac{\text{grams of } BaSO_4 \times 13.734}{\text{grams of oil used}}$$

15B. SULPHUR BY THE CHEMICAL BOMB.

To the perfectly clean and dry bomb as shown in Fig. 135 add ten grams of pure sodium peroxide.

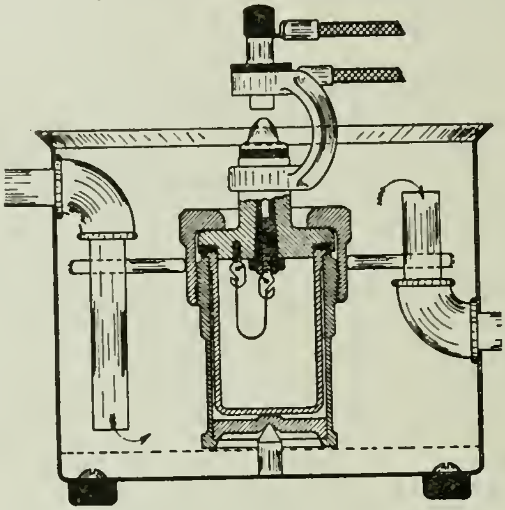


Fig. 135—Parr Sulphur Bomb.

Then add one gram of finely pulverized potassium chlorate.

Thoroughly mix them by shaking.

Add from a weighing pipe approximately one-half gram of oil, which would be about twenty drops.

Mix thoroughly by shaking.

Fit the cover on tightly and screw down the cover with a wrench.

Ignite by holding the bottom of the fusion cup in the small pointed flame of the Bunsen burner for a moment (or electrically).

Remove from the flame as soon as the reaction has commenced which is indicated by the lower portion of the cup becoming a dull red.

After the charge has ignited, the bomb may be cooled in cold water (or maintained in cold water during ignition).

It is now rinsed off with distilled water and placed in a beaker.

The cover is rinsed off with hot distilled water and hot distilled water is squirted into the fusion cup until solution is complete.

The fusion cup is now rinsed off thoroughly with hot distilled water.

The contents of the beaker are boiled to complete solution and filtered.

Hydrochloric acid is added to the filtrate until the reaction is distinctly acid.

Ten cubic centimeter of 5 to 10% barium chloride are now added and barium sulphate is precipitated and filtered in the usual manner.

The barium sulphate is weighed.

This value $\times$ 27.47 gives the percentage of sulphur.

Correction should be made for sulphur present as impurities in the chemicals used.

15C. SULPHUR BY THE ESCHKA METHOD.

This method is not good for oils, in most instances giving a low result, but may be used where accuracy is not necessary. Weigh out approximately 1 gram of the oil and mix it with 2.5 grams of sodium carbonate and 5 grams of calcined magnesia in a platinum dish or crucible. Heat gradually increasing the temperature until the mass has a low red color and the mixture on cooling has a grayish tint. Cool and wash into a 500cc beaker with distilled water and add about 1cc of bromine. Mix until the bromine is thoroughly dissolved and allow some time for the bromine to react. Now add hydrochloric acid until the reaction is decidedly acid, the beaker being covered in the meantime to prevent any mechanical loss. Filter off and wash any undissolved residue. Precipitate in the usual manner with barium chloride and weigh as barium sulphate.

Weight of Barium Sulphate $\times$ 13.73 = % Sulphur.

15F. SULPHUR IN CORROSIVE FORM.

A clean strip of pure sheet copper about one-half inch wide and three inches long is heated to redness in a Bunsen flame, and while red hot dropped into alcohol. The strip is then allowed to dry as quickly as possible in the air and dropped into a sample of the oil contained in a clean test tube about half the length of the copper strip being submerged. The test tube is then closed with a stopper and left to stand over night at a temperature of 150°F.

At the end of this time the copper strip is removed and washed free from oil with gasoline. It is then compared with a similar strip of copper freshly cleaned by heating to redness in a Bunsen flame and dropping into alcohol while hot.

If sulphur or corrosive sulphur compounds are present in the oil the copper test strip will appear discolored when compared with the freshly cleaned copper, since elementary sulphur attacks copper.

15D. SULPHUR IN NAPHTHAS AND ILLUMINATING OILS.

The apparatus is shown in Fig. 136.

Pass two strands of new cotton wicking about 4.5 in. long through the ⅛-in. diameter wick tube so that they are not twisted, but parallel in the wick tube. Trim the wick with very sharp scissors. Pour into the clean dry lamp about 20cc of the oil to be tested, insert the wick and cork and weigh the assembly with an accuracy of 0.001 g. It is advisable to make a blank determination at the same time and under the same conditions by burning sulphur-free alcohol in a similar lamp.

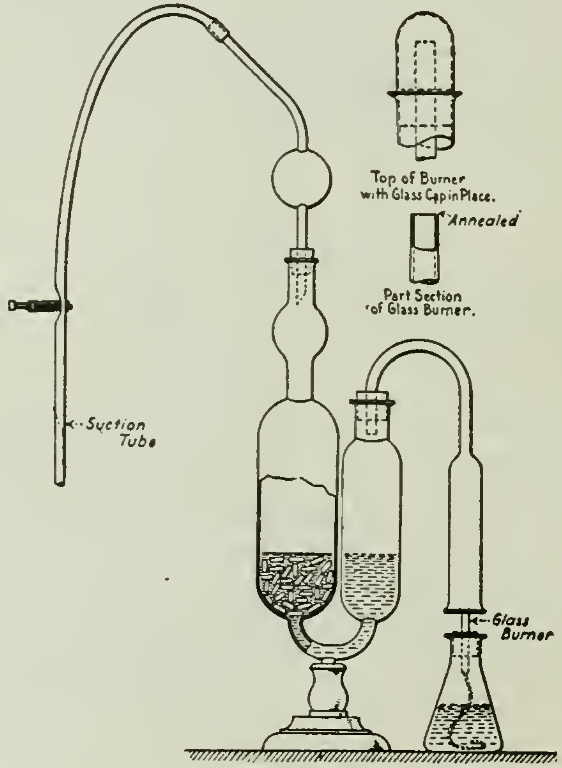


Fig. 136—Sulphur Apparatus for Illuminating Oils.

Rinse out the absorber containing the glass beads thoroughly with distilled water and add exactly 10.0cc of the standard sodium carbonate solution from an accurately calibrated burette, allowing the burette to drain for three minutes before taking the reading. Rinse the chimney and the spray trap with distilled water, dry the chimney and connect both to the absorber as shown in Fig. 136. Set up the apparatus for the blank determination in exactly the same manner and using exactly 10.0cc of the sodium carbonate solution. Apply gentle suction to both absorbers, light both the weighed oil lamp and alcohol lamp and then place in position under the chimneys so that the tops of the wick tubes extend into the chimneys not more than one-sixteenth inch. Adjust the wick height and the suction so that the flame is steady, free from smoke and approximately one-quarter inch high. This requires that the wick be flush with the top of the wick tube for naphthas, and a little higher for illuminating oils. The room must be free from drafts. The suction on the blank should be so adjusted that air is drawn through both determinations at the same rate. Continue burning for about two hours, or less if the sulphur content of the oil is high. During this time the oil should be consumed at the rate of about 1 gm. per hour.

Extinguish the flames and stop the suction on both absorbers. Weigh the oil lamp immediately and calculate by difference the weight of oil consumed. Working with the blank first, disconnect the spray trap and chimney and wash them thoroughly with methyl orange solution, using a wash bottle with a very fine jet and collecting the washings in the absorber. The amount of solution required for washing should not exceed 35cc. Carefully titrate the very faintly yellowish solution in the absorber with standard HCl, added to the suction side of the absorber from an accurately calibrated burette. During this titration, the contents of the absorber should be agitated carefully, either by blowing through a rubber tube held between the operator's lips and connected at the other end with the chimney side of the absorber or else by the use of a suitable rubber syringe bulb. As the end point is approached, draw the liquid back into the chimney side between each addition of acid and then blow it into the suction side, agitating as before. As soon as the first permanent pink color appears, the end point has been reached. Read and record the volume of HCl solution used.

Rinse the chimney and spray trap used in the actual determination into the absorber to which they were connected, exactly as prescribed for the blank. If the methyl orange solution in the absorber has a pink color, too much oil has been burned and the determination must be repeated, burning for a shorter time. Titrate just as in the blank, making sure that the absorber is cold. Read and record the volume of HCl solution required.

Calculate the sulphur content of the oil by substituting the proper values in the following formula:

$$\text{Percentage of Sulphur} = \frac{(\text{HCl for blank, cc} - \text{HCl for sample, cc}) \times 0.1}{\text{grams of oil burned}}$$

If a blank is not run, the formula is:

$$\text{Percentage of Sulphur} = \frac{(Na_2CO_3\text{, cc} - \text{HCl, cc}) \times 0.1}{\text{grams of oil burned}}$$

These formulae are correct only for the standard solutions specified, 1cc of each being equivalent to 0.001 g. of sulphur. The use of solutions of any other strength, such as N/10, is satisfactory and the percentage of sulphur may be calculated.

APPARATUS.

Absorber of chemically resistant glass, about 150cc capacity containing glass beads or short pieces of glass rod in the suction side as shown.

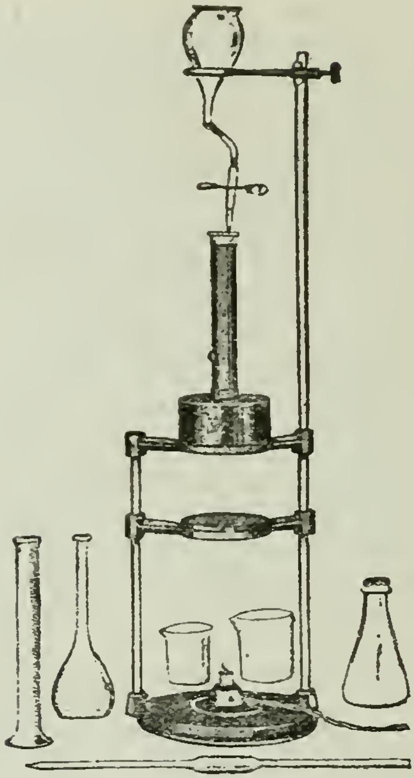


Fig. 137—Sulphur Photometer.

Chimney of chemically resistant glass connected with the absorber by a rubber stopper.

Spray trap of chemically resistant glass connected with the absorber by a rubber stopper.

Small lamp of about 25cc capacity. This lamp may conveniently consist of a 25 to 35cc Erlenmeyer flask and a cork carrying a short section of glass tubing about one-eighth inch in inside diameter. The cork must be grooved along the sides so that air may enter the flask while the oil is being consumed.

Ordinary cotton wicking.

Filter pump or other means for continuous suction and rubber tubing to connect with spray trap.

SOLUTIONS REQUIRED.

Hydrochloric acid—Solution containing 2 275 g. HCl per liter and carefully checked for accuracy.

Sodium Carbonate—Solution containing 3.306 g. Na_2CO_3 per liter. Exactly 10.0cc should be required to neutralize 10.0cc of the hydrochloric acid solution.

Methyl Orange—Solution in distilled water, containing 0.004 g. methyl orange per liter.

15E. SULPHUR TESTS FOR TURPENTINE SUBSTITUTES.

Place 25 grams of dry white lead in a small porcelain dish and mix thoroughly with 50cc of the turpentine substitute to be tested. Cover with a watch glass, place on a steam bath for two hours, remove, and observe the color after eighteen hours. There shall be no appreciable darkening of the white lead. This test must be performed in an atmosphere free from hydrogen sulphide.

Place five drops of the oil on clean white filter paper and allow the liquid to evaporate at room temperature, away from direct sunlight. There should be no oily spot left after thirty minutes.

16A. CARBON AND HYDROGEN IN PETROLEUM PRODUCTS.

The most convenient method is to burn the oil in a special calorimeter bomb of the type of the Kroeker. (Fig. 138.)

The bomb must be perfectly dried on the inside by drawing dry air through the apparatus.

Approximately one gram of oil is now burned exactly as in the determination of heat of combustion.

The bomb is taken from the calorimeter and is connected on the tube side with Drechsel bottles containing moist soda lime in the first bottle and calcium chloride in the second bottle. The outlet of the bomb is now connected in series with a U tube containing granulated zinc to decompose any acid formed in the combustion, with a glass stoppered U tube filled with calcium chloride of about 10 mesh size, with a glass stoppered U tube filled in the first arm with soda lime containing 10% water and the upper part of the second arm with calcium chloride connected then with an aspirator bottle.

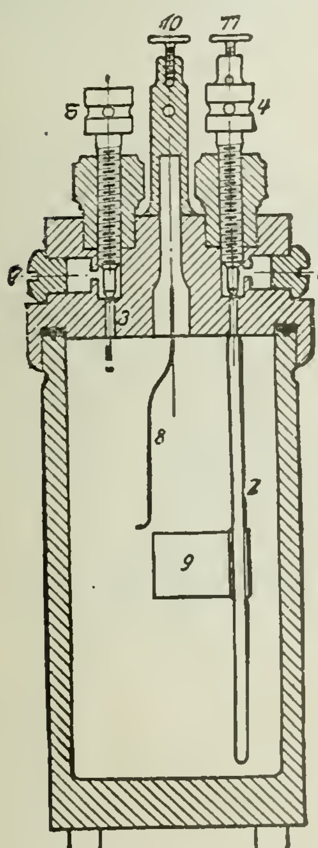


Fig. 138—Kroeker Bomb.

The outlet of the bomb is gradually opened so that at least ten minutes is required to release all of the pressure.

The bomb is now heated and the aspirator is run at such a rate that about five gallons of air are drawn through the bomb during a period of between one and two hours. The carbon is calculated from the increase in weight of the soda lime U tube and the hydrogen is calculated from the increase in weight of the calcium chloride U tube.

$$\frac{CO_2 \times 27.273}{\text{weight of sample}} = \%\ \text{carbon}$$

$$\frac{H_2O \times 11.190}{\text{weight of sample}} = \%\ \text{hydrogen}$$

16B. DETERMINATION OF NITROGEN IN PETROLEUM OR ASPHALT, BY THE KJELDAHL METHOD.

Five grams of the sample are weighed into a pyrex Kjeldahl digesting flask. Fifty cc of the digestion mixture composed of concentrated sulphuric acid containing 20% of phosphorous pentoxide is added to the flask. About one-third gram of mercuric oxide is added and the contents of the flask are heated with a strong flame until the solution has become pale yellow or colorless. The digested material is now cooled, diluted with about 150cc of water and neutralized with strong caustic soda solution. Zinc shavings and some Potassium Sulphide are added. The flask is quickly connected with the condenser tube and the ammonia is distilled off into a 25cc of N/10 sulphuric acid. The excess of acid is titrated with N/10 alkali. Each cubic centimeter of sulphuric acid consumed is equivalent to .001404 gram of nitrogen.

17. DOCTOR TEST FOR GASOLINE.

Reagent.

Sodium plumbite or "doctor" solution—Dissolve 125 grams of sodium hydroxide ($NaOH$) in a liter of distilled water. Add 70 grams of litharge (PbO) and shake vigorously for 15 or 30 minutes or let stand with occasional shaking for at least a day. Allow to settle and decant off the clear liquid. Filtration through a mat of asbestos may be employed if the solution does not settle clear. The solution should be kept in a bottle tightly stoppered.

Test.

Shake vigorously for about 15 seconds two volumes of gasoline and one volume of the "doctor" solution. Note color. A small pinch of flowers of sulphur should be added and the tube again shaken for 15 seconds and allowed to settle. The quantity of sulphur used should be such that practically all of the sulphur floats on the surface, separating the gasoline from the "doctor" solution.

Interpretation.

If the gasoline is discolored or if the sulphur film is so dark that its yellow color is noticeably masked, the test shall be reported as positive, and the gasoline condemned as "sour." If the liquid remains unchanged in color and if the sulphur film is bright yellow, or only slightly discolored with gray or flecked with black, the test shall be reported negative and the gasoline considered "sweet."

18A. OLEFINS OR UNSATURATED HYDROCARBONS AND REFINING LOSS IN PETROLEUM PRODUCTS—WITH BABCOCK BOTTLE.

Use apparatus and equipment as shown in Figs. 139-140.

Weigh up a clean and dry 30% Babcock cream bottle, add to it exactly 5cc of the oil to be tested. Weigh again, giving the amount of oil used. Cool in ice water and add 10cc of concentrated commercial sulphuric acid, letting the acid run down the sides of the bottle. Shake while cooling in the ice water. Keep stoppered with a rubber stopper. Let stand for one-half hour with occasional shaking and constant cooling. Add sufficient concentrated sulphuric acid (commercial) to bring the reading about to the top of the scale on the neck of the bottle. Centrifuge for five minutes in the No. 1 centrifuge with the resistance at the first notch from the left. This gives a speed of 1,000 r.p.m. Keep the rubber stopper in while centrifuging so that there will be no evaporation. The stopper shall be large enough so that it is not forced into the bottle.

The reading on the neck of the bottle divided by five is the net amount of saturated hydrocarbons contained. This multiplied by twenty and taken from 100 gives the per cent of unsaturated hydrocarbons. For great accuracy the oil may be corrected for specific gravity and temperature and for the amount adhering to the sides of the pipet in which case the weighings are used. The waste acid from the Babcock bottle is poured into a bottle from which the sulphuric acid may be recovered by separating the oil and oxidising the organic material in the acid.

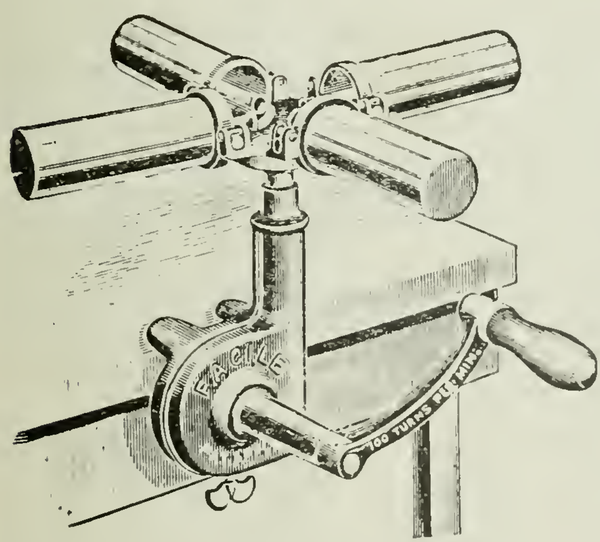


Fig. 139—Hand Centrifuge.

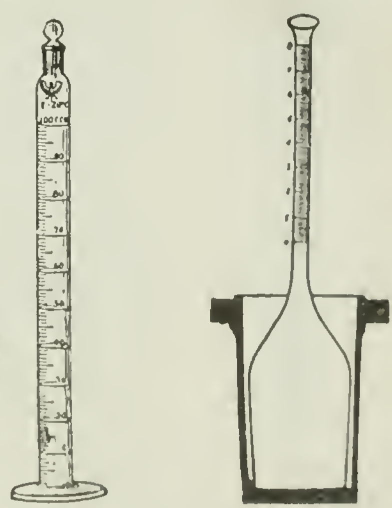


Fig. 140—Olefin Tubes.

18B. METHOD USING A 10CC GLASS STOPPERED CYLINDER.

Use apparatus and equipment as shown in Fig. 140.

Add exactly 5cc of the oil to be tested to the cylinder and 2cc of sulphuric acid of gravity 1.84. Shake thoroughly for about five minutes and place in centrifuge and centrifuge at the rate of 1,000 r.p.m. for five minutes. The shrinkage of the oil in cubic centimeters $\times$ 20 is the percentage of olefins.

18C. REFINING LOSS OF PETROLEUM PRODUCTS.

Use the color tube as shown in Fig. 98.

To a 50cc color tube that is graduated in .1cc and glass stoppered, add 45.0cc of the oil. Add exactly 1cc of 66° Baume' sulphuric acid. Shake thoroughly for about five minutes. Set vertically in a rack for at least one hour and preferably over night. The increase in volume of the acid in the bottom of the tube $\times$ 2-2/9 is the refining loss.

19A. METHOD FOR DETERMINING AROMATIC AND PARAFFIN HYDROCARBONS IN PETROLEUM PRODUCTS.

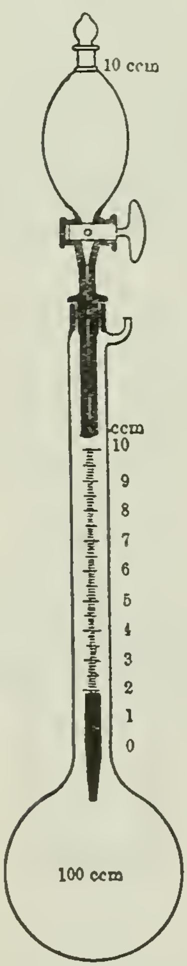


Fig. 141—Tube for Aromatic Determination.

The apparatus is shown in Fig. 141. The flask containing 30cc of fuming nitric acid (specific gravity 1.52) is cooled to —10°C by a salt ice freezing mixture. The separatory funnel is filled to the 10cc mark with the oil under test. The oil is run drop by drop with continuous shaking into the cooled acid during a period of not less than 45 minutes. With uncracked petroleum products 15 minutes is sufficient. The mixture is allowed to stand 15 minutes after completion of the reaction and then enough nitric acid (ordinary concentrated) at —10° temperature is added to the contents of the flask until the oil under the surface is brought into the graduated neck. The volume is read when the neck is at room temperature, the body of the flask being in the freezing mixture. This volume represents the paraffin hydrocarbons.

The mixture is transferred to a separatory funnel, the lower layer run off into a 500cc measuring flask containing 150cc of water. The neck should be graduated for a 10cc portion into 1/10cc. The temperature will rise in proportion to the amount of olefins and aromatics present and more or less oil will separate according to the amount of paraffin hydrocarbons present.

The unattacked oily layer in the separatory funnel is washed with water and then examined for specific gravity and boiling point. The aqueous layer of nitric acid is warmed for 15 minutes to dissolve as completely as possible the resinous substances formed. The cooled liquid is shaken with 100cc of ether, the aqueous layer separated and the ether layer again washed free from acid with water, then with a solution of caustic potash containing 50 grams of KOH in 500cc of water with 50cc of alcohol.

The caustic potash is drawn off and again the ether layer is washed with water. It is now dried with calcium chloride, filtered, the ether evaporated and the residue weighed. The residue consists of reddish brown oil, aromatic nitro-derivatives. The weight divided by .115 gives the percentage of aromatic hydrocarbons.

The difference between the aromatic and cyclic hydrocarbons and the paraffin hydrocarbons and 100% is the amount of olefins. This may be checked by direct determination as shown under olefins.

19B. SHORT METHOD FOR AROMATIC AND CYCLIC HYDROCARBONS.

Distillation of 800cc of the hydrocarbons under examination may be made in a one liter distilling flask in accordance with the apparatus set forth in Fig. 120. Cuts may be made at 95°, 120° and 150°C and the percentage of aromatic compounds calculated from the specific gravity using the following specific gravities as the basis:

Temperature of Cut	Specific Gravity of Aromatic Hydrocarbon	Specific Gravity of Non-Aromatic Hydrocarbon
95°C	0.880	0.720
120°C	0.871	0.730
150°C	0.869	0.760

This is in accordance with the Bulletin No. 114 of the Bureau of Mines, page 95.

20A. FREE FATTY ACIDS.

Accurately weigh 10 g. of the oil into an Erlenmeyer flask, add 50cc of 95% alcohol which has been neutralized with weak caustic soda, and heat to the boiling point. Agitate the flask thoroughly in order to dissolve the free fatty acids as completely as possible. Titrate while hot with aqueous tenth-normal alkali, free from carbonate, using phenolphthalein, alkali blue or turmeric as an indicator, agitating thoroughly after each addition of alkali.

To express results as percentage of oleic acid, use the following equation:

One cc of tenth-normal alkali = .0282 gram of oleic acid. Alkali, 1cc of which is equivalent to 0.5% of oleic acid, may be used. (A. S. T. M. Method, 1918 Standards, page 620.)

20B. COMBINED FATTY ACIDS OR FATTY OILS.

Weigh 10 grams of oil into a 350cc Erlenmeyer flask. Add from a pipet 50cc of the alcoholic potassium hydroxide solution followed by 25cc of the purified benzene (C_6H_6). Connect with a reversed condenser. Boil on steam bath or electric hot plate for 90 minutes, shaking occasionally. Remove and add 25cc of neutral gasoline, and titrate with the half-normal hydrochloric acid solution after adding two or three drops of the phenolphthalein indicator solution until the pink color is destroyed. The absence of the pink color may be determined after the titration has begun, by allowing the solution to stand at rest, approximately a minute, and noting the color of the lower zone. Run two blanks with the same mixture of alcoholic potassium hydroxide solution and purified benzene. From the difference between the number of cubic centimeters of half-normal acid required for the blanks and for the determination, the percentage of fatty oil may be calculated as follows:

$$\frac{\text{No. of cc N/2 acid used} \times .02805 \times 100}{.195 \times \text{weight of oil taken}} = \text{per cent of fatty oil}$$

Solutions:

(a) Approximately half-normal alcoholic potassium hydroxide. Dissolve 30 grams of potassium hydroxide sticks (or an equivalent amount of sodium hydroxide sticks) in 1000cc of purified 92-95% ethyl alcohol. Allow to settle and filter.

(b) Purified benzene. This may be prepared as follows: To 1000cc of "90% benzol" add a stick of sodium hydroxide, boil for an hour, using a condenser loop inside the neck of the flask. Transfer to a large separatory funnel and add sufficient water to cause the liquid to separate into two zones. Draw off the lower zone and discard. Wash the benzene with water once. Transfer the washed benzene to an Engler distillation flask and distill up to 82°C, discarding the residue.

(c) Standard solution of half-normal hydrochloric acid.

(d) Phenolphthalein Indicator. Dissolve one gram of phenolphthalein in 100cc of 95% ethyl alcohol.

(e) Neutral gasoline.

(See also method 11C.)

21. FLOC TEST.

Take a hemispherical iron dish and place a small layer of sand in the bottom. Take a 500cc Florence or Erlenmeyer flask and into it put 300cc of the oil (after filtering if it contains suspended matter). Suspend a thermometer in the oil by means of a cork slotted on the side. Place flask containing the oil in the sand bath and heat bath so that the oil has reached a temperature of 240°F at the end of one hour. Hold oil at temperature of not less than 240°F nor more than 250°F for six hours. The oil may become discolored but there should be no suspended matter formed in the oil. The flask should be given a slight rotary motion and if there is a trace of floc, it can be seen to rise from the center of the bottom.

22. CORROSION AND GUMMING TEST OF GASOLINE AND NAPHTHA.

The gasoline when subjected to the corrosion test shall show no black corrosion and no weighable amount of gum.

Directions for making test:

The apparatus used in this test consists of a freshly polished hemispherical dish of spun copper, approximately 3½ inches in diameter.

Fill this dish within three-eighths inch of the top with the gasoline to be examined and place the dish upon a steam bath. Leave the dish on the steam bath until all volatile portions have disappeared.

If the gasoline contains any dissolved elementary sulphur the bottom of the dish will be blackened.

If the gasoline contains undesirable gum-forming constituents there will be a weighable amount of gum deposited on the dish. Acid residues will show as gum in this test.

23. PENETRATION OF PETROLEUM ASPHALTS AND OTHER BITUMINOUS MATERIALS.

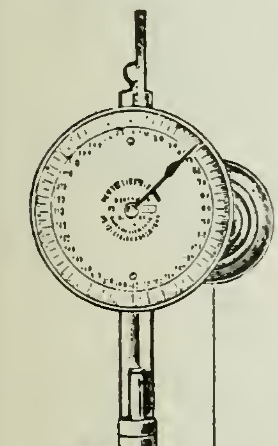


Fig. 142—N.Y.T.L. Penetrometer.

The apparatus used for this test is that shown in Figs. 142, 143 or 144.

The penetration is the consistency of a bituminous material expressed as the distance that a standard needle vertically penetrates a sample of the material under known conditions of loading, time and temperature. When the conditions of test are not specifically mentioned the load, time and temperature are understood to be 100 grams, 5 seconds, 25°C (77°F) respectively and the units of penetration indicate hundredths of a centimeter. The container for holding the material to be tested should be a flat bottomed cylindrical dish 2 3/16 inches in diameter and 1⅛ inches deep or the American Can Co. Gill style ointment box, deep pattern, three ounce capacity.

The needle is a cylindrical steel rod two inches long and with a diameter of 0.04 inch and turned on one end to a sharp point having a taper of one-quarter inch. The bath for the sample and the penetrometer should hold at least ten liters of water. The sample should be melted at the lowest possible temperature and stirred until it is homogeneous and free from air bubbles. It is then poured into the sample container to a depth of about three-quarters of an inch and is allowed to cool for one hour in the air. It is now placed in the water bath maintained within 0.1°C of the temperature of penetration for one hour.

In making the test, the sample is immersed in water and the needle loaded with the specified weight is adjusted to make contact with the surface of the sample. This may be accomplished by making contact of the actual needle point with its image reflected by the surface of the sample or contact may be meted by slightly turning the container so that a faint scratch on the surface of the bitumen is observed. The needle is then released for the specified time and the distance measured by the means provided with the machine. At least three tests shall be made at different points on the surface of the sample and after each test the needle shall be wiped clean of all bituminous matter. The reported penetration is the average of at least three tests whose values do not differ more than four points between the maximum and minimum. Other conditions for penetrations particularly for oil asphalt filler and roofing material shall be the following:

At 0°C (32°F) 200 grams weight 60 seconds.
At 46.1°C (115°F) 50 gram weight 5 seconds.

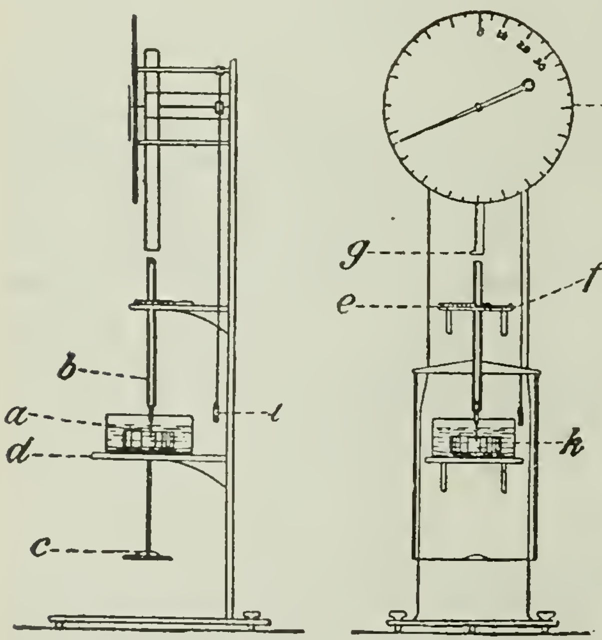


Fig. 143—Dow Penetrometer.

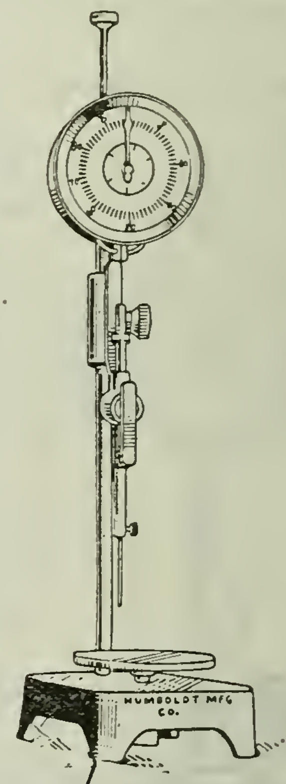


Fig. 144 — Humboldt Penetrometer.

24. DUCTILITY OF BITUMINOUS MATERIALS.

The ductility of an asphalt cement or semi-solid bitumen is the distance which it will elongate before breaking when a briquet of the material is pulled at a specified rate of speed and at a specified temperature. The temperature is to be 77°F and the rate of pulling is five centimeters per minute unless otherwise required.

The bituminous material is melted preferably in an oven at 325°F until it is uniformly and thoroughly fluid. The mold herein described is assembled on a plate so as to prevent the material from sticking to it, the surface of the plate and the inside surfaces of the mold being thoroughly amalgamated.

In filling, the bitumen is poured in a thin stream back and forth from end to end of the mold until it is more than level full. It is left to cool for at least 30 minutes when the excess of bitumen is cut off with a hot spatula so that the mold is just level full.

The briquet with the mold and plate is now placed in the water bath and kept at a temperature of 77°F for at least 1½ hours, when the briquet is removed from the plate and the side pieces detached. The briquet is now fastened in the ductility machine by means of the pins and ring and pulled at the uniform rate of five centimeters per minute. The water shall completely cover the briquet. The temperature shall be within .2°F of 77°F at all times. The average of three tests shall be taken. The ductility machine shall provide for three briquets being pulled at one time. The variation from five centimeters per minute in speed shall not be more than 5%.

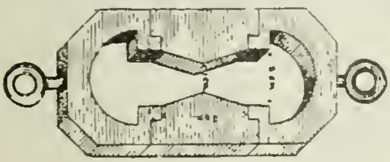


Fig. 145—Ductility Mold

The dimensions of the mold are as follows:

Total length (internal)	7.45-7.55 cm.
Distance between clips	2.97-3.06 cm.
Width of clips at mouth	1.98-2.02 cm.
Width of briquet at minimum cross-section (half way between clips)	0.99-1.01 cm.
Thickness of briquet throughout	0.99-1.01 cm.

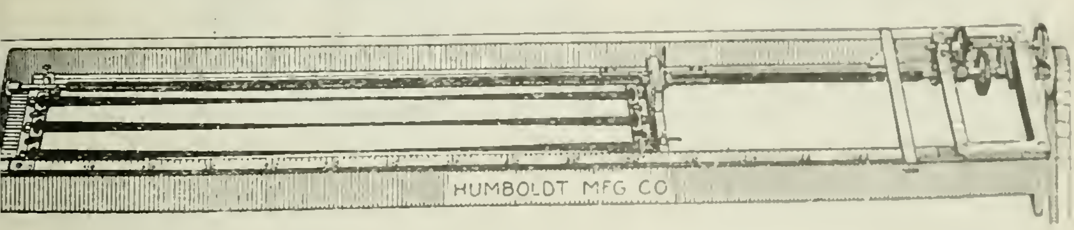


Fig. 146—Ductility Apparatus.

25. LOSS ON HEATING OF OIL AND ASPHALTIC COMPOUNDS.

The loss in weight by oil and asphaltic compounds when they are heated in an oven at a temperature of 163°C (325°F) is determined on 50 grams of the water free substance contained in a flat bottomed dish, the inside dimensions of which are approximately $2\frac{3}{16}$ inches in diameter and $1\frac{3}{8}$ inches deep (this is the 3 ounce Gill style ointment box, deep pattern).

The oven in which the substance is to be heated is brought to temperature before the sample is introduced and the temperature of the sample under test shall be regarded as that of a similar quantity of the same material immediately adjoining it in the oven in which the bulb of a standardized thermometer is immersed. The oven may be any well constructed type either circular or rectangular and the source of heat may be either gas or electricity. The samples under test rest in the same relative position in a single row upon a perforated shelf 9.75 inches in diameter as shown in Fig. 147. A good type of oven is also shown in Fig. 148. The shelf is suspended by a vertical shaft midway in the oven which is revolved by mechanical means at the rate of from 5 to 6 R. P. M.

This method of test is well adapted for the determination of the carbonization value of internal combustion engine lubricating oils 25 grams of the oil are heated as above at 500°F to constant weight. The carbonization value is the percentage of carbonized residue.

(See page 277, line 13.)

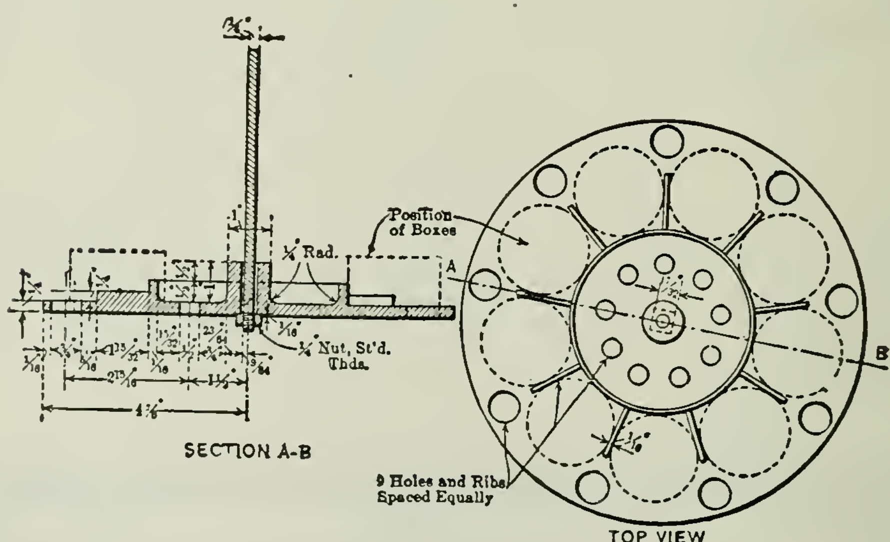


Fig. 147—Heat Loss Shelf.

26. ASPHALT IN OIL AND ASPHALTIC COMPOUNDS.

Fifty grams of the crude oil, fuel oil, lubricating oil, road oil or other material are weighed into a three ounce Gill style ointment box, deep pattern, and placed in an oven heated either by electricity or gas and with good circulation to a temperature of approximately 500°F. Heat is maintained until the consistency of the residue is such that at a temperature of 77°F it has a penetration of 100. The amount of asphalt is reported in terms of the 100° penetration material.

At least two tests should be made on each sample both as checks and to facilitate obtaining results on the basis of 100° penetration. When one sample is softer and one harder than 100° penetration the percentage of asphalt may be obtained by interpolation.

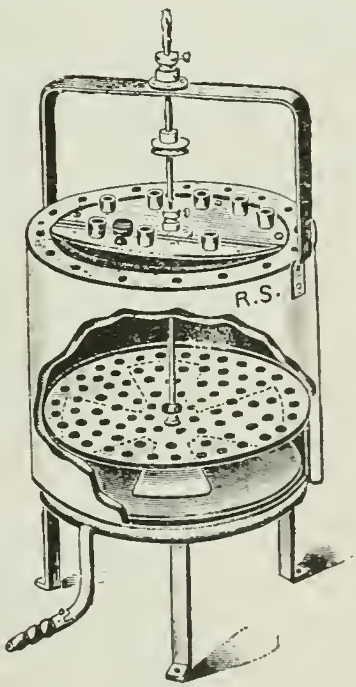


Fig. 148—Oven for Asphalt Determination.

27A. SOLUBILITY IN PETROLEUM ETHER—PRECIPITATION NUMBER OF LUBRICATING OILS. (A. S. T. M.)

This method is commonly used for steam cylinder stocks and black oils and may be used for other lubricating oils.

Exactly 10.0cc. of the oil to be tested is measured in each of two clean and dry centrifuge tubes at room temperature. Each tube shall be filled to the 100cc. mark with U. S. P. petroleum benzine and closed tightly with a softened cork (not a rubber stopper). Each tube is then inverted at least 20 times, allowing the liquid to drain thoroughly from the tapered tip of the tube each time. The tubes are then placed in a water bath at 90° to 95°F for five minutes. The corks are momentarily removed to relieve any pressure and each tube shall again be inverted at least 20 times exactly as before. The success of this method depends to a large degree upon having a thoroughly homogeneous mixture which will drain quickly and completely from the tapered tip when the tube is inverted.

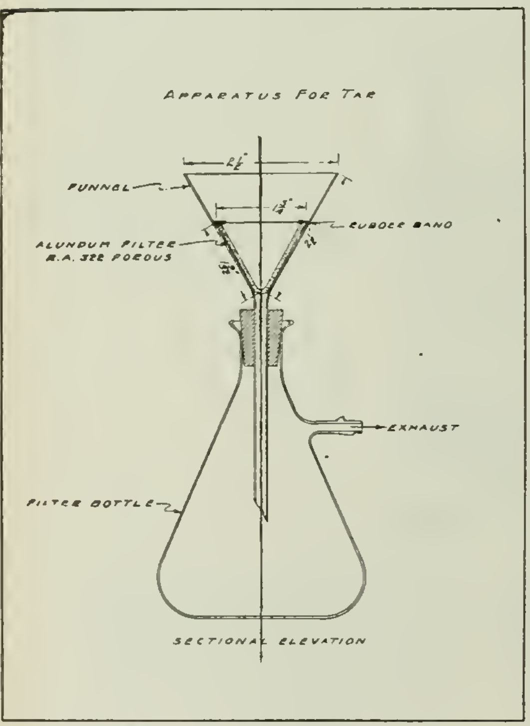


Fig. 149—Solubility Apparatus.

The two centrifuge tubes are then placed in the centrifuge on opposite sides and are whirled at a rate of 1,400 to 1,500 r.p.m. or equivalent for 10 minutes. The volume of sediment at the bottom of each tube is read and recorded, estimating to 0.05cc, if possible. The tubes are then replaced in the centrifuge, again whirled for 10 minutes as before, and removed for reading the volume of the sediment as before. This operation is repeated until the volume of sediment in each tube remains constant for three consecutive readings. In general, not more than four whirlings are required.

The volume of the solid sediment at the bottom of each centrifuge tube is read, estimated to 0.1cc. or closer if possible. If the two readings differ by not more than 0.1cc., the mean of the two shall be reported as the "Precipitation Number." If the two readings differ by more than 0.1cc., two more determinations shall be made and the average of the four determinations shall be reported. See figures — and — for apparatus.

The centrifuge should be capable of whirling at least two 100cc. centrifuge tubes filled with water at the required speed.

Preferred forms of centrifuge shall have a diameter of swing (tip to tip of whirling tubes) of 15 to 17 in. and a speed of at least 1,500 r. p. m. or equivalent. The proper speed may be calculated from the following formula in which D represents the diameter of swing (tip to tip of whirling tubes) of the centrifuge used:

$$\frac{16}{D} \text{ r. p. m.} = 1{,}500$$

27A-2. SOLUBILITY IN PETROLEUM ETHER AND TAR IN CYLINDER STOCK, FLUX AND ASPHALTS.

The apparatus is shown in figure 149.

Weigh out ten grams of the cylinder stock into a 200cc. Erlenmeyer flask (use 1 gram of asphalt).

Add 100cc. of U. S. P. Petroleum Benzin (84-86°Be′ Petroleum Ether).

Stopper and shake until the oil is completely dissolved.

Allow the flask to stand at least one hour, tightly corked.

Prepare a filter cone obtainable from any laboratory supply house, as alundum filter cone R A 232 Porous.

Boil in distilled water, wash thoroughly, dry, and ignite. Cool and weigh.

Attach the apparatus shown to the filter pump and pour the solution of cylinder stock into the porous alundum filter cone.

Press the cone down if necessary so that the rubber band around the top of the cone perfectly seals it.

Drain the Erlenmeyer flask as thoroughly as possible and wash it out using altogether 50cc. additional of the U. S. P. Petroleum Benzin pouring about 10cc. through the filter each time.

Care must be taken to wash thoroughly the top part of the alundum cone and to so distribute the washing that the petroleum benzin comes through perfectly colorless at the last.

Draw air through the residue in the cone until apparently dry, then place in the drying oven at 105°C for one-half hour or until it ceases to lose weight.

Cool in a desiccator and weigh.

The increase in weight is the total insoluble matter.

The cone is now placed back in the funnel and chloroform is poured over it until the chloroform passes through into the filter bottle colorless.

The cone is again dried at 105°C for fifteen minutes.

This loss in weight is tar.

The residue in the cone is ignited in an oxidizing flame or preferably in a muffle for fifteen minutes.

The loss is non-tarry organic matter.

Instead of using the alundum cone a gooch crucible may be used.

27B. SOLUBILITY IN CARBON BISULPHIDE. (TOTAL BITUMEN.)

This test is performed in the same way for asphaltenes or solubility in petroleum naphtha except that a 5-gram sample is preferably used. The same apparatus is used.

27C. SOLUBILITY IN CARBON TETRACHLORIDE.

This test is performed in the same way as for asphaltenes except that the flask containing the carbon tetrachloride must be kept in a dark place. The difference between the solubility in carbon bisulphide and carbon tetrachloride represents the carbenes.

28. RESISTANCE OF ASPHALTIC CEMENT TO OXIDATION.

After being subjected to the following tests the film of asphalt should be brilliant and lustrous, should not be scaly and fragile, should adhere firmly to the metal and should not be dull and cheesy in texture.

A strip of thin sheet iron 2 inches wide and 6 inches long is covered on its lower 4 inches with the melted asphaltic cement. This strip is placed in an oven at 275°F for 15 minutes and allowed to thoroughly drain.

It is removed from the oven and allowed to cool, then placed in an electrically heated oven at a temperature of 450°F for one hour. At the end of the hour, the door of the oven is opened and the heat is turned off, the specimen being allowed to remain in the oven.

The oven shall be one having an outside diameter of 12x12x12 inches with an opening in the top 1 cm. in diameter, the heating elements being in the bottom of the oven. The resistance shall be so distributed that the heat is uniform throughout the oven. The lower end of the strip shall be suspended so that it is at least 3 cm. from the bottom of the oven.

The resistance is preferably so arranged that three different heats can be maintained with a snap switch such that the lowest heat is 325°F, the medium heat is 400°F and the highest heat is 450°F.

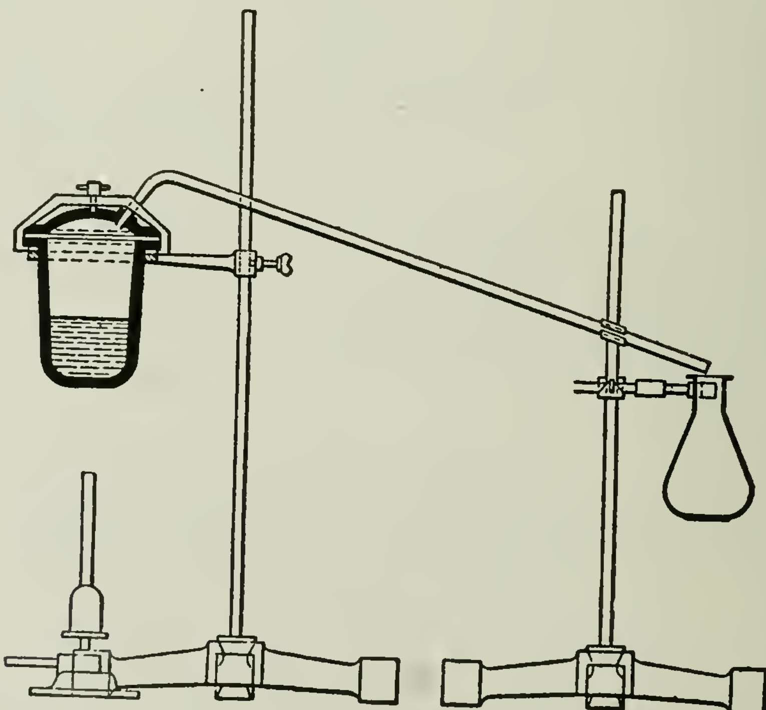


Fig. 150—Paraffin Scale Apparatus for Distillation.

29. PARAFFIN WAX OR SCALE IN PETROLEUM AND BITUMINOUS PRODUCTS.

The apparatus used is shown in Figs. 150 and 151.

Instead of the metal retort, a glass distilling flask with a glass air condenser may be used if desired. One hundred grams of the oil, bitumen or material under examination are weighed into the retort and distilled as rapidly as possible to dry coke. The distillate is caught in a 150cc. Erlenmeyer flask, the weight of which has been previously ascertained. During the early stages of distillation a cold, damp towel wrapped around the stem of the retort will serve to condense the distillate. After high temperatures have been reached, this towel may be removed. When the distillation is completed, the distillate is allowed to cool to room temperature and is then weighed in the flask. This weight minus that of the flask gives the weight of the total distillate.

Five grams of the well mixed distillate is then weighed into a 100cc. Erlenmeyer flask and mixed with 25cc. of Squibb's ether. Twenty-five cc. of Squibb's absolute alcohol is then added, after which the flask is packed closely in a freezing mixture of finely crushed ice and salt maintained at —18°C in a quart tin cup. After remaining 30 minutes in this mixture, the solution is quickly filtered through a No. 575 C. S. & S. 9 cm. hardened filter paper placed in a glass funnel which is packed in a freezing mixture as shown in figure. Vacuum should be employed to hasten filtration. The freezing-mixture reservoir shown in the figure may be made by cutting in half a round glass bottle measuring approximately 120 millimeters in diameter and using the upper half in an inverted position. Any precipitate remaining on the paper should be washed until free from oil with about 50cc. of a 1 to 1 mixture of Squibb's ether and absolute alcohol cooled to —18°C.

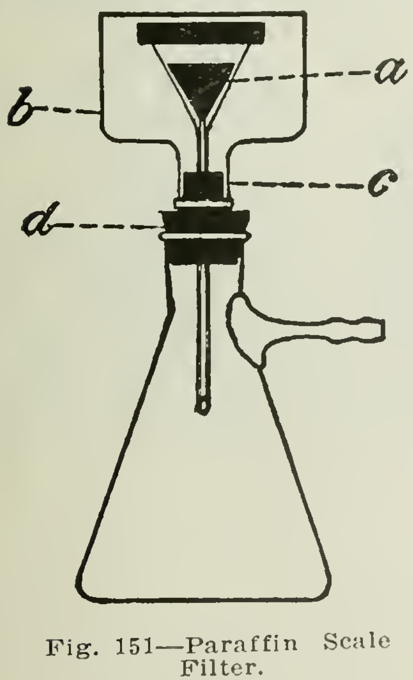


Fig. 151—Paraffin Scale Filter.

After the paper has been sucked dry, it should be removed from the funnel and the adhering paraffin scale should be scraped off into a weighed crystallizing dish and dried on a steam bath. The dish and contents should then be cooled in a desiccator and weighed.

The weight of the paraffin scale so obtained, divided by the weight of the distillate taken and multiplied by the percentage of the total distillate obtained from the original sample, equals the percentage of the paraffin scale.

30A. BITUMEN AND GRADING OF ASPHALT SURFACE MIXTURE.

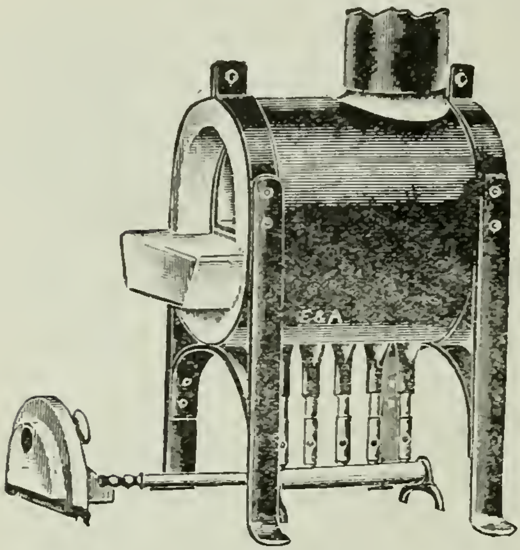


Fig. 152—Surface Mixture Muffle Furnace.

The asphaltic surface is softened by warming and is thoroughly mixed. 100.0 grams are weighed into a thin porcelain dish. This is placed in a gas or electric muffle, as shown in fig. 152, and heated with a good aeration at a temperature not exceeding 700°C, preferably about 500°C, or at a barely perceptible red heat.

It is well to use a pyrometer in the muffle. Usually about two hours is required for the complete combustion of the carbonaceous material. The dish and contents are now removed from the muffle, allowed to cool and weighed. The loss in weight is the percentage of bitumen. The mineral matter is now screened through a nest of screens containing the 1, 2, 4, 10, 20, 40, 80, 200 meshes to the lineal inch. The amount passing each screen and retained on the next is recorded. The exact description of the sizes is as follows:

Mesh	Opening in Inches	Opening in Millimeters	Diameter of Wire, Inch
1	1.050	26.67	0.149
2	0.525	13.33	0.105
4	0.1850	4.699	0.065
10	0.0650	1.651	0.035
20	0.0340	0.864	0.016
40	0.0150	0.381	0.010
80	0.0068	0.173	0.00575
200	0.0029	0.074	0.0021

30B. BITUMEN AND GRADING OF ASPHALTIC SURFACE MIXTURE BY EXTRACTION.

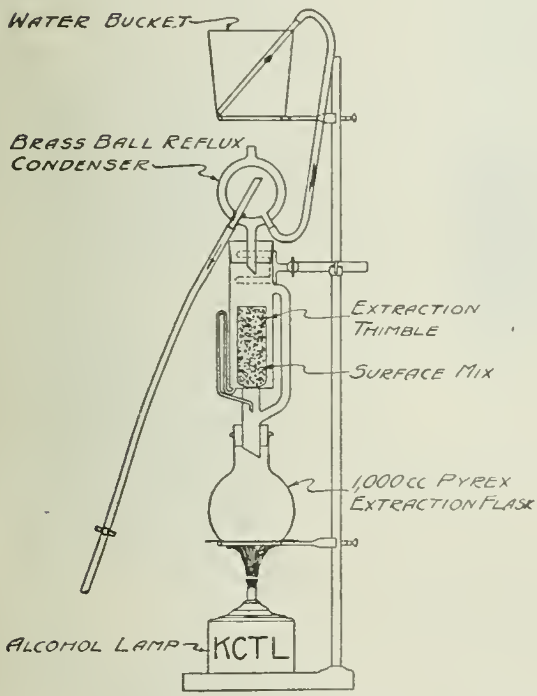


Fig. 155—K. C. T. L. Surface Mixture Extraction Apparatus.

The apparatus used for this analysis is that shown in Fig. 155. It consists of a large metallic soxhlet extractor of about 500 cubic centimeter capacity, a 1,000 cubic centimeter pyrex extraction flask, a brass ball reflux condenser and a very coarse and porous alundum extraction thimble, capable of holding at least 250 grams of the surface mixture, and a means of heating, preferably a 200 watt electric hot plate, although an alcohol lamp or Bunsen burner are suitable.

At least 1,000 grams of the Asphaltic Surface Mixture are placed on a large pie pan under a hot plate, in an oven or over a radiator so that the mixture completely softens. The mixture is now thoroughly stirred and exactly 250 grams are weighed out to the nearest 0.1 gram and are packed into the alundum extraction thimble. The extraction thimble has previously been heated for at least one hour at 105°C. The thimble and the mixture are now weighed and placed in the soxhlet tube of the extractor. Five hundred cubic centimeters of benzol or carbon tetrachloride are added to the soxhlet tube either through the condenser or directly. The apparatus is tightly connected, the stoppers being of cork treating with a solution of pyroxylene in acetone. The flask containing the solvent is now heated

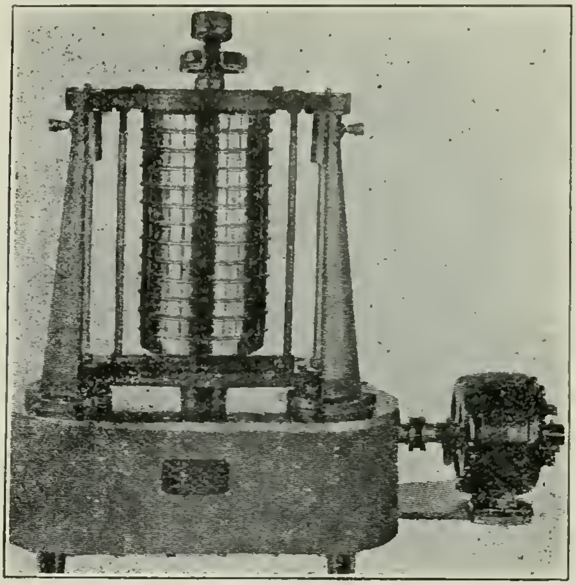


Fig. 154—Screens and Machine for Sieving Surface Mixtures.

for three hours so that the solvent refluxes at least ten times. If a general supply of cold water is not available, ice water may be used for cooling as shown in the figure. At the end of three hours and immediately after the solvent has refluxed the thimble containing the extraction mixture is taken out of the soxhlet tube and dried for one hour at a temperature of 105°C. The loss in weight multiplied by 0.4 is the percentage of bitumen.

The extracted mineral aggregate is examined for the presence of carbonaceous matter, which would be evidence of the overheating of the surface mixture in its manufacture. The mineral is now graded through screens in accordance with the method set forth in paragraph 30-A.

31. TENSILE STRENGTH OF BITUMINOUS SURFACE MIXTURE.

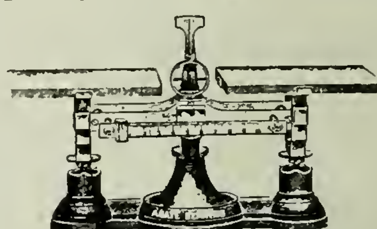


Fig. 153 — Mineral Aggregate Grading Balance.

The surface mixture to be tested is heated to over 240°F to soften it and is thoroughly compressed into a standard cement testing briquet mold. The mold is then packed in ice for at least two hours. It is now quickly put in the tensile strength machine used for testing portland cement and pulled until it fails. Good bituminous surface mixture will give a tensile strength of as high as 600 lbs. per sq. in. Poorly cemented material will give a tensile strength usually lower than 200 lbs. per sq. in.

32. SPECIFIC GRAVITY OF GASES BY VISCOSITY OR EFFUSION METHOD.

The apparatus is shown in Fig. 156.

The apparatus is first filled with distilled water through the reservoir, while the reservoir is in position on its support, and while the three-way cock is set to connect the gas chamber with the surrounding atmosphere. Enough water should be introduced to fill the apparatus to the mark on the glass tube a few centimeters below the stop cock. The water jacket should be filled with water and the whole apparatus allowed to come to room temperature before starting a test. Care should be taken that the apparatus is kept at a constant temperature during any test and no water should be lost from, or added to the reservoir during a test. For each test the temperature of the water in the jacket surrounding the gas chamber should be observed in order to permit correction of the observed specific gravity to the specific gravity of dry gas.

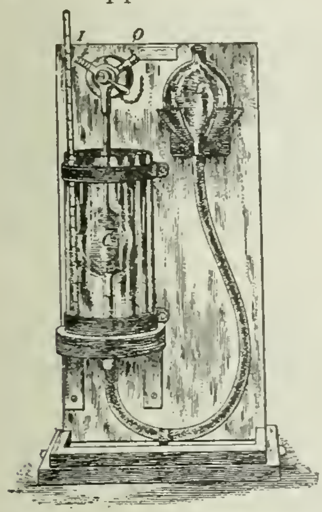


Fig. 156—Apparatus for Specific Gravity of Gases by Effusion Method.

The orifice tube should be screwed in position on the three-way cock and tightened with a small wrench. It is very important that the orifice tube fit gas tight, since if there is a small leak at the base the results will be incorrect. When not in use the orifice tube should be protected from dust and moisture by attaching its cover. It should never be left on the apparatus unless the cock is turned to shut off connection with the gas chamber. This is to prevent the condensation of water vapor in the orifice. The orifice tube should be kept on the screw plug, in the base of the apparatus, which is intended to serve as a holder.

To make a test the gas chamber is filled with a sample of air drawn in through the side connection of the three-way cock by lowering the reservoir. The cock is then closed, the reservoir placed on its support and the air allowed to stand within the gas chamber to become saturated with water vapor and to ensure that it is at the temperature of the apparatus. Sufficient air should be drawn in so that when the sample is compressed by raising the reservoir, the water level will remain below the lower mark. To ensure that the water will drain from the inner surface of the gas chamber to the same extent in each test, the same period of time should be allowed after each filling before beginning the test. At the end of this period, the cock is turned to connect the gas chamber with the orifice and the time of effusion of the air observed by means of a stop watch. The time to be observed is that elapsing between the passage of the water meniscus from the mark below to the mark just above the gas chamber. In timing care should be taken to have the eye on a level with the mark. Several determinations should be made of the time required for the effusion of this volume of air. If the times check within two-fifths second the agreement may be considered satisfactory. It should be noted that an error of 0.5 per cent in timing makes a difference of about one per cent in the apparent specific gravity.

After the air time has been determined, the apparatus should be filled with the gas, whose specific gravity is to be determined. The gas chamber is filled by lowering the reservoir as was done with the air and then allowing the gas to flow out through the orifice. This rinsing of the gas chamber should be done three times to ensure a sample uncontaminated with air. The time for the effusion of the gas is then determined in exactly the same manner as with air.

If the time of effusion with either gas or air is irregular from test to test, this may be the result of moisture condensing in the orifice. This moisture can be removed by blowing dry air through the orifice. Care must be taken at all times to keep the orifice free from dust or water. Especial care should be taken to keep water from getting into the stop cock because it may be blown into the orifice and cause serious trouble. To prevent this, never raise the reservoir from its holder while the cock is open from the gas chamber to the inlet or outlet.

The specific gravity of a gas may be defined as the ratio of the weight of a given volume of gas to the weight of an equal volume of air measured at the same temperature and pressure. The specific gravity of a dry gas referred to dry air is, for all practical purposes, the same for any temperature. But the specific gravity of dry gas compared with dry air is always different from the specific gravity of saturated gas referred to saturated air. Moreover the latter value is different at different temperatures and pressures.

The specific gravity of the gas under the conditions of the test is the ratio of the square of the time for gas effusion to the square of the time for air effusion, i. e.,

$$Ss = \left\{ \frac{Tg}{Ta} \right\}^2$$

The following equations show the relation between the specific gravities of saturated gas compared with saturated air and the specific gravity of dry gas referred to dry air.

$$Ss = \frac{(S + k)}{(1 + k)}$$

$$S = Ss\,(1 + k) - k$$

S = Specific gravity of dry gas referred to dry air.

Ss = Specific gravity of saturated gas referred to saturated air.

The values of k for gas at 760 mm. pressure and at various temperatures are as follows:

Temperature Degrees C.	k
0	0.004
5	.005
10	.008
15	.011
20	.015
25	.020
30	.027

The following is an example of the use of these formulas. The specific gravity (S) of pure dry hydrogen is 0.0695. The specific gravity of saturated hydrogen (Ss) at 20°C is

$$Ss = \frac{0.0695 + 0.015}{1 + 0.015} = 0.0833$$

This is the value which the effusion apparatus would give at 20°C with pure hydrogen.

Where a large number of tests are being run on gases having a limited range of specific gravities it is convenient to prepare a table giving the specific gravity of saturated gas at different temperatures and the corresponding values of the specific gravity of the dry gas, for the range of specific gravity and temperature which will be met with. The derivation of these formulas is discussed in Technologic Paper No. 94, of Bureau of Standards, where further information regarding them may be obtained.

33A. ABSORPTION METHOD FOR TESTING NATURAL AND CASINGHEAD GAS.

Fill the two-armed pipet commonly known as the Hofman apparatus with distilled water. The glass stop cock at the top of the closed graduated arm is a two-way cock, so that the tube above the stop cock can be completely cleared of air. The end of the stop cock through which the outside discharge takes place is closed with a rubber tube and pinch cock. A funnel is set on top of the tube, water is introduced and the tube is washed out with distilled water. The pinch cock is closed, the funnel is removed and the gas is introduced in the usual manner by displacement with water until about 50cc are in the graduated arm. The level of the water is made the same in the two arms and the reading of the quantity of gas is made after it has adjusted itself to the room temperature.

Twenty-five cc of Claroline oil or straw oil are introduced into the open arm. The open arm is now stoppered or held with the thumb so that no air can gain access and the oil is shaken over into the other arm so that it overlies the water. The water is now withdrawn through the stop cock at the lower end of the U. The arm is now filled and kept filled with Claroline or straw oil shaking until the gas ceases to be absorbed. The absorption is calculated in percentage.

The amount of gasoline that may be obtained by absorption from the gas may be approximately calculated from the following table:

Casinghead Gas Yield.

Absorption Percentage	Yield of Gasoline Gallons per 1000 Cu. Ft. of Gas
25	.50
30	.75
35	1.50
40	2.00
50	2.50
60	3.50
80	5.00

One gallon of gasoline obtained from 1000 cu. ft. of gas reduces the volume about 25 to 30 cu. ft. and reduces the heating value about 75 to 100 B. T. U. per cu. ft. or 7½ to 10%. One gallon of gasoline at 20c a gallon would then extract .6c from the value of gas at 20c per 1000 cu. ft. About one-half of the natural gas of the United States contains gasoline in commercially obtainable quantity. Some casinghead gas such as at Sisterville, West Va., gives 13 gallons of gasoline per 1000 cu. ft. and has a heating value of 2500 B. T. U. per cu. ft. Shellac is the best thread dressing material for gasoline and oil joints since it is not soluble in gasoline nor water.

33B. FREEZING METHOD FOR TESTING NATURAL GAS FOR GASOLINE CONTENT.

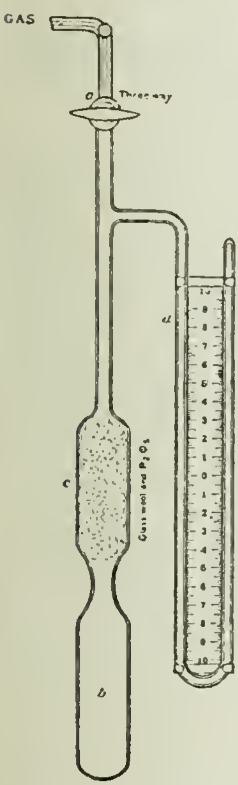


Fig. 157 — Freezing Apparatus for Natural Gas.

This method is from Technical Paper 104, Bureau of Mines, page 26. The sample of natural gas or casinghead gas is introduced in the usual manner into the apparatus shown.

In this apparatus (a) is a three-way stop cock, (c) is a tube filled with glass wool and phosphorus pentoxide for the purpose of drying, (b) is a portion of tube which is introduced into liquid air, (d) is a manometer tube containing mercury and is closed at the further end.

In filling the manometer, the apparatus must be completely exhausted of its air. Sufficient mercury is introduced so that its level rests at the zero point of the scale when under a vacuum. The three-way stop cock at (a) connects to the vacuum pump and to the gas sample container. The sample of gas is drawn in at ordinary atmospheric pressure and the stop cock (a) is closed and the bulb (b) is introduced into the cooling medium. The temperature below 100°C is taken. At this temperature all of the gasoline constituents are completely liquefied. While maintained at this low temperature, the vapor above the liquefied gasoline is exhausted with the vacuum pump thus removing the non-condensible gas. The bulb is now taken out of the refrigerant and allowed to warm up to the temperature at the beginning of the test. The mercury level in the manometer is read, the pressure indicated being the partial pressure of the gasoline in the sample before the dry gas had been removed.

The percentage by volume of gasoline vapor is $\frac{100\,a}{b}$, a being the partial pressure of the gasoline vapor after the test, b being the original atmospheric pressure of the sample. The percentage of gasoline vapor gives the number of pints of gasoline that may be expected in the manufacture of gasoline from the gas under test by the absorption process.

34. COMPLETE ANALYSIS OF GAS.

This apparatus is that described in the Journal of Industrial & Engineering Chemistry by G. A. Burrell and G. G. Oberfell, Vol. 8, page 229.

It is designed for the analysis of a gas mixture containing carbon dioxide, unsaturated hydrocarbons, principally ethylene, oxygen, carbon monoxide, methane, ethane, hydrogen and nitrogen.

In the analysis the capillary train and U tube are swept free of gases by drawing a sample of air into the buret and passing it into the alkaline pyrogallate pipet G to remove oxygen. The residual nitrogen is then passed into all the pipets and through the CuO tube to sweep out other gases that may have been contained therein. The electric current is now turned on the electric heating oven, the temperature having been established by previous experiments. About a 100 watt furnace is required. The temperature desired is between 275 and 300°C. Some of the gas mixture is now drawn into the buret, measured and passed into the pipets E, F and G for the removal respectively of carbon dioxide, illuminants, and oxygen. After these constituents have been removed the stop cocks H, I and J are turned so that communication is made between the buret and the pipet corresponding to J and through the CuO tube. The gas mixture is passed back and forth through the tube furnace until no further diminution in volume is noted by reading the gas volume in the buret. Fifteen minutes is usually required, the carbon monoxide being converted to carbon dioxide and the hydrogen to H_2O. The CO burns more rapidly if any hydrogen is present. When the gas is cooled and no further contraction takes place the remaining volume is read in the buret. The carbon dioxide is now removed by placing the gas mixture into the KOH pipet E. After the hydrogen and carbon monoxide have been determined the residual gas is placed in the KOH pipet for storage and the stop cock is closed. Enough oxygen to burn the paraffin hydrocarbons is then drawn into the buret, measured and passed into the slow combustion pipet J and the platinum spiral is heated to almost white heat. The residual gas is now withdrawn from the pipet E into the buret and from there slowly passed at the rate of not more than 10cc per minute into the pipet J. While operating it is well to cover the slow combustion pipet with gauze as occasionally if the gas is passed in too rapidly an explosion takes place. After combustion is complete, the contraction and the carbon dioxide are measured and the gas again passed into the slow combustion pipet and burned again. A small amount of further contraction may take place but may be ignored unless excessive.

For calculation of results the following example and formulae are useful:

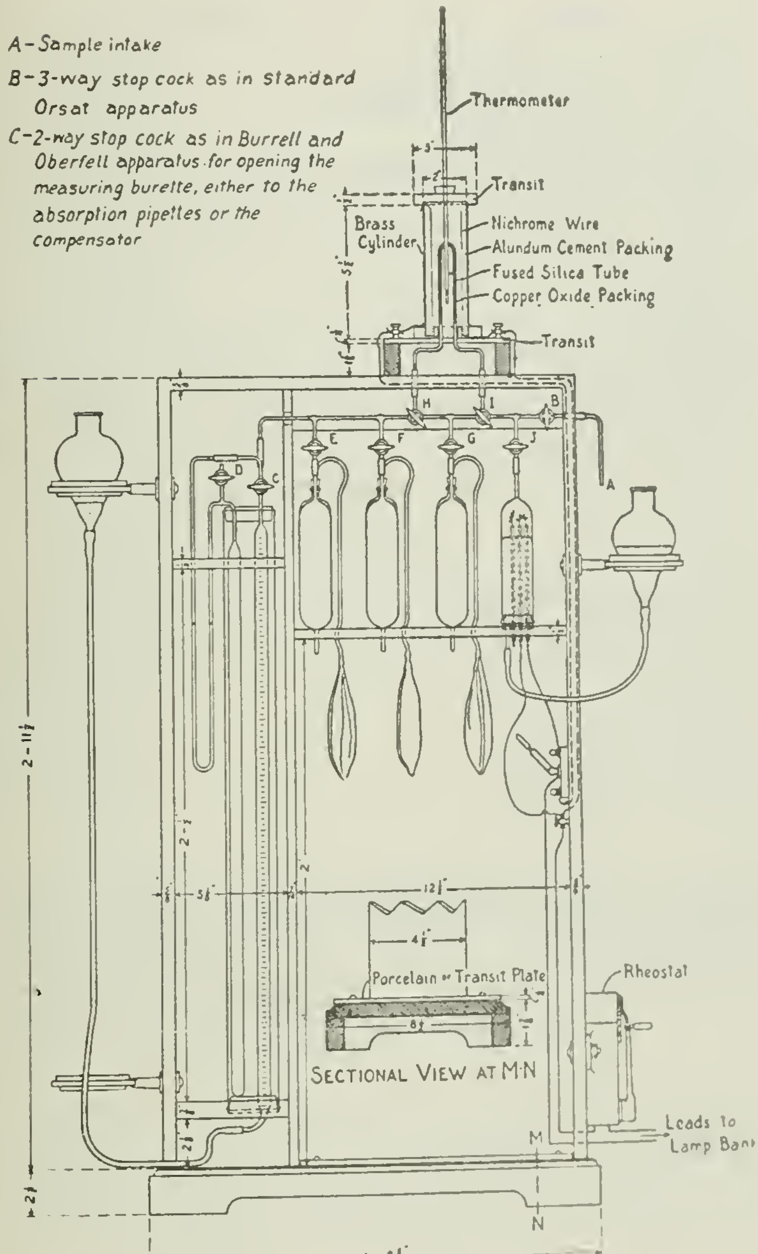


Fig. 158—Orsat-Burrell Apparatus for Analysis of Gas.

Analysis of Gas From Pressure Stills.

a. Volume of sample taken	44.1cc	
b. Volume after KOH absorption	44.0cc	
c. **Carbon Dioxide — CO_2**	0.1cc =	0.22%
d. Volume after Br_2 or Oleum absorption	39.4cc	
e. **Olefins or illuminants**	4.6cc —	10.43%
f. Volume after alkaline pyrogallate absorption	39.3cc	
g. **Oxygen, O_2**	0.1cc —	0.22%
h. Volume after burning in CuO	35.2cc	
i. **Hydrogen, H_2**	4.1cc =	9.30%
j. Volume after absorption in KOH	35.0cc	
k. **Carbon Monoxide CO**	0.2cc =	0.45%
l. Volume taken for slow combustion	17.5cc	
m. Oxygen added	75.6cc	
n. Total volume	93.1cc	
o. Volume after burning	61.5cc	
p. Contraction from burning	32.6cc	
q. Volume after KOH absorption	45.0cc	
r. Contraction from CO_2	16.5cc	
s. **Methane** in sample	16.0cc =	72.56%
t. **Ethane** in sample	0.3cc =	1.36%
u. **Nitrogen** in sample	1.2cc =	5.46%

To calculate amount of methane in the sample from the contraction from burning, "p," and the absorption with KOH, "r," use the following formulae:

$$\text{Methane (s)} = \frac{4p - 5r}{3}$$

$$\text{Ethane (t)} = \frac{4r - 2p}{3}$$

or to obtain % in original gas

$$\%\ \text{Methane} = \frac{100\,js}{al}$$

$$\%\ \text{Ethane} = \frac{100\,jt}{al}$$

$$\%\ \text{Nitrogen} = \frac{100\,ju}{al}$$

35A. HEATING VALUE OF NATURAL GAS BY COMBUSTION.

The usual method of determining the heating value of natural gas by combustion is by the continuous method.

The gas is burned and the water is collected when a certain definite amount of gas has been burned, for example, one-tenth of a foot. With each one-tenth of a foot, the water is collected in a separate receptacle and weighed.

The temperature of the incoming water is recorded and the temperature of the outgoing water, the gases of combustion having been brought to the temperature of the outgoing water. The water condensed from the combustion of the hydrogen in the gas is also collected. From this information, the heating value in B. T. U. is calculated as follows:

t_1 = temperature of incoming water

t_2 = temperature of outgoing water

w = pounds of water passed through

c = pounds of water condensed (average for each 0.1 cu. ft.).

From which B. T. U. per cubic foot $= 10\ (w+c+0.02)\ (t_2\text{-}t_1) — 9704c$

Example:

$t_1 = 63.0°F.$

$t_2 = 111.0°F.$

w = 1.7531 lbs.

c = 0.0091 lbs.

$10\ (1.7531+0.0091+0.02)\ (111.0\text{-}63.0)—(9704)\ (.0091)=855.3—88.3=767$ B. T. U. per cubic foot.

This type of instrument is represented by the Junker and the Sargent calorimeters. Correction of course must be made for the temperature and pressure on the gas in the meter. This type of calorimeter is shown in Fig. 159.

A very clever type of combustion calorimeter for gas is the Union calorimeter offered for sale only in Europe at this time. It depends upon the combustion of a very small quantity of gas resulting in the rise of temperature and expansion of the fluid jacket. The heat of combustion is proportional to the expansion as indicated by a capillary column.

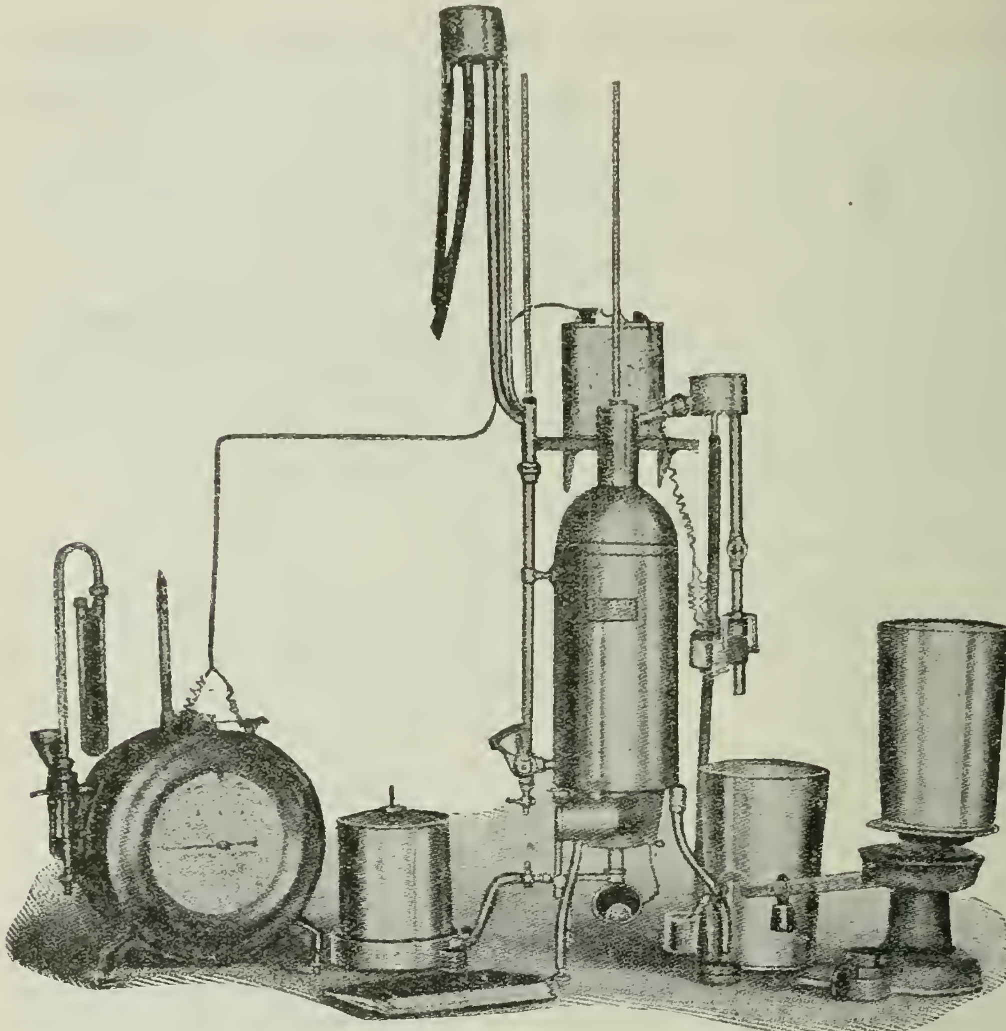


Fig. 159—Gas Calorimeter.

35B. HEATING VALUE OF NATURAL GAS FROM OXYGEN CONSUMED IN BURNING.

The natural gas is burned with an excess of oxygen in a regular combustion pipe J as shown in the apparatus in Fig. 158.

B. T. U. per cu. ft. is equal to $504 \frac{Vo}{Vn}$ where Vo = volume of oxygen consumed in burning Vn volumes of natural gas.

35C. B. T. U. OF GAS BY CALCULATION FROM ANALYSIS.

The heating value of natural gas or any other gas may be calculated as follows:

Percentage of illuminants × 20.00 =
Percentage of CO × 3.41 =
Percentage of CH_4 × 10.65 =
Percentage of H_2 × 3.45 =

The sum of these is the B. T. U. per cubic foot.

REAGENTS USED IN GAS ANALYSIS.

(1) Potassium Hydroxide.

(a) For carbon dioxide determination.

500 grams of commercial potassium hydroxide are dissolved in 1 liter of distilled water. 1cc. of this solution absorbs 40cc. of CO_2.

(b) For the preparation of potassium pyrogallate for oxygen testing.

120 grams of potassium hydrate are dissolved in 100cc. of water. Five grams of crystalline pyrogallic acid are used with 100cc. of this solution.

(2) Potassium Pyrogallate.

This solution is prepared when used except for charging absorption pipet. Five grams mixed with 100cc. of potassium hydrate (b) gives a solution in which 1cc. absorbs 2cc. of oxygen.

(3) Sodium Hydroxide.

One hundred grams are dissolved in 300 grams of water and may be used instead of potassium hydrate where given above.

(4) Cuprous Chloride.

Method of preparation is to place a layer of copper oxide about ⅜ inch deep in the bottom of a two-liter acid bottle. Add an excess of long pieces of heavy copper wire reaching from the top to the bottom of the bottle and fill the bottle with hydrochloric acid of about 1.10 specific gravity. The absorption capacity of this reagent is 4cc. of carbon monoxide CO for each 1cc. of reagent. Metallic copper must always be maintained with the reagent to keep it in good condition.

(5) Ammoniacal Cuprous Chloride.

The acid cuprous chloride as prepared above is treated with ammonia until a faint odor of ammonia is perceptible. Likewise an excess of copper wire is maintained. The absorption capacity is 1cc. of CO to 1cc. of reagent.

(6) Sodium Hypobromite.

This is made of two solutions, one containing 100 grams of caustic soda with 250cc. of distilled water, making 284cc. of solution. The other, 25 grams of liquid bromine, 25 grains of potassium bromine and 200cc. of water. The two solutions are not mixed until ready to use when equal parts are mixed. This reagent is very good for the determination of illuminants.

(7) Fuming Sulphuric Acid.

Ordinary concentrated sulphuric acid is mixed with an equal weight of sulphuric anhydride. One cc. of this reagent absorbs 8cc. of olefins or illuminants.

(8) Palladium Chloride.

Five grams of palladium wire are dissolved in a solution of 30cc. of hydrochloric acid and 2cc. of nitric acid.

The solution is evaporated to dryness on a water bath, 5cc. of hydrochloric acid are added and 25cc. of water and complete solution is made. The solution is diluted to 750cc. It contains one per cent palladous chloride and 1cc. absorbs two-thirds of 1cc. of hydrogen.

Comparison of Temperatures by the Fahrenheit and Centigrade Scales.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
—273°	—459.4						
Absolute Zero							
—200°	—328.0	— 5.6	+22.0	15.6	60.0	36.1	97.0
Temperature of		— 5.0	+23.0	16.0	60.8	36.7	98.0
Liquid Air		— 4.4	+24.0	16.1	61.0	37.0	98.6
—130°	—202.0	— 4.0	+24.8	16.7	62.0	37.2	99.0
Pure Grain Alcohol		— 3.9	+25.0	17.0	62.6	37.8	100.0
Freezes		— 3.3	+26.0	17.2	63.0	38.0	100.4
—70°	—94.0	— 3.0	+26.6	17.8	64.0	38.3	101.0
Ammonia Freezes		— 2.8	+27.0	18.0	64.4	38.9	102.0
—(75°C)		— 2.2	+28.0	18.3	65.0	39.0	102.2
—40°	—40.	— 2.0	+28.4	18.9	66.0	39.4	103.0
Mercury Freezes		— 1.7	+29.0	19.0	66.2	40.0	104.0
(—39.5C)		— 1.1	+30.0	19.4	67.0	40.6	105.0
—30°	—22	— 1.0	+30.2	20.0	68.0	41.0	105.8
Ammonia Liquefies		— 0.6	+31.0	20.6	69.0	41.1	106.0
at —33.7°C		0.	+32.0	21.0	69.8	41.7	107.0
—28	—18.4	+ 0.6	+33.0	21.1	70.0	42.0	107.6
—26	—14.8	1.0	33.8	21.7	71.0	42.2	108.0
—24	—11.2	1.1	34.0	22.0	71.6	42.8	109.0
—22	— 7.6	1.7	35.0	22.2	72.0	43.0	109.4
—20	— 4.0	2.0	35.6	22.8	73.0	43.3	110.0
—19	— 2.2	2.2	36.0	23.0	73.4	43.9	111.0
—18	— 0.4	2.8	37.0	23.3	74.0	44.0	111.2
—17.8	— 0.0	3.0	37.4	23.9	75.0	44.4	112.0
—17.2	+ 1.0	3.3	38.0	24.0	75.2	45.0	113.0
—17.0	+ 1.4	3.9	39.0	24.4	76.0	45.6	114.0
—16.7	+ 2.0	4.0	39.2	25.0	77.0	46.0	114.8
—16.1	+ 3.0	4.4	40.0	25.6	78.0	46.1	115.0
—16.0	+ 3.2	5.0	41.0	26.0	78.8	46.7	116.0
—15.6	+ 4.0	5.6	42.0	26.1	79.0	47.0	116.6
—15.0	+ 5.0	6.0	42.8	26.7	80.0	47.2	117.0
—14.4	+ 6.0	6.1	43.0	27.0	80.6	47.8	118.0
—14.0	+ 6.8	6.7	44.0	27.2	81.0	48.0	118.4
—13.9	+ 7.0	7.0	44.6	27.8	82.0	48.3	119.0
—13.3	+ 8.0	7.2	45.0	28.0	82.4	48.9	120.0
—13.0	+ 8.6	7.8	46.0	28.3	83.0	49.0	120.2
—12.8	+ 9.0	8.0	46.4	28.9	84.0	49.4	121.0
—12.2	+10.0	8.3	47.0	29.0	84.2	50.0	122.0
—12.0	+10.4	8.9	48.0	29.4	85.0	50.6	123.0
—11.7	+11.0	9.0	48.2	30.0	86.0	51.0	123.8
—11.1	+12.0	9.4	49.0	30.6	87.0	51.1	124.0
—11.0	+12.2	10.0	50.0	31.0	87.8	51.7	125.0
—10.6	+13.0	10.6	51.0	31.1	88.0	52.0	125.6
—10.0	+14.0	11.0	51.8	31.7	89.0	52.2	126.0
— 9.4	+15.0	11.1	52.0	32.0	89.6	52.8	127.0
— 9.0	+15.8	11.7	53.0	32.2	90.0	53.0	127.4
— 8.9	+16.0	12.0	53.6	32.8	91.0	53.3	128.0
— 8.3	+17.0	12.2	54.0	33.0	91.4	53.9	129.0
— 8.0	+17.6	12.8	55.0	33.3	92.0	54.0	129.2
— 7.8	+18.0	13.0	55.4	33.9	93.0	54.4	130.0
— 7.2	+19.0	13.3	56.0	34.0	93.2	55.0	131.0
— 7.0	+19.4	13.9	57.0	34.4	94.0	55.6	132.0
— 6.7	+20.0	14.0	57.2	35.0	95.0	56.0	132.8
— 6.1	+21.0	14.4	58.0	35.6	96.0	56.1	133.0
— 6.0	+21.2	15.0	59.0	36.0	96.8	56.7	134.0

Temperature Conversion Tables.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
57.0	134.6	77.8	172.0	98.3	209.0	119.0	246.2
57.2	135.0	78.0	172.4	98.9	210.0	119.4	247.0
57.8	136.0	78.3	173.0	99.0	210.2	120.0	248.0
58.0	136.4	78.9	174.0	99.4	211.0	120.6	249.0
58.3	137.0	79.0	174.2	100.0	212.0	121.0	249.8
58.9	138.0	79.4	175.0	100.6	213.0	121.1	250.0
59.0	138.2	80.0	176.0	101.0	213.8	121.7	251.0
59.4	139.0	80.6	177.0	101.1	214.0	122.0	251.6
60.0	140.0	81.0	177.8	101.7	215.0	122.2	252.0
60.6	141.0	81.1	178.0	102.0	215.6	122.8	253.0
61.0	141.8	81.7	179.0	102.2	216.0	123.0	253.4
61.1	142.0	82.0	179.6	102.8	217.0	123.3	254.0
61.7	143.0	82.2	180.0	103.0	217.4	123.9	255.0
62.0	143.6	82.8	181.0	103.3	218.0	124.0	255.2
62.2	144.0	83.0	181.4	103.9	219.0	124.4	256.0
62.8	145.0	83.3	182.0	104.0	219.2	125.0	257.0
63.0	145.4	83.9	183.0	104.4	220.0	125.6	258.0
63.0	146.0	84.0	183.2	105.0	221.0	126.0	258.8
63.9	147.0	84.4	184.0	105.6	222.0	126.1	259.0
64.0	147.2	85.0	185.0	106.0	222.8	126.7	260.0
64.4	148.0	85.6	186.0	106.1	223.0	127.0	260.6
65.0	149.0	86.0	186.8	106.7	224.0	127.2	261.0
65.6	150.0	86.1	187.0	107.0	224.6	127.8	262.0
66.0	150.8	86.7	188.0	107.2	225.0	128.0	262.4
66.1	151.0	87.0	188.6	107.8	226.0	128.3	263.0
66.7	152.0	87.2	189.0	108.0	226.4	128.9	264.0
67.0	152.6	87.8	190.0	108.3	227.0	129.0	264.2
67.2	153.0	88.0	190.4	108.9	228.0	129.4	265.0
67.8	154.0	88.3	191.0	109.0	228.2	130.0	266.0
68.0	154.4	88.9	192.0	109.4	229.0	130.6	267.0
68.3	155.0	89.0	192.2	110.0	230.0	131.0	267.8
68.9	156.0	89.4	193.0	110.6	231.0	131.1	268.0
69.0	156.2	90.0	194.0	111.0	231.8	131.7	269.0
69.4	157.0	90.6	195.0	111.1	232.0	132.0	269.6
70.0	158.0	91.0	195.8	111.7	233.0	132.2	270.0
70.6	159.0	91.1	196.0	112.0	233.6	132.8	271.0
71.0	159.8	91.7	197.0	112.2	234.0	133.0	271.4
71.1	160.0	92.0	197.6	112.8	235.0	133.3	272.0
71.7	161.0	92.2	198.0	113.0	235.4	133.9	273.0
72.0	161.6	92.8	199.0	113.3	236.0	134.0	273.2
72.2	162.0	93.0	199.4	113.9	237.0	134.4	274.0
72.8	163.0	93.3	200.0	114.0	237.2	135.0	275.0
73.0	163.4	93.9	201.0	114.4	238.0	135.6	276.0
73.3	164.0	94.0	201.2	115.0	239.0	136.0	276.8
73.9	165.0	94.4	202.0	115.6	240.0	136.1	277.0
74.0	165.2	95.0	203.0	116.0	240.8	136.7	278.0
74.4	166.0	95.6	204.0	116.1	241.0	137.0	278.6
75.0	167.0	96.0	204.8	116.7	242.0	137.2	279.0
75.6	168.0	96.1	205.0	117.0	242.6	137.8	280.0
76.0	168.8	96.7	206.0	117.2	243.0	138.0	280.4
76.1	169.0	97.0	206.6	117.8	244.0	138.3	281.0
76.7	170.0	97.2	207.0	118.0	244.4	138.9	282.0
77.0	170.6	97.8	208.0	118.3	245.0	139.0	282.2
77.2	171.6	98.0	208.4	118.9	246.0	139.4	283.0

TEMPERATURE CONVERSION TABLES—Continued.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
140.0	284.0	215.0	419.0	590.0	1094.0	1360.0	2480.0
140.6	285.0	220.0	428.0	600.0	1112.0	1380.0	2516.0
141.0	285.8	225.0	437.0	610.0	1130.0	1400.0	2552.0
141.1	286.0	230.0	446.0	620.0	1148.0	1420.0	2588.0
141.7	287.0	235.0	455.0	630.0	1166.0	1440.0	2624.0
142.0	287.6	240.0	464.0	640.0	1184.0	1460.0	2660.0
142.2	288.0	245.0	473.0	650.0	1202.0	1480.0	2696.0
142.8	289.0	250.0	482.0	660.0	1220.0	1500.0	2732.0
143.0	289.4	254.0	489.2	670.0	1238.0	1520.0	2768.0
143.3	290.0	255.0	491.0	680.0	1256.0	1540.0	2804.0
143.9	291.0	260.0	500.0	690.0	1274.0	1560.0	2840.0
144.0	291.2	265.0	509.0	700.0	1292.0	1580.0	2876.0
144.4	292.0	270.0	518.0	710.0	1310.0	1600.0	2912.0
145.0	293.0	275.0	527.0	720.0	1328.0	1620.0	2918.0
145.0	294.0	280.0	536.0	730.0	1346.0	1640.0	2984.0
146.0	294.8	283.0	541.4	740.0	1364.0	1660.0	3020.0
146.1	295.0	285.0	545.0	750.0	1382.0	1680.0	3056.0
146.7	296.0	288.0	550.4	760.0	1400.0	1700.0	3092.0
147.0	296.6	290.0	554.0	770.0	1418.0	1720.0	3128.0
147.2	297.0	295.0	563.0	780.0	1436.0	1740.0	3164.0
147.8	298.0	300.0	572.0	790.0	1454.0	1760.0	3200.0
148.0	298.4	305.0	581.0	800.0	1472.0	1780.0	3236.0
148.3	299.0	310.0	590.0	810.0	1490.0	1800.0	3272.0
148.9	300.0	315.0	599.0	820.0	1508.0	1825.0	3317.0
149.0	300.2	320.0	608.0	830.0	1526.0	1850.0	3362.0
149.4	301.0	325.0	617.0	840.0	1544.0	1875.0	3407.0
150.0	302.0	330.0	626.0	850.0	1562.0	1900.0	3452.0
152.0	305.6	335.0	635.0	860.0	1580.0	1925.0	3497.0
154.0	309.2	340.0	644.0	870.0	1598.0	1950.0	3542.0
156.0	312.8	345.0	653.0	880.0	1616.0	1975.0	3587.0
158.0	316.4	350.0	662.0	890.0	1634.0	2000.0	3632.0
160.0	320.0	360.0	680.0	900.0	1652.0	2400.0	3812.0
162.0	323.6	370.0	698.0	920.0	1688.0	2500.0	4532.0
164.0	327.2	380.0	716.0	940.0	1724.0	3000.0	5432.0
166.0	330.8	390.0	734.0	960.0	1760.0	3500.0	6332.0
168.0	334.4	400.0	752.0	980.0	1796.0	4000.0	7232.0
170.0	338.0	410.0	770.0	1000.0	1832.0	5000.0	9032.0
172.0	341.6	420.0	788.0	1020.0	1868.0	6000.0	10832.0
174.0	345.2	430.0	806.0	1040.0	1904.0		
176.0	348.8	440.0	824.0	1060.0	1940.0		
178.0	352.4	450.0	842.0	1080.0	1976.0		
180.0	356.0	460.0	860.0	1100.0	2012.0		
182.0	359.6	470.0	878.0	1120.0	2048.0		
184.0	363.2	480.0	896.0	1140.0	2084.0		
186.0	366.8	490.0	914.0	1160.0	2120.0		
188.0	370.4	500.0	932.0	1180.0	2156.0		
190.0	374.0	510.0	950.0	1200.0	2192.0		
192.0	377.6	520.0	968.0	1220.0	2228.0		
194.0	381.2	530.0	986.0	1240.0	2264.0		
196.0	384.8	540.0	1004.0	1260.0	2300.0		
198.0	388.4	550.0	1022.0	1280.0	2336.0		
200.0	392.0	560.0	1040.0	1300.0	2372.0		
205.0	401.0	570.0	1058.0	1320.0	2408.0		
210.0	410.0	580.0	1076.0	1340.0	2444.0		

TEMPERATURE READING CONVERSION FACTORS.

Temp. Centigrade = 5/9 (F.—32) = 5/4 R.
Temp. Fahrenheit = 9/5 C. + 32 = 9/4 R. + 32.
Temp. Reaumur = 4/5 C. = 4/9 (F.—32).

BAUME', SPECIFIC GRAVITY AND POUNDS PER GALLON. (U. S. BUREAU OF STANDARDS.)

	0	1	2	3	4	5	6	7	8	9
10	1.0000	.9993	.9986	.9979	.9972	.9964	.9957	.9950	.9943	.9936
	8.328	8.322	8.317	8.311	8.305	8.299	8.293	8.287	8.281	8.275
11	.9929	.9922	.9915	.9908	.9901	.9894	.9887	.9880	.9873	.9866
	8.269	8.263	8.258	8.252	8.246	8.240	8.234	8.228	8.223	8.217
12	.9859	.9852	.9845	.9838	.9831	.9825	.9818	.9811	.9804	.9797
	8.211	8.205	8.194	8.194	8.188	8.182	8.176	8.171	8.165	8.159
13	.9790	.9783	.9777	.9770	.9763	.9756	.9749	.9743	.9736	.9729
	8.153	8.148	8.142	8.137	8.131	8.125	8.119	8.114	8.108	8.102
14	.9722	.9715	.9709	.9702	.9695	.9688	.9682	.9675	.9669	.9662
	8.096	8.091	8.086	8.080	8.074	8.069	8.063	8.058	8.052	8.047
15	.9655	.9649	.9642	.9635	.9629	.9622	.9615	.9609	.9602	.9596
	8.041	8.035	8.030	8.024	8.019	8.013	8.007	8.002	7.997	7.991
16	.9589	.9582	.9582	.9569	.9563	.9556	.9550	.9543	.9537	.9530
	7.986	7.980	7.975	7.969	7.964	7.959	7.953	7.948	7.942	7.937
17	.9524	.9517	.9511	.9504	.9498	.9492	.9485	.9479	.9472	.9466
	7.931	7.926	7.921	7.915	7.910	7.904	7.899	7.894	7.888	7.883
18	.9459	.9453	.9447	.9440	.9434	.9428	.9421	.9415	.9409	.9402
	7.877	7.872	7.867	7.861	7.856	7.851	7.846	7.841	7.835	7.830
19	.9396	.9390	.9383	.9377	.9371	.9365	.9358	.9352	.9346	.9340
	7.825	7.820	7.814	7.809	7.804	7.799	7.793	7.788	7.783	7.778
20	.9333	.9327	.9321	.9315	.9309	.9302	.9296	.9290	.9284	.9278
	7.772	7.767	7.762	7.757	7.752	7.747	7.742	7.736	7.731	7.726
21	.9272	.9265	.9259	.9253	.9247	.9241	.9235	.9229	.9223	.9217
	7.721	7.716	7.711	7.706	7.701	7.696	7.690	7.685	7.680	7.675
22	.9211	.9204	.9198	.9192	.9186	.9180	.9174	.9168	.9162	.9156
	7.670	7.665	7.660	7.655	7.650	7.645	7.640	7.635	7.630	7.625
23	.9150	.9144	.9138	.9132	.9126	.9121	.9115	.9109	.9103	.9097
	7.620	7.615	7.610	7.605	7.600	7.595	7.590	7.585	7.580	7.575
24	.9091	.9085	.9079	.9073	.9067	.9061	.9056	.9050	.9044	.9038
	7.570	7.565	7.561	7.556	7.551	7.546	7.541	7.536	7.531	7.526
25	.9032	.9026	.9021	.9015	.9009	.9003	.8997	.8992	.8986	.8980
	7.522	7.517	7.512	7.507	7.502	7.497	7.493	7.488	7.483	7.478
26	.8974	.8969	.8963	.8957	.8951	.8946	.8940	.8934	.8929	.8923
	7.473	7.469	7.464	7.459	7.454	7.449	7.445	7.440	7.435	7.430
27	.8917	.8912	.8906	.8900	.8895	.8889	.8883	.8878	.8872	.8866
	7.425	7.421	7.416	7.411	7.407	7.402	7.397	7.393	7.388	7.383
28	.8861	.8855	.8850	.8844	.8838	.8833	.8827	.8822	.8816	.8811
	7.378	7.374	7.369	7.365	7.360	7.355	7.351	7.346	7.341	7.337
29	.8805	.8799	.8794	.8788	.8783	.8777	.8772	.8766	.8761	.8755
	7.332	7.328	7.323	7.318	7.314	7.309	7.305	7.300	7.295	7.291
30	.8750	.8745	.8739	.8734	.8728	.8723	.8717	.8712	.8706	.8701
	7.286	7.282	7.277	7.273	7.268	7.264	7.259	7.254	7.249	7.245
31	.8696	.8690	.8685	.8679	.8674	.8669	.8663	.8658	.8653	.8647
	7.241	7.236	7.232	7.227	7.223	7.218	7.214	7.210	7.205	7.201
32	.8642	.8637	.8631	.8626	.8621	.8615	.8610	.8605	.8600	.8594
	7.196	7.192	7.187	7.183	7.178	7.173	7.169	7.165	7.161	7.156
33	.8589	.8584	.8578	.8573	.8568	.8563	.8557	.8552	.8547	.8542
	7.152	7.147	7.143	7.139	7.134	7.130	7.125	7.121	7.117	7.113
34	.8537	.8531	.8526	.8521	.8516	.8511	.8505	.8500	.8496	.8490
	7.108	7.104	7.100	7.095	7.091	7.087	7.082	7.078	7.074	7.069
35	.8485	.8480	.8475	.8469	.8464	.8459	.8454	.8449	.8444	.8439
	7.065	7.061	7.057	7.052	7.048	7.044	7.039	7.035	7.031	7.027
36	.8434	.8429	.8424	.8419	.8413	.8408	.8403	.8398	.8393	.8388
	7.022	7.018	7.014	7.010	7.006	7.001	6.997	6.993	6.989	6.985
37	.8383	.8378	.8373	.8368	.8363	.8358	.8353	.8348	.8343	.8338
	6.980	6.976	6.972	6.968	6.964	6.960	6.955	6.951	6.947	6.943
38	.8333	.8328	.8323	.8318	.8314	.8309	.8304	.8299	.8294	.8289
	6.939	6.935	6.930	6.926	6.922	6.918	6.914	6.910	6.906	6.902

BAUME, SPECIFIC GRAVITY AND POUNDS PER GALLON—Con.

U. S. BUREAU OF STANDARDS—Con.

	0	1	2	3	4	5	6	7	8	9
39	.8284	.8279	.8274	.8269	.8264	.8260	.8255	.8250	.8245	.8240
	6.898	6.894	6.889	6.885	6.881	6.877	6.873	6.869	6.865	6.861
40	.8235	.8230	.8226	.8221	.8216	.8211	.8206	.8202	.8197	.8192
	6.857	6.853	6.849	6.845	6.841	6 837	6.833	6.829	6.825	6.821
41	.8187	.8182	.8178	.8173	.8168	.8163	.8159	.8154	.8149	.8144
	6.817	6.813	6.809	6.805	6.801	6.797	6.793	6.789	6.785	6.781
42	.8140	.8135	.8130	.8125	.8121	.8116	.8111	.8107	.8102	.8097
	6.777	6.773	6.769	6.765	6.761	6.758	6.754	6.750	6.746	6.742
43	.8092	.8088	.8083	.8078	.8074	.8069	.8065	.8060	.8055	.8051
	6.738	6.734	6.730	6.726	6.722	6.718	6.715	6.711	6.707	6.703
44	.8046	.8041	.8037	.8032	.8028	.8023	.8018	.8014	.8009	.8005
	6.699	6.695	6.691	6.688	6.684	6 680	6.676	6.672	6.668	6.665
45	.8000	.7995	.7991	.7986	.7982	.7977	.7973	.7968	.7964	.7959
	6.661	6.657	6.653	6.649	6.646	6.642	6.638	6.634	6.630	6.627
46	.7955	.7950	.7946	.7941	.7937	.7932	.7928	.7923	.7919	.7914
	6.623	6.619	6.616	6.612	6.608	6.604	6.600	6.597	6.593	6.589
47	.7910	.7905	.7901	.7896	.7892	.7887	.7883	.7878	.7874	.7870
	6 586	6.582	6.578	6.574	6.571	6.567	6.563	6.560	6.556	6.552
48	.7865	.7861	.7856	.7852	.7848	.7843	.7839	.7834	.7830	.7826
	6.548	6.545	6.541	6.537	6.534	6 530	6.526	6.523	6.519	6.515
49	.7821	.7817	.7812	.7808	.7804	.7799	.7795	.7791	.7786	.7782
	6.511	6.508	6.504	6.501	6.497	6.494	6.490	6.486	6.483	6.479
50	.7778	.7773	.7769	.7765	.7761	.7756	.7752	.7748	.7743	.7739
	6.476	6.472	6.468	6.465	6.461	6.458	6.454	6.450	6.447	6.443
51	.7735	.7731	.7726	.7722	.7717	.7713	.7709	.7705	.7701	.7697
	6.440	6.436	6.432	6.429	6.425	6.421	6.418	6.415	6.411	6.408
52	.7692	.7688	.7684	.7680	.7675	.7671	.7667	.7663	.7659	.7654
	6.404	6.401	6.397	6.394	6.390	6 387	6.383	6.380	6.376	6.373
53	.7650	.7646	.7642	.7638	.7634	.7629	.7625	.7621	.7617	.7613
	6.369	6.366	6.362	6.359	6.355	6.351	6.348	6.345	6.341	6.338
54	.7609	.7605	.7600	.7596	.7592	.7588	.7584	.7580	.7576	.7572
	6.334	6.331	6.327	6.324	6.321	6.317	6.314	6.311	6.307	6.304
55	.7568	.7563	.7559	.7555	.7551	.7547	.7543	.7539	.7535	.7531
	6 300	6.296	6.293	6.290	6.287	6.283	6.280	6.276	6.273	6.270
56	.7527	.7523	.7519	.7515	.7511	.7507	.7503	.7499	.7495	.7491
	6.266	6.263	6.250	6.256	6.253	6.249	6.246	6.243	6.240	6.236
57	.7487	.7483	.7479	.7475	.7471	.7467	.7463	.7459	.7455	.7451
	6.233	6.229	6.226	6.223	6.219	6.216	6.213	6.209	6.206	6.203
58	.7447	.7443	.7439	.7435	.7431	.7427	.7423	.7419	.7415	.7411
	6.199	6.196	6.193	6.190	6.186	6.183	6.180	6.176	6.173	6.170
59	.7407	.7403	.7400	.7396	.7392	.7388	.7384	.7380	.7376	.7372
	6.166	6.163	6.160	6.157	6.154	6.150	6.147	6.144	6.141	6.137
60	.7368	.7365	.7361	.7357	.7353	.7349	.7345	.7341	.7338	.7334
	6.134	6.131	6.128	6.124	6.121	6 118	6.115	6.112	6.108	6.105
61	.7330	.7326	.7322	.7318	.7315	.7311	.7307	.7303	.7299	.7295
	6.102	6.099	6.096	6.093	6 090	6.086	6.983	6.080	6.077	6.073
62	.7292	.7288	.7284	.7280	.7277	.7273	.7269	.7265	.7261	.7258
	6.070	6.067	6.064	6.060	6.057	6.054	6.051	6.948	6.045	6.042
63	.7254	.7250	.7246	.7243	.7239	.7235	.7231	.7228	.7224	.7220
	6.038	6.035	6.032	6.029	6.026	6.023	6.020	6.017	6 014	6.010
64	.7216	.7213	.7209	.7205	.7202	.7198	.7194	.7191	.7187	.7183
	6 007	6.004	6.001	5.998	5.995	5 992	5.989	5.986	5.983	5.980
65	.7179	.7176	.7172	.7168	.7165	.7161	.7157	.7154	.7150	.7147
	5.976	5.973	5.970	5.967	5.964	5.961	5.958	5.955	5.952	5.949
66	.7143	.7139	.7136	.7132	.7128	.7125	.7121	.7117	.7114	.7110
	5.946	5.943	5.940	5.937	5.934	5.931	5.928	5.925	5.922	5.919
67	.7107	.7103	.7099	.7096	.7092	.7089	.7085	.7081	.7078	.7074
	5.916	5.913	5.910	5.907	5.904	5.901	5.898	5.895	5.892	5.889

BAUMÉ, SPECIFIC GRAVITY AND POUNDS PER GALLON—Con.

U. S. BUREAU OF STANDARDS—Con.

	0	1	2	3	4	5	6	7	8	9
68	.7071	.7067	.7064	.7060	.7056	.7053	.7049	.7046	.7042	.7039
	5.886	5.883	5.880	5.877	5.874	5.871	5.868	5.865	5.862	5.859
69	.7035	.7032	.7028	.7025	.7021	.7018	.7014	.7011	.7007	.7004
	5.856	5.853	5.850	5.848	5.845	5.842	5.839	5.836	5.833	5.830
70	.7000	.6997	.6993	.6990	.6986	.6983	.6979	.6976	.6972	.6969
	5.827	5.824	5.821	5.818	5.815	5.812	5.810	5.807	5.804	5.801
71	.6965	.6962	.6958	.6955	.6951	.6948	.6944	.6941	.6938	.6934
	5.798	5.795	5.792	5.789	5.786	5.784	5.781	5.778	5.775	5.772
72	.6931	.6927	.6924	.6920	.6917	.6914	.6910	.6907	.6903	.6900
	5.769	5.766	5.763	5.760	5.758	5.755	5.752	5.749	5.746	5.744
73	.6897	.6893	.6890	.6886	.6883	.6880	.6876	.6873	.6869	.6866
	5.741	5.738	5.735	5.732	5.729	5.727	5.724	5.721	5.718	5.715
74	.6863	.6859	.6856	.6853	.6849	.6846	.6843	.6839	.6836	.6833
	5.712	5.710	5.707	5.704	5.701	5.698	5.696	5.693	5.690	5.687
75	.6829	.6826	.6823	.6819	.6816	.6813	.6809	.6806	.6803	.6799
	5.685	5.682	5.679	5.676	5.673	5.671	5.668	5.665	5.662	5.660
76	.6796	.6793	.6790	.6786	.6783	.6780	.6776	.6773	.6770	.6767
	5.657	5.654	5.652	5.649	5.646	5.643	5.640	5.638	5.635	5.632
77	.6763	.6760	.6757	.6753	.6750	.6747	.6744	.6740	.6737	.6734
	5.629	5.627	5.624	5.621	5.618	5.616	5.613	5.610	5.608	5.605
78	.6731	.6728	.6724	.6721	.6718	.6715	.6711	.6708	.6705	.6702
	5.602	5.600	5.597	5.594	5.592	5.589	5.586	5.584	5.581	5.578
79	.6699	.6695	.6692	.6689	.6686	.6683	.6679	.6676	.6673	.6670
	5.576	5.573	5.570	5.568	5.565	5.562	5.560	5.557	5.554	5.552
80	.6667	.6663	.6660	.6657	.6654	.6651	.6648	.6645	.6641	.6638
	5.549	5.546	5.543	5.541	5.538	5.536	5.533	5.531	5.528	5.525
81	.6635	.6632	.6629	.6626	.6623	.6619	.6616	.6613	.6610	.6607
	5.522	5.520	5.517	5.515	5.512	5.510	5.507	5.504	5.502	5.499
82	.6604	.6601	.6598	.6594	.6591	.6588	.6585	.6582	.6579	.6576
	5.497	5.494	5.491	5.489	5.486	5.484	5.481	5.478	5.476	5.473
83	.6573	.6570	.6567	.6564	.6560	.6557	.6554	.6551	.6548	.6545
	5.471	5.468	5.456	5.463	5.460	5.458	5.455	5.453	5.450	5.448
84	.6542	.6539	.6536	.6533	.6530	.6527	.6524	.6521	.6518	.6515
	5.445	5.443	5.440	5.437	5.435	5.432	5.430	5.427	5.425	5.422
85	.6512	.6509	.6506	.6503	.6500	.6497	.6494	.6490	.6487	.6484
	5.420	5.417	5.415	5.412	5.410	5.407	5.405	5.402	5.400	5.397
86	.6482	.6479	.6476	.6473	.6470	.6467	.6464	.6461	.6558	.6455
	5.395	5.392	5.390	5.387	5.385	5.382	5.380	5.377	5.375	5.372
87	.6452	.6449	.6446	.6443	.6440	.6437	.6434	.6431	.6428	.6425
	5.370	5.367	5.365	5.362	5.360	5.357	5.355	5.352	5.350	5.347
88	.6422	.6419	.6416	.6413	.6410	.6407	.6404	.6401	.6399	.6396
	5.345	5.343	5.340	5.338	5.335	5.333	5.330	5.328	5.325	5.323
89	.6393	.6390	.6387	.6384	.6391	.6378	.6375	.6372	.6369	.6367
	5.320	5.318	5.316	5.313	5.311	5.308	5.306	5.304	5.301	5.299
90	.6364	.6361	.6358	.6355	.6352	.6349	.6346	.6343	.6341	.6338
	5.296	5.294	5.291	5.289	5.286	5.284	5.281	5.279	5.277	5.275
91	.6335	.6332	.6329	.6326	.6323	.6321	.6318	.6315	.6312	.6309
	5.272	5.270	5.267	5.265	5.263	5.261	5.258	5.256	5.253	5.251
92	.6306	.6303	.6301	.6298	.6295	.6292	.6289	.6286	.6284	.6281
	5.248	5.246	5.214	5.241	5.239	5.237	5.234	5.232	5.230	5.227
93	.6278	.6275	.6272	.6270	.6267	.6264	.6261	.6258	.6256	.6253
	5.225	5.222	5.220	5.218	5.216	5.213	5.210	5.208	5.206	5.204
94	.6250	.6247	.6214	.6242	.6239	.6236	.6233	.6231	.6228	.6225
	5.201	5.199	5.196	5.194	5.192	5.190	5.187	5.185	5.183	5.180
95	.6222	.6219	.6217	.6214	.6211	.6208	.6206	.6203	.6200	.6197
	5.178	5.176	5.174	5.171	5.169	5.166	5.164	5.162	5.160	5.157
96	.6195	.6192	.6189	.6186	.6184	.6181	.6178	.6176	.6173	.6170
	5.155	5.153	5.150	5.148	5.146	5.144	5.142	5.140	5.137	5.135
97	.6167	.6165	.6162	.6159	.6157	.6154	.6151	.6148	.6146	.6143
	5.132	5.130	5.128	5.126	5.124	5.121	5.119	5.116	5.114	5.112
98	.6140	.6138	.6135	.6132	.6130	.6127	.6124	.6122	.6119	.6116
	5.110	5.108	5.106	5.103	5.101	5.099	5.096	5.094	5.092	5.090
99	.6114	.6111	.6108	.6106	.6103	.6100	.6098	.6095	.6092	.6090
	5.088	5.085	5.083	5.081	5.079	5.076	5.074	5.072	5.070	5.068
.00	.6087	....	....	....	....	....	....	....	....	....
	5.066	....	....	....	....	....	....	....	....	....

BAUME' GRAVITY BY PETROLEUM ASSOCIATION FORMULA EQUIVALENTS OF SPECIFIC GRAVITY AND WEIGHT IN POUNDS PER U. S. GALLON FOR OILS OR FLUIDS LIGHTER THAN WATER. (With Extension of Table for Oils Heavier Than Water.)

(MODULUS 141.5 TAGLIABUE.)

Baume'	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
4	1.044	1.043	1.042	1.041	1.041	1.040	1.039	1.039	1.038	1.037
	8.70	8.69	8.68	8.67	8.67	8.66	8.66	8.65	8.65	8.64 Pds
5	1.037	1.036	1.035	1.034	1.034	1.033	1.032	1.032	1.031	1.030
	8.64	8.63	8.62	8.61	8.61	8.61	8.60	8.60	8.59	8.58 Pds
6	1.029	1.028	1.027	1.026	1.026	1.025	1.024	1.024	1.023	1.022
	8.57	8.56	8.56	8.55	8.55	8.54	8.53	8.53	8.52	8.51 Pds
7	1.022	1.021	1.020	1.019	1.019	1.018	1.017	1.017	1.016	1.015
	8.51	8.51	8.50	8.49	8.49	8.48	8.47	8.47	8.46	8.46 Pds
8	1.014	1.013	1.012	1.011	1.011	1.010	1.009	1.009	1.008	1.007
	8.45	8.49	8.43	8.42	8.42	8.41	8.41	8.41	8.40	8.39 Pds
9	1.007	1.006	1.005	1.004	1.004	1.003	1.002	1.002	1.001	1.000
	8.39	8.38	8.37	8.36	8.36	8.36	8.35	8.35	8.34	8.33 Pds
10	1.000	.9993	.9986	.9979	.9972	.9965	.9958	.9951	.9944	.9937
	8.331	8.325	8.319	8.314	8.308	8.302	8.296	8.290	8.284	8.279
11	.9930	.9923	.9916	.9909	.9902	.9895	.9888	.9881	.9874	.9868
	8.273	8.267	8.261	8.255	8.249	8.244	8.238	8.232	8.226	8.221
12	.9861	.9854	.9847	.9840	.9833	.9826	.9820	.9813	.9806	.9799
	8.215	8.209	8.204	8.198	8.192	8.186	8.181	8.175	8.169	8.164
13	.9792	.9786	.9779	.9772	.9765	.9759	.9752	.9745	.9738	.9732
	8.158	8.153	8.147	8.141	8.135	8.130	8.124	8.119	8.113	8.108
14	.9725	.9718	.9712	.9705	.9698	.9692	.9685	.9679	.9672	.9665
	8.102	8.096	8.091	8.085	8.079	8.074	8.069	8.064	8.058	8.052
15	.9659	.9652	.9646	.9639	.9632	.9626	.9619	.9613	.9606	.9600
	8.047	8.041	8.036	8.030	8.024	8.019	8.014	8.009	8.003	7.998
16	.9593	.9587	.9580	.9574	.9567	.9561	.9554	.9548	.9542	.9535
	.7992	7.987	7.981	7.976	7.970	7.965	7.959	7.954	7.949	7.944
17	.9529	.9522	.9516	.9509	.9503	.9497	.9490	.9484	.9478	.9471
	7.939	7.933	7.928	7.922	7.917	7.912	7.906	7.901	7.896	7.890
18	.9465	.9459	.9452	.9446	.9440	.9433	.9427	.9421	.9415	.9408
	7.885	7.880	7.874	7.869	7.864	7.859	7.854	7.849	7.844	7.838
19	.9402	.9396	.9390	.9383	.9377	.9371	.9365	.9359	.9352	.9346
	7.833	7.828	7.823	7.817	7.812	7.807	7.802	7.797	7.791	7.786
20	.9340	.9334	.9328	.9322	.9315	.9309	.9303	.9297	.9291	.9285
	7.781	7.776	7.771	7.766	7.760	7.755	7.750	7.745	7.740	7.735
21	.9279	.9273	.9267	.9260	.9254	.9248	.9242	.9236	.9230	.9224
	7.730	7.725	7.720	7.715	7.710	7.705	7.700	7.695	7.690	7.685
22	.9218	.9212	.9206	.9200	.9194	.9188	.9182	.9176	.9170	.9165
	7.680	7.675	7.670	7.665	7.660	7.655	7.650	7.645	7.640	7.635
23	.9159	.9153	.9147	.9141	.9135	.9129	.9123	.9117	.9111	.9106
	7.630	7.625	7.620	7.615	7.610	7.605	7.600	7.595	7.590	7.586
24	.9100	.9094	.9088	.9982	.9076	.9071	.9065	.9059	.9053	.9047
	7.581	7.576	7.571	7.566	7.561	7.557	7.552	7.547	7.542	7.537
25	.9042	.9036	.9030	.9024	.9018	.9013	.9007	.9001	.8996	.8990
	7.533	7.528	7.523	7.518	7.513	7.509	7.504	7.499	7.495	7.490
26	.8984	.8978	.8973	.8967	.8961	.8956	.8950	.8944	.8939	.8933
	7.485	7.480	7.475	7.471	7.465	7.461	7.456	7.451	7.447	7.442
27	.8927	.8922	.8916	.8911	.8905	.8899	.8894	.8888	.8883	.8877
	7.437	7.433	7.428	7.424	7.419	7.414	7.410	7.405	7.400	7.395
28	.8871	.8866	.8860	.8855	.8849	.8844	.8838	.8833	.8827	.8822
	7.390	7.386	7.381	7.377	7.372	7.378	7.363	7.359	7.354	7.350
29	.8816	.8811	.8805	.8800	.8794	.8789	.8783	.8778	.8772	.8767
	7.345	7.340	7.335	7.331	7.326	7.322	7.318	7.313	7.308	7.304
30	.8762	.8756	.8751	.8745	.8740	.8735	.8729	.8724	.8718	.8713
	7.300	7.295	7.290	7.285	7.281	7.277	7.272	7.268	7.263	7.259
31	.8708	.8702	.8697	.8692	.8686	.8681	.8676	.8670	.8665	.8660
	7.255	7.250	7.245	7.241	7.236	7.232	7.228	7.223	7.219	7.215
32	.8654	8649	.8644	.8639	.8633	.8628	.8623	.8618	.8612	.8607
	7.210	7.205	7.201	7.197	7.192	7.188	7.184	7.180	7.175	7.170
33	.8602	.8597	.8591	.8586	.8581	.8576	.8571	.8565	.8560	.8555
	7.166	7.162	7.157	7.153	7.149	7.145	7.141	7.136	7.131	7.127
34	.8550	.8545	.8510	.8534	.8529	.8524	.8519	.8514	.8509	.8504
	7.123	7.119	7.115	7.110	7.106	7.101	7.097	7.093	7.089	7.085

BAUME', SPECIFIC GRAVITY AND POUNDS PER GALLON—Con. (MODULUS 141.5.)

Baume'	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
35	.8498 7.080	.8493 7.076	.8488 7.071	.8483 7.067	.8478 7.063	.8473 7.059	.8468 7.055	.8463 7.051	.8458 7.046	.8453 7.042
36	.8448 7.038	.8443 7.034	.8438 7.030	.8433 7.026	.8428 7.021	.8423 7.017	.8418 7.013	.8413 7.009	.8408 7.005	.8403 7.001
37	.8398 6.996	.8393 6.992	.8388 6.988	.8383 6.984	.8378 6.980	.8373 6.976	.8368 6.971	.8363 6.967	.8358 6.963	.8353 6.959
38	.8348 6.955	.8343 6.951	.8338 6.946	.8333 6.942	.8328 6.938	.8324 6.935	.8319 6.931	.8314 6.926	.8309 6.922	.8304 6.918
39	.8299 6.914	.8294 6.910	.8289 6.906	.8285 6.902	.8280 6.898	.8275 6.894	.8270 6.890	.8265 6.886	.8260 6.881	.8256 6.878
40	.8251 6.874	.8246 6.870	.8241 6.866	.8236 6.861	.8232 6.858	.8227 6.854	.8222 6.850	.8217 6.846	.8212 6.841	.8208 6.838
41	.8203 6.834	.8198 6.830	.8193 6.826	.8189 6.822	.8184 6.818	.8179 6.814	.8174 6.810	.8170 6.806	.8165 6.802	.8160 6.798
42	.8156 6.795	.8151 6.791	.8146 6.786	.8142 6.783	.8137 6.779	.8132 6.775	.8128 6.771	.8123 6.767	.8118 6.763	.8114 6.760
43	.8109 6.756	.8104 6.751	.8100 6.748	.8095 6.744	.8090 6.740	.8086 6.736	.8081 6.732	.8076 6.728	.8072 6.725	.8067 6.721
44	.8063 6.717	.8058 6.713	.8053 6.709	.8049 6.706	.8044 6.701	.8040 6.698	.8035 6.694	.8031 6.691	.8026 6.868	.8022 6.683
45	.8017 6.679	.8012 6.675	.8008 6.671	.8003 6.667	.7999 6.664	.7994 6.660	.7990 6.656	.7985 6.652	.7981 6.649	.7976 6.645
46	.7972 6.641	.7967 6.637	.7963 6.634	.7958 6.630	.7954 6.626	.7949 6.623	.7945 6.619	.7941 6.616	.7936 6.611	.7932 6.608
47	.7927 6.604	.7923 6.601	.7918 6.596	.7914 6.593	.7909 6.589	.7905 6.586	.7901 6.582	.7896 6.578	.7892 6.575	.7887 6.571
48	.7883 6.567	.7879 6.564	.7874 6.560	.7870 6.556	.7865 6.552	.7861 6.549	.7857 6.546	.7852 6.542	.7848 6.538	.7844 6.535
49	.7839 6.531	.7835 6.527	.7831 6.524	.7826 6.520	.7822 6.517	.7818 6.513	.7813 6.500	.7809 6.506	.7805 6.502	.7800 6.498
50	.7796 6.495	.7792 6.492	.7788 6.488	.7783 6.484	.7779 6.481	.7775 6.477	.7770 6.473	.7766 6.470	.7762 6.467	.7758 6.463
51	.7753 6.459	.7749 6.456	.7745 6.452	.7741 6.449	.7736 6.415	.7732 6.442	.7728 6.438	.7724 6.435	.7720 6.432	.7715 6.427
52	.7711 6.424	.7707 6.421	.7703 6.417	.7699 6.111	.7694 6.410	.7690 6.407	.7686 6.403	.7682 6.400	.7678 6.397	.7674 6.393
53	.7669 6.389	.7665 6.386	.7661 6.382	.7657 6.379	.7653 6.376	.7649 6.372	.7645 6.369	.7640 6.365	.7636 6.362	.7632 6.358
54	.7628 6.355	.7624 6.352	.7620 6.348	.7616 6.345	.7612 6.342	.7608 6.338	.7603 6.334	.7599 6.331	.7595 6.327	.7591 6.324
55	.7587 6.321	.7583 6.317	.7579 6.314	.7575 6.311	.7571 6.307	.7567 6.301	.7563 6.301	.7559 6.297	.7555 6.291	.7551 6.291
56	.7547 6.287	.7543 6.284	.7539 6.281	.7535 6.277	.7531 6.274	.7527 6.271	.7523 6.267	.7519 6.264	.7515 6.261	.7511 6.257
57	.7507 6.254	.7503 6.251	.7499 6.247	.7495 6.244	.7491 6.241	.7487 6.237	.7483 6.234	.7479 6.231	.7475 6.227	.7471 6.224
58	.7467 6.221	.7463 6.217	.7459 6.214	.7455 6.211	.7451 6.207	.7447 6.201	.7443 6.204	.7440 6.198	.7436 6.195	.7432 6.191
59	.7428 6.188	.7424 6.185	.7420 6.182	.7416 6.178	.7412 6.175	.7408 6.172	.7405 6.169	.7401 6.166	.7397 6.162	.7393 6.159
60	.7389 6.156	.7385 6.152	.7381 6.149	.7377 6.146	.7374 6.143	.7370 6.140	.7366 6.137	.7362 6.133	.7358 6.130	.7354 6.127
61	.7351 6.124	.7347 6.121	.7343 6.117	.7339 6.114	.7335 6.111	.7332 6.108	.7328 6.105	.7324 6.102	.7320 6.098	.7316 6.095
62	.7313 6.092	.7390 6.089	.7305 6.086	.7301 6.082	.7298 6.080	.7294 6.077	.7290 6.073	.7286 6.070	.7283 6.067	.7279 6.064
63	.7275 6.061	.7271 6.057	.7268 6.055	.7264 6.052	.7260 6.048	.7256 6.045	.7253 6.042	.7249 6.039	.7245 6.036	.7242 6.043
64	.7238 6.030	.7234 6.027	.7230 6.023	.7227 6.021	.7223 6.017	.7219 6.014	.7216 6.012	.7212 6.008	.7208 6.005	.7205 6.002
65	.7201 5.999	.7197 5.996	.7194 5.993	.7190 5.990	.7186 5.987	.7183 5.984	.7179 5.981	.7175 5.977	.7172 5.975	.7168 5.972
66	.7165 5.969	.7161 5.966	.7157 5.962	.7154 5.960	.7150 5.957	.7146 5.953	.7143 5.951	.7139 5.918	.7136 5.945	.7132 5.912
67	.7128 5.938	.7125 5.936	.7121 5.933	.7118 5.930	.7114 5.927	.7111 5.924	.7107 5.921	.7103 5.918	.7100 5.915	.7096 5.912

BAUME', SPECIFIC GRAVITY AND POUNDS PER GALLON—Con.
(MODULUS 141.5.)

	0	1	2	3	4	5	6	7	8	9
68	.7093	.7089	.7086	.7082	.7079	.7075	.7071	.7068	.7064	.7061
	5.909	5.906	5.903	5.900	5.898	5.894	5.891	5.888	5.885	5.883
69	.7057	.7054	.7050	.7047	.7043	.7040	.7036	.7033	.7029	.7026
	5.879	5.877	5.873	5.871	5.868	5.865	5.862	5.859	5.856	5.853
70	.7022	.7019	.7015	.7012	.7008	.7005	.7001	.6998	.6995	.6991
	5.850	5.848	5.844	5.842	5.838	5.836	5.833	5.830	5.828	5.824
71	.6988	.6984	.6981	.6977	.6974	.6970	.6967	.6964	.6960	.6957
	5.822	5.818	5.816	5.813	5.810	5.807	5.804	5.802	5.798	5.796
72	.6953	.6950	.6946	.6943	.6940	.6936	.6933	.6929	.6926	.6923
	5.793	5.790	5.787	5.784	5.782	5.778	5.776	5.773	5.770	5.768
73	.6919	.6916	.6912	.6909	.6906	.6902	.6899	.6896	.6892	.6889
	5.764	5.762	5.758	5.756	5.753	5.750	5.748	5.745	5.742	5.739
74	.6886	.6882	.6879	.6876	.6872	.6869	.6866	.6862	.6859	.6856
	5.737	5.733	5.731	5.728	5.725	5.723	5.720	5.717	5.714	5.712
75	.6852	.6849	.6846	.6842	.6839	.6836	.6832	.6829	.6826	.6823
	5.708	5.706	5.703	5.700	5.698	5.695	5.692	5.689	5.687	5.684
76	.6819	.6816	6813	.6809	.6806	.6803	.6800	.6796	.6793	.6790
	5.681	5.678	5.676	5.673	5.670	5.668	5.665	5.662	5.659	5.657
77	.6787	.6783	.6780	.6777	.6774	.6770	.6767	.6764	.6761	.6757
	5.654	5.651	5.648	5.646	5.643	5.640	5.638	5.635	5.633	5.629
78	.6754	.6751	.6748	.6745	.6741	.6738	.6735	.6732	.6728	.6725
	5.627	5.624	5.622	5.619	5.616	5.613	5.611	5.608	5.605	5.603
79	.6722	.6719	.6716	.6713	.6709	.6706	.6703	.6700	.6697	.6693
	5.600	5.597	5.595	5.593	5.589	5.587	5.584	5.582	5.579	5.576
80	.6690	.6687	.6684	.6681	.6678	.6675	.6671	.6668	.6665	.6662
	5.573	5.571	5.568	5.566	5.563	5.561	5.558	5.555	5.553	5.550
81	.6659	.6656	.6653	.6649	.6646	.6643	.6640	.6637	.6634	.6631
	5.548	5.545	5.543	5.540	5.537	5.534	5.532	5.529	5.527	5.524
82	.6628	.6625	.6621	.6618	.6615	.6612	.6609	.6606	.6603	.6600
	5.522	5.519	5.516	5.513	5.511	5.508	5.506	5.503	5.501	5.498
83	.6597	.6594	.6591	.6588	.6584	.6581	.6578	.6575	.6572	.6569
	5.496	5.493	5.491	5.488	5.485	5.483	5.480	5.478	5.475	5.473
84	.6566	.6563	.6560	.6557	.6554	.6551	.6548	.6545	.6542	.6539
	5.470	5.468	5.465	5.463	5.460	5.458	5.455	5.453	5.450	5.448
85	.6536	.6533	.6530	.6527	.6524	.6521	.6518	.6515	.6512	.6509
	5.445	5.443	5.440	5.438	5.435	5.433	5.430	5.428	5.425	5.423
86	.6506	.6503	.6500	.6497	.6494	.6491	.6488	.6485	.6482	.6479
	5.420	5.418	5.415	5.419	5.410	5.408	5.405	5.403	5.400	5.398
87	.6476	.6473	.6470	.6467	.6464	.6461	.6458	.6455	.6452	.6449
	5.395	5.393	5.390	5.388	5.385	5.383	5.380	5.378	5.375	5.373
88	.6446	.6444	.6441	.6438	.6435	.6432	.6429	.6426	.6423	.6420
	5.370	5.368	5.366	5.363	5.361	5.358	5.356	5.353	5.351	5.349
89	.6417	.6414	.6411	.6409	.6406	.6403	.6400	.6397	.6394	.6391
	5.346	5.344	5.341	5.339	5.237	5.334	5.332	5.329	5.327	5.324
90	.6388	.6385	.6382	.6380	.6377	.6374	.6371	.6368	.6365	.6362
	5.322	5.319	5.317	5.315	5.313	5.310	5.308	5.305	5.303	5.300
91	.6360	.6357	.6354	.6351	.6348	.6345	.6342	.6340	.6337	.6334
	5.299	5.296	5.294	5.291	5.289	5.286	5.284	5.282	5.279	5.277
92	.6331	.6328	.6325	.6323	.6320	.6317	.6314	.6311	.6309	.6306
	5.274	5.272	5.269	5.268	5.265	5.263	5.260	5.258	5.256	5.254
93	.6303	.6300	.6297	.6294	.6292	.6289	.6286	.6283	.6281	.6278
	5.251	5.249	5.246	5.244	5.242	5.239	5.237	5.234	5.233	5.230
94	.6275	.6272	.6269	.6267	.6264	.6261	.6258	.6256	.6253	.6250
	5.228	5.225	5.223	5.221	5.219	5.216	5.214	5.212	5.209	5.207
95	.6247	.6244	.6242	.6239	.6236	.6233	.6231	.6228	.6225	.6223
	5.204	5.202	5.200	5.198	5.195	5.193	5.191	5.189	5.186	5.184
96	.6220	.6217	.6214	.6212	.6209	.6206	.6203	.6201	.6198	.6195
	5.182	5.179	5.177	5.175	5.173	5.170	5.168	5.166	5.164	5.161
97	.6193	.6190	.6187	.6184	.6182	.6179	.6176	.6174	.6171	.6168
	5.159	5.157	5.154	5.152	5.150	5.148	5.145	5.144	5.141	5.139
98	.6166	.6163	.6160	.6158	.6155	.6152	.6150	.6147	.6144	.6141
	5.137	5.134	5.132	5.130	5.128	5.125	5.124	5.121	5.119	5.116
99	.6139	.6136	.6134	.6131	.6128	.6126	.6123	.6120	.6118	.6115
	5.114	5.112	5.110	5.108	5.105	5.104	5.101	5.099	5.097	5.094

REDUCTION OF BAUME' GRAVITY READINGS TO 60 F.

(This table shows the degrees Baume' at 60° F of oils having, at the designated temperatures, the observed degrees Baume' indicated. For example, if the observed degrees Baume' is 20.0 at 78° F, the true degrees Baume' at 60° F will be 19.0. Intermediate values not given in the table may be conveniently interpolated. For example, if the observed degrees Baume' is 20.4 at 78° F, the true degrees Baume' at 60° F will be 19.4. The headings "Observed Degrees Baume'" and "Observed Temperature" signify the true indication of the hydrometer and the true temperature of the oil—that is, the observed readings corrected, if necessary, for instrumental errors.)

Observed Temperature in ° F.	Observed Degrees Baume'								
	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0
	Corresponding Degrees Baume at 60° F.								
60	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0
62	7.9	8.9	9.9	10.9	11.9	12.9	13.9	14.9	15.9
64	7.8	8.0	9.8	10.8	11.8	12.8	13.8	14.8	15.8
66	7.7	8.7	9.7	10.7	11.7	12.7	13.7	14.7	15.7
68	7.6	8.6	9.6	10.6	11.6	12.6	13.6	14.7	15.7
70	7.5	8.5	9.5	10.5	11.5	12.5	13.6	14.6	15.6
72	7.4	8.4	9.4	10.5	11.5	12.5	12.5	14.5	15.5
74	7.3	8.3	9.3	10.4	11.4	12.4	13.4	14.5	15.5
76	7.2	8.2	9.2	10.3	11.3	12.3	13.3	14.4	15.4
78	7.1	8.1	9.1	10.2	11.2	12.2	13.3	14.3	15.3
80	7.1	8.1	9.1	10.1	11.1	12.2	13.2	14.3	15.3
82	6.9	7.9	9.0	10.1	11.1	12.1	13.1	14.2	15.2
84	6.8	7.8	8.9	10.0	11.0	12.0	13.0	14.1	15.1
86	6.7	7.7	8.8	9.9	10.9	11.9	13.9	14.1	15.0
88	6.7	7.6	8.8	9.8	10.8	11.8	12.9	14.0	15.0
90	6.6	7.6	8.7	9.8	10.8	11.8	12.8	13.9	14.9
92	6.5	7.5	8.6	9.7	10.7	11.7	12.7	13.8	14.8
94	6.4	7.4	8.5	9.6	10.6	11.6	12.7	13.7	14.7
96	6.3	8.3	8.4	9.5	10.5	11.5	12.6	13.7	14.7
98	6.3	7.3	8.3	9.4	10.5	11.4	12.5	13.6	14.6
100	6.2	7.2	8.3	9.4	10.4	11.4	12.4	13.5	14.5
102	6.1	7.1	8.2	9.3	10.3	11.3	12.3	13.5	14.4
104	6.0	7.0	8.1	9.2	10.2	11.2	12.3	13.4	14.4
106	5.9	6.9	8.0	9.1	10.1	11.1	12.2	13.3	14.3
108	5.8	6.8	8.0	9.0	10.0	11.0	12.1	13.2	14.2
110	5.7	6.7	7.9	9.0	9.9	10.9	12.0	13.2	14.1
112	5.6	6.6	7.8	8.9	9.9	10.9	12.0	13.1	14.1
114	5.5	6.5	7.7	8.8	9.8	10.8	11.9	13.0	14.0
116	5.4	6.4	7.6	8.7	9.7	10.7	11.8	12.9	13.9
118	5.4	6.4	7.5	8.6	9.6	10.6	11.7	12.8	13.9
120	5.3	6.3	7.4	8.5	9.6	10.5	11.7	12.8	13.8
122	5.2	6.2	7.3	8.4	9.4	10.5	11.6	12.7	13.8
124	5.1	6.1	7.2	8.3	9.3	10.4	11.5	12.6	13.7
126	5.0	6.0	7.1	8.2	9.2	10.3	11.4	12.5	13.6
128	4.9	5.9	7.0	8.1	9.1	10.2	11.3	12.4	13.5
130	4.8	5.8	6.9	8.0	9.1	10.2	11.3	12.4	13.5
132	4.7	5.7	6.8	7.9	9.0	11.1	11.2	12.3	13.4
134	4.6	5.6	6.7	7.8	8.9	10.0	11.1	12.2	13.3
136	4.5	5.5	6.6	7.7	8.8	9.9	11.0	12.1	13.2
138	4.4	5.4	6.5	7.6	8.8	9.8	10.9	12.0	13.1
140	4.3	5.4	6.5	7.6	8.7	9.8	10.9	11.9	13.0
142	4.2	5.3	6.4	7.5	8.6	9.7	10.8	11.9	13.0
144	4.1	52.	6.3	7.4	8.5	9.6	10.7	11.8	12.9
146	4.0	5.1	6.2	7.3	8.4	9.5	10.6	11.7	12.8
148	3.9	5.0	6.1	7.2	8.3	9.4	10.5	11.6	12.7
150	3.8	4.9	6.0	7.1	8.2	9.3	10.4	11.5	12.6

REDUCTION OF BAUME GRAVITY READINGS TO 60 F—Con.

Observed Temperature in ° F.	Observed Degrees Baume′									
	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0
	Corresponding Degrees Baume′ at 60° F.									
30	18.6	19.7	20.7	21.7	22.7	23.7	24.8	25.8	26.9	27.9
32	18.6	19.6	20.6	21.6	22.6	23.6	24.7	25.7	26.8	27.8
34	18.5	19.5	20.5	21.5	22.5	23.5	24.6	25.6	26.7	27.7
36	18.3	19.4	20.4	21.4	22.4	23.4	24.5	25.5	26.5	27.5
38	18.2	19.3	20.3	21.3	22.3	23.3	24.4	25.4	26.4	27.4
40	18.1	19.1	20.1	21.2	22.2	23.2	24.2	25.2	26.2	27.2
42	18.0	19.0	20.0	21.1	22.1	23.1	24.1	25.1	26.1	27.1
44	17.9	18.9	19.9	20.9	21.9	22.9	23.9	24.9	26.0	27.0
46	17.8	18.8	19.8	20.8	21.8	22.8	23.8	24.8	25.9	26.9
48	17.6	18.7	19.7	20.7	21.7	22.7	23.7	24.7	25.8	26.8
50	17.5	18.6	19.6	20.6	21.6	22.6	23.6	24.6	25.6	26.6
52	17.4	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5
54	17.3	18.3	19.3	20.3	21.3	22.3	23.3	24.3	25.4	26.4
56	17.2	18.2	19.2	20.2	21.2	22.2	23.2	24.2	25.3	26.3
58	17.1	18.1	19.1	20.1	21.1	22.1	23.1	24.1	25.1	26.1
60	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0
62	16.9	17.9	18.9	19.9	20.9	21.9	22.9	23.9	24.9	25.9
64	16.8	17.8	18.8	19.8	20.8	21.8	22.8	23.8	24.7	25.7
66	16.7	17.7	18.7	19.7	20.7	21.7	22.7	23.7	24.6	25.6
68	16.6	17.6	18.6	19.5	20.5	21.5	22.5	23.5	24.5	25.5
70	16.5	17.5	18.5	19.4	20.4	21.4	22.4	23.4	24.4	25.4
72	16.4	17.4	18.4	19.3	20.3	21.3	22.3	23.3	24.3	25.3
74	16.3	17.3	18.2	19.2	20.2	21.2	22.2	23.2	24.1	25.1
76	16.2	17.2	18.1	19.1	20.1	21.1	22.1	23.1	24.0	25.0
78	16.1	17.1	18.0	19.0	19.9	20.9	21.9	22.9	23.9	24.9
80	16.0	17.0	17.9	18.9	19.8	20.8	21.8	22.8	23.8	24.8
82	15.9	16.9	17.8	18.8	19.7	20.7	21.7	22.7	23.7	24.7
84	15.8	16.8	17.7	18.7	19.6	20.6	21.6	22.6	23.5	24.5
86	15.7	17.6	17.6	18.6	19.5	20.5	21.5	22.5	23.4	24.4
88	15.5	16.5	17.5	18.4	19.4	20.4	21.3	22.3	23.3	24.3
90	15.4	16.4	17.3	18.3	19.3	20.3	21.2	22.2	23.2	24.2
92	15.3	16.3	17.2	18.2	19.2	20.2	21.1	22.1	23.1	24.1
94	15.2	16.2	17.1	18.1	19.1	20.1	21.0	22.0	23.0	24.0
96	15.1	16.1	17.0	18.0	19.0	20.0	20.9	21.9	22.8	23.8
98	15.0	16.0	16.9	17.9	18.8	19.8	20.8	21.8	22.7	23.7
100	14.9	15.9	16.8	17.8	18.7	19.7	20.7	21.7	22.6	23.6
102	14.8	15.8	16.7	17.7	18.6	19.6	20.5	21.5	22.5	23.5
104	14.7	15.7	16.6	17.6	18.5	19.5	20.4	21.4	22.4	23.4
106	14.5	15.5	16.4	17.5	18.4	19.4	20.3	21.3	22.3	23.3
108	14.4	15.4	16.3	17.3	18.2	19.2	20.2	21.2	22.2	23.1
110	14.3	15.3	16.2	17.2	18.1	19.1	20.1	21.1	22.0	23.0
112	14 2	15.2	16.1	17.1	18.0	19.0	20.0	21.0	21.9	22.9
114	14.1	15.1	16.0	17.0	17.9	18.9	19.9	20.9	21.8	22.8
116	14.0	15.0	15.9	16.9	17.8	18.8	19.8	20.8	21.7	22.7
118	13.9	14.9	15.8	16.8	17.7	18.7	19.6	20.6	21.5	22.5
120	13.8	14.8	15.7	16.7	17.6	18.6	19.5	20.5	21.4	22.4

REDUCTION OF BAUME GRAVITY READINGS TO 60 F—Con.

Observed Temperature in ° F	Observed Degrees Baume'									
	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	25.0	36.0
	Corresponding Degrees Baume' at 60° F									
30	29.0	30.0	31.0	32.0	33.1	34.1	35.2	36.2	37.3	38.3
32	28.8	29.8	30.9	31.9	33.0	34.0	35.0	36.0	37.1	38.1
34	28.7	29.7	30.8	31.8	32.8	33.8	34.8	35.8	36.9	38.0
36	28.5	29.5	30.6	31.6	32.7	33.7	34.7	35.7	36.8	37.8
38	28.4	29.4	30.5	31.5	32.5	33.5	34.5	35.5	36.6	37.7
40	28.3	29.3	30.4	31.4	32.4	33.4	34.4	35.4	36.5	37.5
42	28.2	29.2	30.2	31.2	32.2	33.2	34.3	35.3	36.3	37.3
44	28.1	29.1	30.1	31.1	32.1	33.1	34.2	35.2	36.2	37.2
46	27.9	28.9	29.9	30.9	31.9	32.9	34.0	35.0	36.1	37.1
48	27.8	28.8	29.8	30.8	31.8	32.8	33.9	34.9	35.9	36.9
50	27.6	38.6	29.7	30.7	31.7	32.7	33.7	34.7	35.7	36.7
52	27.5	28.5	29.6	30.6	31.6	32.6	33.6	34.6	35.6	36.6
54	27.4	28.4	29.4	30.4	31.4	32.4	33.4	34.4	35.4	36.4
56	27.3	28.3	29.3	30.3	31.3	32.3	33.3	34.3	35.3	36.3
58	27.1	28.1	29.1	30.1	31.1	32.1	33.1	34.1	35.1	36.1
60	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0
62	26.9	27.9	28.9	29.9	30.9	31.9	32.9	33.9	34.9	35.9
64	26.7	27.7	28.7	29.7	30.7	31.7	32.7	33.7	34.7	35.7
66	26.6	27.6	28.6	29.6	30.6	31.6	32.6	33.6	34.6	35.6
68	26.5	27.5	28.4	29.4	30.4	31.4	32.4	33.4	34.4	25.4
70	26.4	27.4	28.3	29.3	30.3	31.3	32.2	33.2	34.2	35.2
72	26.3	27.3	28.2	29.2	30.2	31.2	32.1	33.1	34.1	35.1
74	26.1	27.1	28.1	29.1	30.1	31.1	32.0	33.0	33.9	34.9
76	26.0	27.0	27.9	28.9	29.9	30.9	31.8	32.8	33.8	34.8
78	25.8	26.8	27.8	28.8	29.8	30.8	31.7	32.7	33.6	34.6
80	25.7	26.7	27.7	28.7	29.7	30.7	31.6	32.6	33.5	34.5
82	25.6	26.6	27.6	28.6	29.5	30.5	31.5	32.5	33.4	34.4
84	25.5	26.5	27.5	28.5	29.4	30.4	31.3	32.3	33.2	34.2
86	25.4	26.4	27.3	28.3	29.2	30.2	31.2	32.2	33.1	34.1
88	25.2	26.2	27.2	28.2	29.1	30.1	31.0	32.0	33.0	34.0
90	25.1	26.1	27.0	28.0	29.0	30.0	30.9	31.9	32.9	33.9
92	25.0	26.0	26.9	27.9	28.9	29.9	30.8	31.8	32.7	33.7
94	24.9	25.9	26.8	27.8	28.8	29.8	30.7	31.6	32.6	33.6
96	24.7	25.7	26.7	27.7	28.6	29.6	30.5	31.5	32.5	33.5
98	24.6	25.6	26.6	27.6	28.5	29.5	30.4	31.4	32.3	33.3
100	24.5	25.5	26.4	27.4	28.3	29.3	30.3	31.3	32.2	33.2
102	24.4	25.4	26.3	27.3	28.2	29.2	30.2	31.2	32.1	33.0
104	24.3	25.3	26.2	27.1	28.1	29.1	30.0	31.0	31.9	32.9
106	24.2	25.2	26.1	27.0	28.0	29.0	29.9	30.9	31.8	32.7
108	24.0	25.0	25.9	26.9	27.8	28.8	29.7	30.7	31.6	32.6
110	23.9	24.9	25.8	26.8	27.7	28.7	29.6	30.6	31.5	32.5
112	23.8	24.8	25.7	26.7	27.6	28.6	29.5	30.4	31.4	32.3
114	23.7	24.7	25.6	26.6	27.5	28.4	29.3	30.3	31.2	32.2
116	23.6	24.6	25.5	26.4	27.3	28.3	29.2	30.2	31.1	32.1
118	23.4	24.4	25.3	26.3	27.2	28.2	29.1	30.1	31.0	32.0
120	23.3	24.3	25.2	26.2	27.1	28.1	29.0	30.0	30.9	31.9

REDUCTION OF BAUME GRAVITY READINGS TO 60 F—Con.

Observed Temperature in ° F	Observed Degrees Baume'									
	37.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0	45.0	46.0
	Corresponding Degrees Baume' at 60° F									
30	39.3	40.3	41.4	42.4	43.5	44.5	45.6	46.6	47.7	48.7
32	39.2	40.2	41.3	42.3	43.4	44.3	45.4	46.4	47.5	48.5
34	39.0	40.0	41.1	42.1	43.2	44.2	45.3	46.3	47.3	48.3
36	38.9	39.9	41.0	42.0	43.1	44.0	45.1	46.1	47.2	48.2
38	38.7	39.7	40.8	41.8	42.9	43.9	45.0	46.0	47.0	48.0
40	38.5	39.5	40.6	41.6	42.7	43.7	44.8	45.8	46.8	47.8
42	38.4	39.4	40.5	41.5	42.5	43.5	44.6	45.6	46.6	47.6
44	38.2	39.2	40.3	41.3	42.4	43.4	44.4	45.4	45.4	47.4
46	38.1	39.1	40.1	41.1	42.2	43.2	44.2	45.2	46.2	47.2
48	37.9	38.9	39.9	40.9	42.0	43.0	44.1	45.1	46.1	47.1
50	37.8	38.8	39.8	40.8	41.8	42.8	43.9	44.9	45.9	46.9
52	37.6	38.6	39.6	40.7	41.7	42.6	43.7	44.7	45.7	46.7
54	37.4	38.4	39.5	40.5	41.5	42.5	43.5	44.5	45.5	46.5
56	37.3	38.3	39.3	40.3	41.3	42.2	43.3	44.3	45.3	46.3
58	37.1	38.1	39.1	40.1	41.1	42.1	43.1	44.1	45.2	46.2
60	37.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0	45.0	46.0
62	36.9	37:9	38.9	39.9	40.9	41.9	42.9	43.9	44.9	45.9
64	36.7	37.7	38.7	39.7	40.7	41.7	42.7	43.7	44.7	45.7
66	36.6	37.6	38.6	39.5	40.5	41.5	42.5	43.5	44.5	45.5
68	36.4	37.4	38.4	39.4	40.4	41.4	42.4	43.3	44.3	45.3
70	36.2	37.2	38.2	39.2	40.2	41.2	42.2	43.1	44.1	45.1
72	36.1	37.1	38.1	39.1	40.0	41.0	42.0	43.0	44.0	45.0
74	35.9	36.9	37.9	38.9	39.8	40.8	41.8	42.8	43.8	44.8
76	35.8	36.8	37.8	38.7	39.7	40.7	41.7	42.7	43.6	44.6
78	35.6	36.6	37.6	38.6	39.5	40.5	41.5	42.5	43.4	44.4
80	35.5	36.5	37.5	38.5	39.4	40.4	41.3	42.3	43.2	44.2
82	35.3	36.3	37.3	38.3	39.2	40.2	41.2	42.2	43.1	44.1
84	35.2	36.2	37.2	38.2	39.1	40.1	41.0	42.0	42.9	43.9
86	35.1	36.1	37.0	38.0	38.9	39.9	40.9	41.9	42.8	43.8
88	34.9	35.9	36.9	37.9	38.8	39.8	40.7	41.7	42.6	43.6
90	34.8	35.8	36.7	37.7	38.6	39.6	40.5	41.5	42.5	43.5
92	34.6	35.6	36.6	37.6	38.5	39.5	40.4	41.4	42.3	43.3
94	34.5	35.5	36.4	37.4	38.3	39.3	40.2	41.2	42.2	43.2
96	34.4	35.4	36.3	37.3	38.2	39.2	40.1	41.1	42.0	43.0
98	34.2	35.2	36.1	37.1	38.0	39.0	39.9	40.9	41.8	42.8
100	34.1	35.1	36.0	37.0	37.9	38.9	39.8	40.7	41.6	42.6
102	33.9	34.9	35.8	36.8	37.7	38.7	39.6	40.6	41.5	42.5
104	33.8	34.8	35.7	36.7	37.6	38.6	39.5	40.4	41.3	42.3
106	33.6	34.6	35.5	36.5	37.4	38.4	39.3	40.3	41.2	42.2
108	33.5	34.5	35.4	36.4	37.3	38.3	39.2	40.1	41.0	42.0
110	33.4	34.4	35.3	36.3	37.2	38.1	39.0	40.0	40.9	41.8
112	33.2	34.2	35.1	36.1	37.0	38.0	38.9	39.8	40.7	41.6
114	33.1	34.1	35.0	36.0	36.9	37.8	38.7	39.7	40.6	41.5
116	33.0	34.0	34.9	35.9	36.8	37.7	38.6	39.5	40.4	41.4
118	32.9	33.9	34.8	35.7	36.6	37.5	38.4	39.4	40.3	41.2
120	32.8	33.7	34.6	35.6	36.5	37.4	38.3	39.2	40.1	41.0

REDUCTION OF BAUME GRAVITY READINGS TO 60 F—Con.

Observed Temperature in ° F.	Observed Degrees Baume′									
	47.0	48.0	49.0	50.0	51.0	52.0	53.0	54.0	55.0	56.0
	Corresponding Degrees Baume′ at 60° F.									
30	49.8	50.8	51.9	53.0	54.1	55.1	56.2	57.3	58.4	59.4
32	49.6	50.6	51.7	52.8	53.9	54.9	56.0	57.1	58.2	59.2
34	49.4	50.4	51.5	52.6	53.7	54.7	55.8	56.8	57.9	58.9
36	49.3	50.3	51.4	52.4	53.5	54.5	55.6	56.6	57.7	58.7
38	49.1	50.1	51.2	52.2	53.3	54.3	55.4	56.4	57.5	58.5
40	48.9	49.9	51.0	52.0	53.0	54.1	55.2	56.2	57.2	58.2
42	48.7	49.7	50.8	51.8	52.8	53.8	54.9	56.0	57.0	58.0
44	48.5	49.5	50.6	51.6	52.6	53.6	54.7	55.7	56.8	57.8
46	48.3	49.3	50.4	51.4	52.4	53.4	54.5	55.5	56.5	57.5
48	48.1	49.1	50.2	51.2	52.2	53.2	54.2	55.2	56.3	57.3
50	47.9	48.9	50.0	51.0	52.0	53.0	54.0	55.0	56.1	57.1
52	47.7	48.7	49.8	50.8	51.8	52.8	53.8	54.8	55.9	56.9
54	47.6	48.6	49.6	50.6	51.6	52.6	53.6	54.6	55.6	56.6
56	47.4	48.4	49.4	40.4	51.4	52.4	53.4	54.4	55.4	56.4
58	47.2	48.2	49.2	50.2	51.2	52.2	53.2	54.2	55.2	56.2
60	47.0	48.0	49.0	50.0	51.0	52.0	53.0	54.0	55.0	56.0
62	46.9	47.9	48.8	49.8	50.8	51.8	52.8	53.8	54.8	55.8
64	46.7	47.7	48.6	49.6	50.6	51.6	52.6	53.6	54.6	55.6
66	46.5	47.5	48.4	49.4	50.4	51.4	52.4	53.4	54.4	55.4
68	46.3	47.3	48.3	49.3	50.3	51.3	52.2	53.2	54.2	55.2
70	46.1	47.1	48.1	49.1	50.1	51.1	52.0	53.0	54.0	55.0
72	46.0	47.0	47.9	48.9	49.9	50.9	51.8	52.8	52.8	54.8
74	45.8	46.8	47.7	48.7	49.7	50.7	51.6	52.6	53.5	54.5
76	45.6	46.6	47.5	48.5	49.5	50.5	51.4	52.4	53.3	54.3
78	45.4	46.4	47.3	48.3	49.3	50.3	51.2	52.2	53.1	54.1
80	45.2	46.2	47.2	48.2	49.1	50.1	51.0	52.0	52.9	53.9
82	45.1	46.1	47.0	48.0	48.9	49.9	50.8	51.8	52.7	53.7
84	44.9	45.9	46.8	47.8	48.7	49.7	50.6	51.6	52.5	53.5
86	44.7	45.7	46.6	47.6	48.5	49.5	50.4	51.4	52.3	53.3
88	44.5	45.5	46.4	47.4	48.3	49.3	50.2	51.2	52.1	53.1
90	44.4	45.4	46.3	47.3	48.2	49.2	50.1	51.0	51.9	52.9
92	44.2	45.2	46.1	47.1	48.0	49.0	49.9	50.9	51.8	52.7
94	44.1	45.1	46.0	46.9	47.8	48.8	49.7	50.7	51.6	52.5
96	43.9	44.9	45.8	46.7	47.6	48.6	49.5	50.5	51.4	52.3
98	43.7	44.7	45.6	46.6	47.5	48.4	49.3	50.3	51.2	52.1
100	43.5	44.5	45.4	46.4	47.3	48.3	49.2	50.1	51.0	51.9
102	43.4	44.3	45.2	46.2	47.1	48.1	49.0	49.9	50.8	51.7
104	43.2	44.1	45.0	46.0	46.9	47.9	48.8	49.7	50.6	51.5
106	43.1	44.0	44.9	45.8	46.7	47.7	48.6	49.5	50.4	51.3
108	42.9	43.9	44.8	45.7	46.6	47.5	48.4	49.4	50.3	51.2
110	42.7	43.7	44.6	45.6	46.5	47.4	48.3	49.2	50.1	51.0
112	42.5	43.5	44.4	45.4	46.3	47.2	48.1	49.0	49.9	50.8
114	42.4	43.4	44.3	45.3	46.2	47.1	48.0	48.8	49.7	50.6
116	42.3	43.3	44.2	45.1	46.0	46.9	47.8	48.6	49.5	50.4
118	42.1	43.1	44.0	44.9	45.8	46.7	47.6	48.4	49.3	50.2
120	41.9	42.9	43.8	44.7	45.6	46.5	46.4	48.2	49.1	50.0

REDUCTION OF BAUME GRAVITY READINGS TO 60 F—Con.

Observed temperature in ° F	Observed degrees Baumé									
	57.0	58.0	59.0	60.0	61.0	62.0	63.0	64.0	65.0	66.0
	Corresponding degrees Baumé at 60° F									
30	60.5	61.6	62.7	63.7	64.8	65.8	66.9	67.9	69.0	70.0
32	60.3	61.3	62.4	63.4	64.5	65.5	66.6	67.7	68.8	69.8
34	60.0	61.0	62.1	63.1	64.2	65.2	66.3	67.4	68.5	69.5
36	59.8	60.8	61.9	62.9	64.0	65.0	66.1	67.1	68.2	69.2
38	59.5	60.5	61.6	62.6	63.7	64.7	65.8	66.8	67.9	68.9
40	59.3	60.3	61.4	62.4	63.5	64.5	65.5	66.5	67.6	68.6
42	59.1	60.1	61.2	62.2	63.3	64.3	65.3	66.3	67.4	68.4
44	58.9	59.9	61.0	62.0	63.0	64.0	65.0	66.0	67.1	68.1
46	58.6	59.6	60.7	61.7	62.7	63.7	64.8	65.8	66.8	67.8
48	58.4	59.4	60.4	61.4	62.5	63.5	64.5	65.5	66.5	67.5
50	58.1	59.1	60.2	61.2	62.2	63.2	64.2	65.2	66.2	67.2
52	57.9	58.9	60.0	61.0	62.0	63.0	64.0	65.0	66.0	67.0
54	57.7	58.7	59.8	60.8	61.8	62.8	63.8	64.8	65.8	66.8
56	57.5	58.5	59.5	60.5	61.5	62.5	63.6	64.6	65.6	66.6
58	57.3	58.3	59.3	60.3	61.3	62.3	63.3	64.3	65.3	66.3
60	57.0	58.0	59.0	60.0	61.0	62.0	63.0	64.0	65.0	66.0
62	56.8	57.8	58.8	59.8	60.8	61.8	62.7	63.7	64.7	65.7
64	56.6	57.6	58.6	59.6	60.5	61.5	62.5	63.5	64.5	65.5
66	56.4	57.4	58.3	59.3	60.3	61.3	62.3	63.3	64.2	65.2
68	56.1	57.1	58.1	59.1	60.1	61.1	62.1	63.1	64.0	65.0
70	55.9	56.9	57.9	58.9	59.8	60.8	61.8	62.8	63.8	64.8
72	55.7	56.7	57.7	58.7	59.6	60.6	61.6	62.6	63.5	64.5
74	55.5	56.5	57.4	58.4	59.3	60.3	61.3	62.3	63.2	64.2
76	55.3	56.3	57.2	58.2	59.1	60.1	61.0	62.0	63.0	64.0
78	55.0	56.0	57.0	58.0	58.9	59.9	64.8	61.8	62.8	63.8
80	54.8	55.8	56.8	57.8	58.7	59.7	60.6	61.6	62.6	63.6
82	54.6	55.6	56.5	57.5	58.4	59.4	60.4	61.4	62.3	63.3
84	54.4	55.4	56.3	57.3	58.2	59.2	60.1	61.1	62.0	63.0
86	54.2	55.2	56.1	57.1	58.0	59.0	59.9	60.9	61.8	62.8
88	54.0	55.0	55.9	56.9	57.8	58.8	59.7	60.6	61.5	62.5
90	53.8	54.8	55.7	56.7	57.6	58.6	59.5	60.4	61.3	62.3
92	53.6	54.6	55.5	56.5	57.4	58.4	59.3	60.2	61.1	62.1
94	53.4	54.3	55.2	56.2	57.1	58.1	59.0	59.9	60.8	61.8
96	53.2	54.1	55.0	56.0	56.9	57.9	58.8	59.7	60.6	61.6
98	53.0	53.9	54.8	55.8	56.7	57.6	58.5	59.5	60.4	61.3
100	52.8	53.7	54.6	55.6	56.5	57.4	58.3	59.3	60.2	61.1
102	52.6	53.5	54.4	55.4	56.3	57.2	58.1	59.0	59.9	60.9
104	52.4	53.3	54.2	55.2	56.1	57.0	57.9	58.8	59.7	60.7
106	52.2	53.1	54.0	55.0	55.9	56.8	57.7	58.6	59.5	60.4
108	52.1	53.0	53.9	54.8	55.7	56.6	57.5	58.4	59.3	60.2
110	51.9	52.8	53.7	54.6	55.5	56.4	57.3	58.2	59.1	60.0
112	51.7	52.6	53.5	54.4	55.2	56.2	57.1	58.0	58.9	59.8
114	51.5	52.4	53.3	54.2	55.1	56.0	56.9	57.8	58.7	59.6
116	51.3	52.2	53.1	54.0	54.9	55.8	56.7	57.6	58.4	59.3
118	51.1	52.0	52.9	53.8	54.7	55.6	56.5	57.4	58.2	59.1
120	50.9	51.8	52.7	53.6	54.5	55.4	56.3	57.2	58.0	58.9

REDUCTION OF BAUME GRAVITY READINGS TO 60 F—Con.

Observed Temperature in ° F.	Observed Degrees Baume'.									
	67.0	68.0	69.0	70.0	71.0	72.0	73.0	74.0	75.0	76.0
	Corresponding Degrees Baume' at 60° F.									
30	71.1	72.1	73.2	74.3	75.4	76.4	77.5	78.5	79.6	80.7
32	70.9	71.9	73.0	74.0	75.1	76.1	77.2	78.2	79.3	80.4
34	70.6	71.6	72.7	73.7	74.8	75.8	76.9	77.9	79.0	80.1
36	70.3	71.3	72.4	73.4	74.5	75.5	76.6	77.6	78.7	79.7
38	70.0	71.0	72.1	73.1	74.2	75.2	76.3	77.3	78.4	79.4
40	69.7	70.7	71.8	72.8	73.9	74.9	76.0	77.0	78.1	79.1
42	69.4	70.4	71.5	72.5	73.6	74.6	75.7	76.7	77.8	78.8
44	69.1	70.1	71.2	72.2	73.3	74.3	75.4	76.4	77.5	78.5
46	68.8	69.8	70.9	71.9	73.0	74.0	75.1	76.1	77.1	78.1
48	68.6	69.6	70.6	71.6	72.7	73.7	74.8	75.8	76.8	77.8
50	68.3	69.3	70.4	71.4	72.5	73.5	74.5	75.5	76.5	77.5
52	68.0	69.0	70.1	71.1	72.2	73.2	74.2	75.2	76.2	77.2
54	67.8	68.8	69.9	70.9	71.9	72.9	73.9	74.9	75.9	76.9
56	67.6	68.6	69.6	70.6	71.6	72.6	73.6	74.6	75.6	76.6
58	67.3	68.3	69.3	70.3	71.3	72.3	73.3	74.3	75.3	76.3
60	67.0	68.0	69.0	70.0	71.0	72.0	73.0	74.0	75.0	76.0
62	66.7	67.7	68.7	69.7	70.7	71.7	72.7	73.7	74.7	75.7
64	66.4	67.4	68.4	69.4	70.4	71.4	72.4	73.4	74.4	75.4
66	66.2	67.2	68.2	69.2	70.1	71.1	72.1	73.1	74.1	75.1
68	66.0	67.0	67.9	68.9	69.8	70.8	71.8	72.8	73.8	74.8
70	65.7	66.7	67.6	68.6	69.5	70.5	71.5	72.5	73.5	74.5
72	65.4	66.4	67.4	68.4	69.3	70.3	71.2	72.2	73.2	74.2
74	65.2	66.2	67.2	68.2	69.1	70.1	71.0	72.0	72.9	73.9
76	64.9	65.9	66.9	67.9	68.8	69.8	70.8	71.8	72.7	73.7
78	64.7	65.6	66.6	67.6	68.5	69.5	70.5	71.5	72.4	73.4
80	64.5	65.4	66.4	67.4	68.3	69.3	70.2	71.2	72.1	73.1
82	64.2	65.2	66.1	67.1	68.0	69.0	69.9	70.9	71.8	72.8
84	63.9	64.9	65.9	66.8	67.7	68.7	69.6	70.6	71.5	72.5
86	63.7	64.7	65.8	66.6	67.5	68.4	69.3	70.3	71.3	72.3
88	63.4	64.4	65.3	66.3	67.2	68.2	69.1	70.1	71.0	72.9
90	63.2	64.2	65.1	66.1	67.0	68.0	68.9	69.9	60.8	71.7
92	63.0	64.0	64.9	65.8	66.7	67.7	68.6	69.6	70.5	71.4
94	62.7	63.7	64.6	65.6	66.5	67.4	68.3	69.3	70.2	71.1
96	62.5	63.5	64.4	65.4	66.3	67.2	68.1	69.0	69.9	70.8
98	62.2	63.2	64.1	65.1	66.0	66.9	67.8	68.8	69.7	70.6
100	62.0	63.0	63.9	64.9	65.8	66.7	67.6	68.5	69.4	70.4
102	61.8	62.8	63.7	64.6	65.5	66.4	67.3	68.2	69.1	70.1
104	61.6	62.5	63.4	64.3	65.2	66.1	67.0	67.9	68.8	69.8
106	61.3	62.3	63.2	64.1	65.0	65.9	66.8	67.7	68.6	69.5
108	61.1	62.0	62.9	63.8	64.8	65.7	66.6	67.5	68.4	69.3
110	60.9	61.8	62.7	63.6	64.5	65.4	66.3	67.2	68.1	69.0
112	60.7	61.6	62.5	63.3	64.2	65.2	66.1	67.0	67.8	68.7
114	60.5	61.4	62.3	63.1	64.0	64.9	65.8	66.7	67.6	68.5
116	60.2	61.1	62.0	62.9	63.8	64.7	65.6	66.5	67.4	68.3
118	60.0	60.9	61.8	62.7	63.6	64.5	65.4	66.3	67.1	68.0
120	59.8	60.7	61.6	62.5	63.3	64.2	65.1	66.0	66.8	67.7

REDUCTION OF BAUME GRAVITY READINGS TO 60 F—Con.

Observed temperature in °F	Observed degrees Baumé									
	77.0	78.0	79.0	80.0	81.0	82.0	83.0	84.0	85.0	86.0
	Corresponding degrees Baumé at 60° F									
30	81.8	82.9	84.0	85.0	86.1	87.1	88.2	89.3	90.4	91.5
32	81.5	82.6	83.7	84.7	85.8	86.8	87.9	89.0	90.1	91.1
34	81.2	82.2	83.3	84.3	85.4	86.4	87.5	88.6	89.7	90.7
36	80.8	81.9	83.0	84.0	85.1	86.1	87.2	88.2	89.3	90.3
38	80.5	81.5	82.6	83.6	84.7	85.7	86.8	87.8	88.9	89.9
40	80.1	81.1	82.2	83.2	84.3	85.3	86.4	87.4	88.5	89.5
42	79.8	80.8	81.9	82.9	84.0	85.0	86.1	87.1	88.2	89.2
44	79.5	80.5	81.6	82.6	83.7	84.7	85.8	86.8	87.8	88.8
46	79.2	80.2	81.3	82.3	83.4	84.4	85.4	86.5	87.5	88.5
48	78.9	79.9	81.0	82.0	83.0	84.0	85.1	86.1	87.1	88.1
50	78.6	79.6	80.6	81.6	82.6	83.6	84.7	85.7	86.7	87.7
52	78.2	79.2	80.3	81.3	82.3	83.3	84.3	85.3	86.3	87.3
54	77.9	78.9	79.9	81.0	82.0	83.0	84.0	85.0	86.0	87.0
56	77.6	78.6	79.6	80.6	81.6	82.6	83.7	84.7	85.7	86.7
58	77.3	78.3	79.3	80.3	81.3	82.3	83.3	84.3	85.3	86.3
60	77.0	78.0	79.0	80.0	81.0	82.0	83.0	84.0	85.0	86.0
62	76.7	77.7	78.7	79.7	80.7	81.7	82.7	83.7	84.7	85.7
64	76.4	77.4	78.4	79.4	80.4	81.4	82.3	83.4	84.3	85.3
66	76.1	77.1	78.1	79.1	80.0	81.0	82.0	83.0	84.0	85.0
68	75.8	76.8	77.7	78.7	79.7	80.7	81.7	82.7	83.7	84.7
70	75.5	76.5	77.4	78.4	79.4	80.4	81.4	82.4	83.3	84.3
72	75.2	76.2	77.1	78.1	79.1	80.1	81.1	82.1	83.0	84.0
74	74.9	75.9	76.8	77.8	78.8	79.8	80.7	81.7	82.7	83.7
76	74.6	75.6	76.5	77.5	78.4	79.4	80.4	81.4	82.4	83.4
78	74.3	75.3	76.2	77.2	78.1	79.1	80.1	81.1	82.0	83.0
80	74.0	75.0	75.9	76.9	77.8	78.8	79.8	80.8	81.7	82.7
82	73.7	74.7	75.6	76.6	77.5	78.5	79.4	80.4	81.3	82.3
84	73.4	74.5	75.3	76.3	77.2	78.2	79.1	80.1	81.0	82.0
86	73.2	74.1	75.0	76.0	76.9	77.9	78.8	79.8	80.7	81.7
88	72.9	73.9	74.8	75.8	76.7	77.6	78.5	79.5	80.4	81.4
90	72.6	73.6	74.5	75.5	76.4	77.3	78.2	79.2	80.1	81.1
92	72.3	73.3	74.2	75.2	76.1	77.0	77.9	78.9	79.8	80.8
94	72.0	73.0	73.9	74.9	75.8	76.7	77.6	78.6	79.5	80.5
96	71.7	72.7	73.6	74.6	75.5	76.4	77.3	78.3	79.2	80.2
98	71.5	72.4	73.3	74.3	75.2	76.1	77.0	78.0	78.9	79.8
100	71.2	72.1	73.0	74.0	74.9	75.8	76.7	77.6	78.5	79.5
102	71.0	71.9	72.8	73.7	74.6	75.5	76.4	77.3	78.2	79.2
104	70.7	71.6	72.5	73.4	74.3	75.2	76.1	77.0	77.9	78.8
106	70.4	71.3	72.2	73.1	74.0	74.9	75.8	76.7	77.6	78.5
108	70.1	71.0	71.9	72.8	73.7	74.6	75.5	76.4	77.3	78.2
110	69.8	70.7	71.6	72.5	73.4	74.3	75.2	76.1	77.0	77.9
112	69.6	70.5	71.4	72.3	73.2	74.1	74.9	75.8	76.7	77.6
114	69.4	70.3	71.2	72.1	72.9	73.8	74.6	75.5	76.4	77.3
116	69.1	70.0	70.9	71.8	72.6	73.5	74.3	75.2	76.1	77.0
118	68.8	69.7	70.6	71.5	72.3	73.2	74.0	74.9	75.8	76.7
120	68.5	69.4	70.3	71.2	72.0	72.9	73.7	74.6	75.5	76.4

BAUME', SPECIFIC GRAVITY AND POUNDS PER GALLON—Con.

Observed temperature in ° F	Observed degrees Baumé									
	87.0	88.0	89.0	90.0	91.0	92.0	93.0	94.0	95.0	96.0
	Corresponding degrees Baumé at 60° F									
30	92.6	93.6	94.7	95.7						
32	92.2	93.2	94.3	95.3						
34	91.8	92.9	93.9	94.9	95.9					
36	91.4	92.5	93.6	94.6	95.6					
38	91.0	92.1	93.2	94.2	95.2					
40	90.6	91.7	92.8	93.8	94.9	95.9				
42	90.3	91.3	92.4	93.4	94.5	95.5				
44	89.9	90.9	92.0	93.0	94.1	95.1	96.1			
46	89.6	90.6	91.7	92.7	93.7	94.7	95.7			
48	89.2	90.2	91.3	92.3	93.3	94.3	95.3			
50	88.8	89.8	90.9	91.9	92.9	93.9	94.9	95.9		
52	88.4	89.4	90.5	91.5	92.5	93.5	94.5	95.5		
54	88.0	89.0	90.1	91.1	92.1	93.1	94.1	95.1		
56	87.7	88.7	89.7	90.7	91.7	92.7	93.7	94.7	95.7	
58	87.3	88.3	89.4	90.4	91.4	92.4	93.4	94.4	95.4	
60	87.0	88.0	89.0	90.0	91.0	92.0	93.0	94.0	95.0	96.0
62	86.7	87.7	88.6	89.6	90.6	91.6	92.6	93.6	94.6	95.6
64	86.3	87.3	88.3	89.3	90.3	91.3	92.2	93.2	94.2	95.2
66	86.0	87.0	88.0	89.0	89.9	90.9	91.8	92.8	93.8	94.8
68	85.6	86.6	87.6	88.6	89.5	90.5	91.4	92.4	93.4	94.4
70	85.3	86.3	87.3	88.3	89.2	90.1	91.0	92.0	93.0	94.0
72	85.0	86.0	86.9	87.9	88.8	89.8	90.7	91.7	92.7	93.7
74	84.6	85.6	86.5	87.5	88.4	89.4	90.3	91.3	92.3	93.3
76	84.3	85.3	86.2	87.2	88.1	89.1	90.0	91.0	92.0	93.0
78	84.0	85.0	85.9	86.9	87.8	88.7	89.6	90.6	91.6	92.6
80	83.6	84.6	85.5	86.5	87.4	88.4	89.3	90.2	91.2	92.2
82	83.2	84.2	85.1	86.1	87.0	88.0	88.9	89.8	90.8	91.8
84	82.9	83.8	84.7	85.7	86.6	87.6	88.5	89.4	90.4	91.4
86	82.6	83.5	84.4	85.4	86.3	87.3	88.2	89.1	90.0	91.0
88	82.3	83.2	84.1	85.1	86.0	87.0	87.9	88.8	89.7	90.7
90	82.0	82.9	83.8	84.8	85.7	86.6	87.5	88.4	89.3	90.3
92	81.7	82.6	83.5	84.4	85.3	86.2	87.1	88.1	89.0	90.0
94	81.3	82.2	83.1	84.1	85.0	85.9	86.8	87.7	88.6	89.6
96	81.0	81.9	82.8	83.7	84.6	85.6	86.5	87.4	88.3	89.3
98	80.7	81.6	82.5	83.4	84.3	85.2	86.1	87.0	88.0	89.0
100	80.4	81.3	82.2	83.1	84.0	84.9	85.8	86.7	87.6	88.6
102	80.1	81.0	81.9	82.8	83.7	84.6	85.5	86.4	87.3	88.3
104	79.7	80.6	81.5	82.5	83.4	84.3	85.2	86.1	87.0	87.9
106	79.4	80.3	81.2	82.1	83.0	83.9	84.8	85.7	86.6	87.6
108	79.1	80.0	80.9	81.8	82.7	83.6	84.5	85.4	86.3	87.2
110	78.8	79.7	80.6	81.5	82.4	83.3	84.2	85.1	86.0	86.9
112	78.5	79.4	80.3	81.2	82.1	83.0	83.8	84.7	85.6	86.6
114	78.2	79.1	80.0	80.9	81.7	82.6	83.5	84.4	85.3	86.2
116	77.9	78.8	79.7	80.6	81.4	82.3	83.2	84.1	85.0	85.9
118	77.5	78.4	79.3	80.2	81.1	82.0	82.8	83.7	84.6	85.6
120	77.2	78.1	79.0	79.9	80.8	81.7	82.5	83.4	84.3	85.2

Reduction of Specific Gravity Readings to 60°F.

This table shows the specific gravities at 60°/60°F of oils having, at the designated temperatures, the observed specific gravities indicated. For example, if the observed specific gravity is 0.614 at 80°F, the true specific gravity at 60°/60°F is 0.621 (under 0.610) plus 0.004 or 0.625. The headings "Observed specific gravity" and "Observed temperature" signify the true indication of the hydrometer and the true temperature of the oil; that is, the observed readings corrected, if necessary, for instrumental errors.

Observed Specific Gravity.

Observed Temperature, ° F.	0.600	0.610	0.620	0.630	0.640	0.650	0.660	0.670	0.680	0.690
30......	0.584	0.594	0.604	0.614	0.624	0.634	0.644	0.654	0.665	0.675
32......	.585	.595	.606	.616	.625	.635	.645	.655	.666	.676
34......	.586	.596	.607	.617	.626	.636	.646	.656	.667	.677
36......	.587	.597	.608	.618	.627	.637	.647	.657	.668	.678
38......	.588	.598	.609	.619	.628	.638	.648	.659	.669	.679
40......	.589	.599	.610	.620	.6295	.6395	.6495	.660	.670	.680
42......	.590	.600	.611	.620	.6305	.6405	.6505	.661	.671	.681
44......	.591	.601	.612	.621	.6315	.6415	.6515	.662	.672	.682
46......	.592	.602	.613	.622	.6325	.6425	.6525	.663	.673	.683
48......	.593	.603	.614	.623	.6335	.6435	.6535	.664	.674	.684
50......	.595	.605	.615	.6245	.6345	.645	.654	.665	.675	.685
52......	.596	.606	.616	.626	.636	.646	.656	.666	.676	.686
54......	.597	.607	.617	.627	.637	.647	.657	.667	.677	.677
56......	.598	.608	.618	.628	.638	.648	.658	.668	.678	.688
58......	.599	.609	.619	.629	.639	.649	.659	.669	.679	.689
60......	.600	.610	.620	.630	.640	.650	.660	.670	.680	.690
62......	.601	.611	.621	.631	.641	.651	.661	.671	.681	.691
64......	.602	.612	.622	.632	.642	.652	.662	.672	.682	.692
66......	.603	.613	.623	.633	.643	.653	.663	.673	.683	.693
68......	.604	.614	.6245	.6345	.644	.654	.664	.674	.684	.694
70......	.605	.615	.6255	.6355	.645	.655	.665	.675	.685	.695
72......	.606	.616	.6265	.6365	.646	.656	.666	.676	.686	.696
74......	.607	.617	.6275	.6375	.647	.657	.667	.677	.687	.6965
76......	.608	.618	.6285	.6385	.648	.658	.668	.678	.6875	.6975
78......	.609	.620	.6295	.6395	.649	.659	.669	.679	.6885	.6985
80......	.611	.621	.630	.640	.650	.660	.670	.680	.689	.699
82......	.612	.622	.632	.641	.651	.661	.671	.671	.690	.700
84......	.613	.623	.633	.642	.652	.662	.672	.682	.691	.701
86......	.614	.624	.634	.643	.653	.663	.673	.683	.692	.702
88......	.615	.625	.635	.644	.654	.664	.674	.683	.693	.703
90......	.616	.626	.636	.645	.655	.665	.675	.684	.694	.704
92......	.617	.627	.637	.646	.656	.666	.676	.685	.695	.705
94......	.618	.628	.638	.647	.657	.667	.677	.686	.696	.706
96......	.619	.629	.639	.648	.658	.668	.678	.687	.697	.707
98......	.620	.630	.640	.649	.659	.669	.679	.688	.698	.708
100......	.621	.631	.641	.650	.660	.670	.680	.689	.699	.709
102......	.622	.632	.642	.651	.661	.671	.680	.690	.700	.710
104......	.623	.633	.643	.652	.662	.672	.681	.691	.701	.711
106......	.624	.634	.644	.653	.663	.673	.682	.692	.702	.712
108......	.625	.635	.645	.654	.664	.674	.683	.693	.703	.712
110......	.626	.636	.646	.655	.665	.675	.684	.694	.704	.713
112......	.627	.637	.647	.656	.666	.676	.685	.695	.704	.714
114......	.629	.638	.648	.657	.667	.677	.686	.696	.705	.715
116......	.630	.639	.649	.658	.668	.678	.687	.697	.706	.716
118......	.631	.640	.650	.659	.669	.679	.688	.698	.707	.717
120......	.632	.641	.651	.660	.670	.680	.689	.699	.708	.718

REDUCTION OF SPECIFIC GRAVITY TO 60°F—Continued.

Observed Specific Gravity.

Observed Temperature, ° F.	0 700	0.710	0.720	0.730	0.740	0.750	0.760	0.770	0.780	0 790
30......	0.685	0.695	0.705	0.716	0 726	0.736	0.746	0.757	0.767	0.777
32......	.686	.696	.706	.717	.727	.737	.747	.758	.768	778
34......	.687	.697	.707	.718	.728	.738	.748	.759	.769	.779
36......	.688	.698	.708	.719	.729	.739	.749	.760	.770	.780
38......	.689	.699	.709	.720	.730	.740	.750	.761	.771	.781
40......	.6905	.7005	.7105	.7205	.7310	.7140	.7515	.7615	.7715	7820
42......	.6915	.7015	.7115	.7215	.7315	.7420	.7520	7625	7725	7825
44......	.6925	.7025	.7125	.7225	7325	.7430	.7530	.7630	7735	7835
46......	.6935	.7035	.7135	.7235	7335	.7440	.7540	.7640	.7740	7845
48......	.6940	.7045	.7145	.7245	.7345	.7445	.7550	7650	7750	7850
50......	.6950	.7055	.7155	.7255	.7355	7455	.7555	.7660	.7760	7860
52......	.6960	.7065	.7165	.7265	.7365	.7465	.7565	.7665	.7765	7870
54......	.6970	.7070	.7170	.7270	.7370	.7475	.7575	.7675	7775	7875
56......	.6980	.7080	.7180	.7280	.7380	.7480	.7580	.7685	7785	7885
58......	.6990	.7090	.7190	.7290	.7390	.7490	.7590	7690	7790	7890
60......	.7000	.7100	.7200	.7300	.7400	.7500	.7690	.7700	.7800	7900
62......	.7010	.7110	.7210	.7310	.7410	.7510	.7610	.7710	7810	7905
64......	.7020	.7120	.7220	.7320	7415	.7515	.7615	7715	7815	7915
66......	.7030	.7130	.7225	.7325	.7425	.7525	.7625	.7725	7825	7925
68......	.7040	.7135	.7235	.7335	.7435	.7535	.7630	.7730	7830	7930
70......	.7050	.7145	.7245	.7345	.7445	.7545	.7640	7740	7840	7940
72......	.7055	.7155	.7255	.7355	.7450	.7550	7650	7750	7850	7945
74......	.7065	.7165	.7265	.7365	.7460	.7560	.7655	7755	7855	7955
76......	.7075	.7175	.7275	.7370	.7470	.7570	7665	.7765	7865	7965
78......	.7085	.7185	.7285	.7380	.7480	.7580	7675	.7775	7875	7970
80......	.709	.719	.729	.739	.748	.758	.768	778	788	798
82......	.710	.720	.730	.740	.749	.759	.769	779	789	798
84......	.711	.721	.731	.741	750	.760	770	780	789	799
86......	.712	.722	.732	.741	.751	.761	771	.780	790	800
88......	.713	.723	.733	.742	.752	.762	771	.781	791	801
90......	.714	.724	.733	.743	753	.763	772	.782	792	802
92......	.715	.724	.734	.744	.754	.763	.773	783	793	802
94......	.716	.725	.735	.745	.755	.764	774	784	793	803
96......	.716	.726	.736	.746	.755	765	.775	784	794	804
98......	.717	.727	.737	.747	.756	.766	775	785	795	805
100......	.718	.728	.738	.747	.757	.767	776	786	796	805
102......	.719	.729	.739	.748	.758	768	777	787	796	806
104......	.720	.730	.740	.749	.759	768	778	788	797	807
106......	.721	.731	.741	.750	.760	769	779	788	798	808
108......	.722	.732	.741	.751	.760	.770	779	789	799	808
110......	.723	.733	.742	.751	761	.771	780	790	799	809
112......	.724	.734	.743	.753	.762	772	781	791	800	810
114......	.725	.734	.744	.753	.763	.772	782	791	801	811
116......	.726	.735	.745	.754	.764	.773	783	792	802	811
118......	.726	.736	.746	.755	.765	.774	784	793	803	812
120......	.727	.737	.746	756	765	775	784	794	803	813

REDUCTION OF SPECIFIC GRAVITY TO 60°F—Continued.

Observed Specific Gravity.

Observed Temperature, ° F.	0.800	0.810	0.820	0.830	0.840	0.850	0.860	0.870	0.880	0.890
30......	0.788	0.798	0.808	0.818	0.828	0.839	0.849	0.859	0.869	0.879
32......	.788	.799	.809	.819	.829	.839	.849	.860	.870	.880
34......	.789	.799	.810	.820	.830	.840	.850	.860	.870	.880
36......	.790	.800	.811	.821	.831	.841	.851	.861	.871	.881
38......	.791	.801	.812	.822	.832	.842	.852	.862	.872	.882
40......	.7920	.8020	.8125	.8225	.8325	.8425	.8525	.8625	.8730	.8830
42......	.7930	.8030	.8130	.8230	.8335	.8435	.8535	.8635	.8735	.8840
44......	.7935	.8035	.8140	.8240	.8340	.8440	.8540	.8640	.8740	.8840
46......	.7945	.8045	.8145	.8245	.8345	.8450	.8550	.8650	.8750	.8850
48......	.7950	.8050	.8155	.8255	.8355	.8455	.8555	.8655	.8755	.8855
50......	.7960	.8060	.8160	.8260	.8365	.8465	.8565	.8665	.8765	.8865
52......	.7970	.8070	.8170	.8270	.8370	.8470	.8570	.8670	.8770	.8870
54......	.7975	.8075	.8175	.8280	.8380	.8480	.8580	.8680	.8780	.8880
56......	.7985	.8085	.8185	.8285	.8385	.8485	.8585	.8685	.8785	.8885
58......	.7995	.8095	.8195	.8295	.8395	.8495	.8595	.8695	.8795	.8895
60......	.8000	.8100	.8200	.8300	.8400	.8500	.8600	.8700	.8800	.8900
62......	.8005	.8105	.8205	.8305	.8405	.8505	.8605	.8705	.8805	.8905
64......	.8015	.8115	.8215	.8315	.8415	.8515	.8615	.8715	.8815	.8915
66......	.8025	.8125	.8220	.8320	.8420	.8520	.8620	.8720	.8820	.8920
68......	.8030	.8130	.8230	.8330	.8430	.8530	.8630	.8730	.8830	.8930
70......	.8040	.8140	.8240	.8340	.8440	.8540	.8635	.8735	.8835	.8935
72......	.8045	.8145	.8245	.8345	.8445	.8545	.8645	.8745	.8845	.8940
74......	.8055	.8155	.8255	.8355	.8455	.8550	.8650	.8750	.8850	.8950
76......	.8065	.8160	.8260	.8360	.8460	.8560	.8660	.8760	.8860	.8955
78......	.8070	.8170	.8270	.8370	.8470	.8565	.8665	.8765	.8865	.8965
80......	.808	.817	.827	.837	.847	.857	.867	.877	.887	.897
82......	.808	.818	.828	.838	.848	.858	.868	.878	.888	.898
84......	.809	.819	.829	.839	.849	.859	.868	.878	.888	.898
86......	.810	.820	.830	.839	.849	.859	.869	.879	.889	.899
88......	.811	.820	.830	.840	.850	.860	.870	.880	.890	.900
90......	.812	.821	.831	.841	.851	.861	.871	.881	.891	.900
92......	.812	.822	.832	.842	.852	.861	.871	.881	.891	.901
94......	.813	.823	.832	.842	.852	.862	.872	.882	.892	.902
96......	.814	.823	.833	.843	.853	.863	.873	.883	.893	.903
98......	.815	.824	.834	.844	.854	.864	.873	.883	.893	.903
100......	.815	.825	.835	.844	.854	.864	.874	.884	.894	.904
102......	.816	.826	.835	.845	.855	.865	.875	.885	.895	.905
104......	.817	.826	.836	.846	.856	.866	.876	.886	.895	.905
106......	.817	.827	.837	.847	.857	.866	.876	.886	.896	.906
108......	.818	.828	.838	.847	.857	.867	.877	.887	.897	.907
110......	.819	.829	.838	.848	.858	.868	.878	.888	.898	.907
112......	.820	.829	.839	.849	.859	.869	.878	.888	.898	.908
114......	.820	.830	.840	.850	.859	.869	.879	.889	.899	.909
116......	.821	.831	.840	.850	.860	.870	.880	.890	.900	.909
118......	.822	.832	.841	.851	.861	.871	.881	.890	.900	.910
120......	.823	.832	.842	.852	.862	.872	.881	.891	.901	.911

REDUCTION OF SPECIFIC GRAVITY TO 60°F—Continued.

Observed Specific Gravity.

Observed Temperature ° F.	0.900	0.910	0.920	0.930	0.940	0.950	0.960	0.970	0.980	0.990	1.000
60.........	0.900	0.910	0.920	0.930	0 940	0.950	0.960	0.970	0.980	0.990	1 000
62.........	.901	.911	.921	.931	.941	.951	.961	971	.981	.991	1.001
64.........	.901	.911	.921	.931	.941	.951	.961	.971	.981	.991	1 001
66.........	.902	.912	.922	.932	.942	.952	.962	.972	.982	.992	1 002
68.........	.903	.913	.923	.933	.943	.953	.963	.973	.983	.993	1 003
70.........	.904	.914	.924	.934	.944	.954	.964	.974	.984	.994	1.004
72.........	.904	.914	.924	.934	.944	.954	.964	.974	.984	.994	1.004
74.........	.905	.915	.925	.935	.945	.955	.965	.975	.985	.995	1.005
76.........	.906	.916	.926	.936	.946	.956	.966	.976	.986	.996	1.006
78.........	.906	.916	.926	.936	.946	.957	.967	.976	.986	.996	1.006
80.........	.907	.917	.927	.937	.947	.957	.967	.977	.987	.997	1 007
82.........	.907	.917	.927	.937	.947	.958	.968	.978	.988	.998	1 008
84.........	.908	.918	.928	.938	.948	.959	.969	.979	.989	.998	1.008
86.........	.909	.919	.929	.939	.949	.959	.969	.979	.989	.999	1 009
88.........	.910	.920	.930	.940	.950	.960	.970	.980	.990	1.000	1 010
90.........	.910	.920	.930	.940	.951	.961	.971	.981	.991	1.001	1 011
92.........	.911	.921	.931	.941	.952	.962	.972	.982	.991	1 001	1 011
94.........	.912	.922	.932	.942	.952	.962	.972	.982	.992	1.002	1 012
96.........	.913	.922	.932	.942	.953	.963	.973	.983	.993	1 003	1 013
98.........	.913	.923	.933	.943	.954	.964	.974	.984	.993	1.003	1 013
100.........	.914	.924	.934	.944	.955	.965	.975	.984	.994	1.004	1 014
102.........	.915	.925	.935	.944	.955	.965	.975	.985	.995	1.005	1 015
104.........	.915	.925	.935	.945	.956	.966	.976	.986	.996	1 005	1 015
106.........	.916	.926	.936	.946	.957	.967	.977	.987	.996	1.006	1 016
108.........	.917	.927	.937	.947	.958	.968	.978	.987	.997	1.007	1 017
110.........	.917	.927	.937	.947	.958	.968	.978	.988	.998	1 008	1 018
112.........	.918	.928	.938	.948	.959	.969	.979	.989	.998	1 008	1 018
114.........	.919	.929	.939	.949	.960	.970	.980	.989	.999	1 009	1 019
116.........	.919	.929	.939	.949	.960	.970	.980	.990	1 000	1 010	1 020
118.........	.920	.930	.940	.950	.961	.971	.981	.991	1 001	1 010	1 020
120.........	.921	.931	.941	.951	.962	.972	.982	.992	1 001	1 011	1 021
122.........	.922	.932	.942	.952	.963	.973	.983	.992	1 002	1 012	1 022
124.........	.923	.933	.943	.953	.963	.973	983	.993	1 003	1 012	1 022
126.........	.924	.934	.944	.954	.964	.974	.984	.994	1 003	1 013	1 023
128.........	.925	.935	.945	.955	.965	.975	.985	994	1 004	1 014	1 024
130.........	.926	.936	.946	.956	.966	.976	.986	995	1 005	1 015	1 024
132.........	.927	.937	.947	.957	.966	.976	.986	996	1 006	1 015	1 025
134.........	.927	.937	.947	.957	.967	.977	.987	997	1 006	1 016	1 026
136.........	.928	.938	.948	.958	.968	.978	.988	997	1 007	1 017	1 027
138.........	.929	.939	.949	.959	.968	.978	.988	998	1 008	1 017	1 027
140.........	.930	.940	.950	.960	.969	.979	.989	999	1 008	1 018	1 028
142.........	.930	.940	.950	.960	.970	.980	.990	1 000	1 009	1 019	1 029
144.........	.931	.941	.951	.961	.971	981	.991	1 000	1 010	1 019	1 029
146.........	.932	.942	.952	.962	.971	.981	.991	1 001	1 011	1 020	1 030
148.........	.933	.943	.953	.963	.972	.982	.992	1 002	1 011	1 021	1 031
150.........	.933	.943	.953	.963	.973	.983	993	1 002	1 012	1 022	1 032

REDUCTION OF SPECIFIC GRAVITY TO 60°F—Continued.

OBSERVED SPECIFIC GRAVITY.

Observed Temperature, ° F.	1.010	1.020	1.030	1.040	1.050	1.060	1.070	1.080	1.090	1.100
60......	1.010	1.020	1.030	1.040	1.050	1.060	1.070	1.080	1.090	1.100
62......	1.011	1.021	1.031	1.041	1.051	1.061	1.071	1.081	1.091	1.101
64......	1.011	1.021	1.031	1.041	1.051	1.061	1.071	1.081	1.091	1.101
66......	1.012	1.022	1.032	1.042	1.052	1.062	1.072	1.082	.1092	1.102
68......	1.013	1.023	1.033	1.043	1.053	1.063	1.073	1.083	1.093	1.103
70......	1.013	1.023	1.033	1.043	1.053	1.063	1.073	1.083	1.093	1.103
72......	1.014	1.024	1.034	1.044	1.054	1.064	1.074	1.084	1.094	1.104
74......	1.015	1.025	1.035	1.045	1.055	1.065	1.075	1.085	1.095	1.105
76......	1.016	1.026	1.035	1.045	1.055	1.065	1.075	1.085	1.095	1.105
78......	1.016	1.026	1.036	1.046	1.056	1.066	1.076	1.086	1.096	1.106
80......	1.017	1.027	1.037	1.047	1.057	1.067	1.077	1.087	1.097	1.107
82......	1.018	1.028	1.037	1.047	1.057	1.067	1.077	1.087	1.097	1.107
84......	1.018	1.028	1.038	1.048	1.058	1.068	1.078	1.088	1.098	1.108
86......	1.019	1.029	1.039	1.049	1.059	1.069	1.079	1.089	1.099	1.108
88......	1.020	1.030	1.040	1.050	1.059	1.069	1.079	1.089	1.099	1.109
90......	1.020	1.030	1.040	1.050	1.060	1.070	1.080	1.090	1.100	1.110
92......	1.021	1.031	1.041	1.051	1.061	10 71	1.081	1.091	1.101	1.110
94......	1.022	1.032	1.042	1.052	1.061	1.071	1.081	1.091	1.101	1.111
96......	1.022	1.032	1.042	1.052	1.062	1.072	1.082	1.092	1.102	1.112
98......	1.023	1.033	1.043	1.053	1.063	1.073	1.083	1.093	1.103	1.112
100......	1.024	1.034	1.044	1.054	1.063	1.073	1.083	1.093	1.103	1.113
102......	1.024	1.034	1.044	1.054	1.064	1.074	1.084	1.094	1.104	1.114
104......	1.025	1.035	1.045	1.055	1.065	1.075	1.085	1.095	1.105	1.114
106......	1.026	1.036	1.046	1.056	1.065	1.075	1.085	1.095	1.105	1.115
108......	1.027	1.037	1.046	1.056	1.066	1.076	1.086	1.096	1.106	1.116
110......	1.027	1.037	1.047	1.057	1.067	1.077	1.087	1.097	1.107	1.116
112......	1.028	1.038	1.048	1.058	1.067	1.077	1.087	1.097	1.107	1.117
114......	1.029	1.039	1.048	1.058	1.068	1.078	1.088	1.098	1.108	1.118
116......	1.029	1.039	1.049	1.059	1.069	1.079	1.088	1.098	1.108	1.118
118......	1.030	1.040	1.050	1.060	1.069	1.079	1.089	1.099	1.109	1.119
120......	1.031	1.041	1.050	1.060	1.070	1.080	1.090	1.100	1.110	1.120
122......	1.031	1.041	1.051	1.061	1.071	1.081	1.090	1.100	1.110	1.120
124......	1.032	1.042	1.052	1.062	1.071	1.081	1.091	1.101	1.111	1.121
126......	1.033	1.043	1.052	1.062	1.072	1.082	1.092	1.102	1.112	1.121
128......	1.033	1.043	1.053	1.063	1.073	1.083	1.092	1.102	1.112	1.122
130......	1.034	1.044	1.054	1.064	1.073	1.083	1.093	1.103	1.113	1.123
132......	1.035	1.045	1.054	1.064	1.074	1.084	1.094	1.104	1.114	1.123
134......	1.036	1.046	1.055	1.065	1.075	1.085	1.094	1.104	1.114	1.124
136......	1.036	1.046	1.056	1.066	1.075	1.085	1.095	1.105	1.115	1.125
138......	1.037	1.047	1.057	1.067	1.076	1.086	1.096	1.106	1.116	1.125
110......	1.038	1.048	1.057	1.067	1.077	1.087	1.096	1.106	1.116	1.126
112......	1.038	1.048	1.058	1.068	1.077	1.087	1.097	1.107	1.117	1.127
114......	1.039	1.049	1.059	1.169	1.078	1.088	1.098	1.108	1.118	1.127
146......	1.040	1.050	1.059	1.069	1.079	1.089	1.098	1.108	1.118	1.129
148......	1.040	1.050	1.060	1.070	1.079	1.089	1.099	1.109	1.119	1.128
150......	1.041	1.051	1.061	1.071	1.080	1.090	1.100	1.110	1.120	1.129

Specific Gravity Tables.

Equivalent of Degrees Baume' (American Standard) and Specific Gravity at 60°F.

$$\text{Degrees Baume}' = 145 - \frac{145}{\text{Sp. Gr.}}$$ FOR LIQUIDS HEAVIER THAN WATER.

Degrees Baume'	Specific Gravity	Degrees Baume'	Specific Gravity	Degrees Baume'	Specific Gravity	Degrees Baume'	Specific Gravity
0.0	1.0000	.7	1.0262	.4	1.0538	.1	1.0829
.1	1.0007	.8	1.0269	.5	1.0545	.2	1.0837
.2	1.0014	.9	1.0276	.6	1.0553	.3	1.0845
.3	1.0021	4.0	1.0284	.7	1.0561	.4	1.0853
.4	1.0028	.1	1.0291	.8	1.0569	.5	1.0861
.5	1.0035	.2	1.0298	.9	1.0576	.6	1.0870
.6	1.0042	.3	1.0306	8.0	1.0584	.7	1.0878
.7	1.0049	.4	1.0313	.1	1.0592	.8	1.0886
.8	1.0055	.5	1.0320	.2	1.0599	.9	1.0894
.9	1.0062	.6	1.0328	.3	1.0607	12.0	1.0902
1.0	1.0069	.7	1.0335	.4	1.0615	.1	1.0910
.1	1.0076	.8	1.0342	.5	1.0623	.2	1.0919
.2	1.0083	.9	1.0350	.6	1.0630	.3	1.0927
.3	1.0090	5.0	1.0357	.7	1.0638	.4	1.0935
.4	1.0097	.1	1.0365	.8	1.0646	.5	1.0943
.5	1.0105	.2	1.0372	.9	1.0654	.6	1.0952
.6	1.0112	.3	1.0379	9.0	1.0662	.7	1.0960
.7	1.0119	.4	1.0387	.1	1.0670	.8	1.0968
.8	1.0126	.5	1.0394	.2	1.0677	.9	1.0977
.9	1.0133	.6	1.0402	.3	1.0685	13.0	1.0985
2.0	1.0140	.7	1.0409	.4	1.0693	.1	1.0993
.1	1.0147	.8	1.0417	.5	1.0701	.2	1.1002
.2	1.0154	.9	1.0424	.6	1.0709	.3	1.1010
.3	1.0161	6.0	1.0432	.7	1.0717	.4	1.1018
.4	1.0168	.1	1.0439	.8	1.0725	.5	1.1027
.5	1.0175	.2	1.0447	.9	1.0733	.6	1.1035
.6	1.0183	.3	1.0454	10.0	1.0741	.7	1.1043
.7	1.0190	.4	1.0462	.1	1.0749	.8	1.1052
.8	1.0197	.5	1.0469	.2	1.0757	.9	1.1060
.9	1.0204	.6	1.0477	.3	1.0765	14.0	1.1069
3.0	1.0211	.7	1.0484	.4	1.0773	.1	1.1077
.1	1.0218	.8	1.0492	.5	1.0781	.2	1.1086
.2	1.0226	.9	1.0500	.6	1.0789	.3	1.1094
.3	1.0233	7.0	1.0507	.7	1.0797	.4	1.1103
.4	1.0240	.1	1.0515	.8	1.0805	.5	1.1111
.5	1.0247	.2	1.0522	.9	1.0813	.6	1.1120
.6	1.0255	.3	1.0530	11.0	1.0821	.7	1.1128

EQUIVALENT BAUME' DEGREES—Con.

Degrees Baume'	Specific Gravity	Degrees Baume'	Specific Gravity	Degrees Baume'	Specific Gravity	Degrees Baume'	Specific Gravity
.8	1.1137	.2	1.1526	.6	1.1944	28.0	1.2393
.9	1.1145	.3	1.1535	.7	1.1954	.1	1.2404
15.0	1.1154	.4	1.1545	.8	1.1964	.2	1.2414
.1	1.1162	.5	1.1554	.9	1.1974	.3	1.2425
.2	1.1171	.6	1.1563	24.0	1.1983	.4	1.2436
.3	1.1180	.7	1.1572	.1	1.1993	.5	1.2446
.4	1.1188	.8	1.1581	.2	1.2003	.6	1.2457
.5	1.1197	.9	1.1591	.3	1.2013	.7	1.2468
.6	1.1206	20.0	1.1600	.4	1.2023	.8	1.2478
.7	1.1214	.1	1.1609	.5	1.2033	.9	1.2489
.8	1.1223	.2	1.1619	.6	1.2043	29.0	1.2500
.9	1.1232	.3	1.1628	.7	1.2053	.1	1.2511
16.0	1.1240	.4	1.1637	.8	1.2063	.2	1.2522
.1	1.1249	.5	1.1647	.9	1.2073	.3	1.2532
.2	1.1258	.6	1.1656	25.0	1.2083	.4	1.2543
.3	1.1267	.7	1.1665	.1	1.2093	.5	1.2554
.4	1.1275	.8	1.1675	.2	1.2104	.6	1.2565
.5	1.1284	.9	1.1684	.3	1.2114	.7	1.2576
.6	1.1293	21.0	1.1694	.4	1.2124	.8	1.2587
.7	1.1302	.1	1.1703	.5	1.2134	.9	1.2598
.8	1.1310	.2	1.1712	.6	1.2144	30.0	1.2609
.9	1.1319	.3	1.1722	.7	1.2154	.1	1.2620
17.0	1.1328	.4	1.1731	.8	1.2164	.2	1.2631
.1	1.1337	.5	1.1741	.9	1.2175	.3	1.2642
.2	1.1346	.6	1.1750	26.0	1.2185	.4	1.2653
.3	1.1355	.7	1.1760	.1	1.2195	.5	1.2664
.4	1.1364	.8	1.1769	.2	1.2205	.6	1.2675
.5	1.1373	.9	1.1779	.3	1.2216	.7	1.2686
.6	1.1381	22.0	1.1789	.4	1.2226	.8	1.2697
.7	1.1390	.1	1.1798	.5	1.2236	.9	1.2708
.8	1.1399	.2	1.1808	.6	1.2247	31.0	1.2719
.9	1.1408	.3	1.1817	.7	1.2257	.1	1.2730
18.0	1.1417	.4	1.1827	.8	1.2267	.2	1.2742
.1	1.1426	.5	1.1837	.9	1.2278	.3	1.2753
.2	1.1435	.6	1.1846	27.0	1.2288	.4	1.2764
.3	1.1444	.7	1.1856	.1	1.2299	.5	1.2775
.4	1.1453	.8	1.1866	.2	1.2309	.6	1.2787
.5	1.1462	.9	1.1876	.3	1.2319	.7	1.2798
.6	1.1472	23.0	1.1885	.4	1.2330	.8	1.2809
.7	1.1481	.1	1.1895	.5	1.2340	.9	1.2821
.8	1.1490	.2	1.1905	.6	1.2351	32.0	1.2832
.9	1.1499	.3	1.1915	.7	1.2361	.1	1.2843
19.0	1.1508	.4	1.1924	.8	1.2372	.2	1,2855
.1	1.1517	.5	1.1934	.9	1.2383	.3	1.2866

EQUIVALENT BAUME′ DEGREES—Con.

Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity
.4	1.2877	.8	1.3401	.2	1.3969	.6	1.4588
.5	1.2889	.9	1.3414	.3	1.3983	.7	1.4602
.6	1.2900	37.0	1.3426	.4	1.3996	.8	1.4617
.7	1.2912	.1	1.3438	.5	1.4010	.9	1.4632
.8	1.2923	.2	1.3451	.6	1.4023	46.0	1.4646
.9	1.2935	.3	1.3463	.7	1.4037	.1	1.4661
33.0	1.2946	.4	1.3476	.8	1.4050	.2	1.4676
.1	1.2958	.5	1.3488	.9	1.4064	.3	1.4691
.2	1.2970	.6	1.3501	42.0	1.4078	.4	1.4706
.3	1.2981	.7	1.3514	.1	1.4091	.5	1.4721
.4	1.2993	.8	1.3526	.2	1.4105	.6	1.4736
.5	1.3004	.9	1.3539	.3	1.4119	.7	1.4751
.6	1.3016	38.0	1.3551	.4	1.4133	.8	1.4766
.7	1.3028	.1	1.3564	.5	1.4146	.9	1.4781
.8	1.3040	.2	1.3577	.6	1.4160	47.0	1.4796
.9	1.3051	.8	1.3653	.7	1.4174	.1	1.4811
34.0	1.3063	.4	1.3602	.8	1.4188	.2	1.4826
.1	1.3075	.5	1.3615	.9	1.4202	.3	1.4841
.2	1.3087	.6	1.3628	43.0	1,4216	.4	1.4857
.3	1.3098	.7	1.3641	.1	1.4230	.5	1.4872
.4	1.3110	.8	1.3653	.2	1.4244	.6	1.4887
.5	1.3122	.9	1.3666	.3	1.4258	.7	1.4902
.6	1.3134	39.0	1.3679	.4	1.4272	.8	1.4918
.7	1.3146	.1	1.3692	.5	1.4286	.9	1.4933
.8	1.3158	.2	1.3705	.6	1.4300	48.0	1.4948
9	1.3170	.3	1.3718	.7	1.4314	.1	1.4964
35.0	1.3182	.4	1.3731	.8	1.4328	.2	1.4979
.1	1.3194	.5	1.3744	.9	1.4342	.3	1.4995
.2	1.3206	.6	1.3757	44.0	1.4356	.4	1.5010
.3	1.3218	.7	1.3770	.1	1.4371	.5	1.5026
.4	1.3230	.8	1.3783	.2	1.4385	.6	1.5041
.5	1.3242	.9	1.3796	.3	1.4399	.7	1.5057
.6	1.3254	40.0	1.3810	.4	1.4414	.8	1.5073
.7	1.3266	.1	1.3823	.5	1.4428	.9	1.5088
.8	1.3278	.2	1.3836	.6	1.4442	49.0	1.5104
.9	1.3291	.3	1.3849	.7	1.4457	.1	1.5120
36.0	1.3303	.4	1.3862	.8	1.4471	.2	1.5136
.1	1.3315	.5	1,3876	.9	1.4486	.3	1.5152
.2	1.3327	.6	1.3889	45.0	1.4500	.4	1.5167
.3	1.3329	.7	1.3902	.1	1.4515	.5	1.5183
.4	1.3352	.8	1.3916	.2	1.4529	.6	1.5199
.5	1.3364	.9	1.3928	.3	1.4544	.7	1.5215
.6	1.3376	41.0	1.3942	.4	1.4558	.8	1.5231
.7	1.3389	.1	1.3956	.5	1.4573	.9	1.5247

EQUIVALENT BAUME′ DEGREES—Con.

Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity
50.0	1.5263	.1	1.6129	.1	1.7079	.1	1.8148
.1	1.5279	.2	1.6147	.2	1.7099	.2	1.8170
.2	1.5295	.3	1.6165	.3	1.7119	.3	1.8193
.3	1.5312	.4	1.6183	.4	1.7139	.4	1.8216
.4	1.5328	.5	1.6201	.5	1.7160	.5	1.8239
.5	1.5344	.6	1.6219	.6	1.7180	.6	1.8262
.6	1.5360	.7	1.6237	.7	1.7200	.7	1.8285
.7	1.5376	.8	1.6256	.8	1.7221	.8	1.8308
.8	1.5393	.9	1.6459	.9	1.7241	.9	1.8331
.9	1.5409	56.0	1.6292	61.0	1.7262	66.0	1.8354
51.0	1.5426	.1	1.6310	.1	1.7282	.1	1.8378
.1	1.5442	.2	1.6329	.2	1.7303	.2	1.8401
.2	1.5458	.3	1.6347	.3	1.7324	.3	1.8424
.3	1.5475	.4	1.6366	.4	1.7344	.4	1.8448
.4	1.5491	.5	1.6384	.5	1.7365	.5	1.8471
.5	1.5508	.6	1.6403	.6	1.7386	.6	1.8495
.6	1.5525	.7	1.6421	.7	1.7407	.7	1.8519
.7	1.5541	.8	1.6440	.8	1.7428	.8	1.8542
.8	1.5558	.9	1.6459	.9	1.7449	9	1.8566
.9	1.5575	57.0	1.6477	62.0	1.7470	67.0	1.8590
52.0	1.5591	.1	1.6496	.1	1.7491	.1	1.8614
.1	1.5608	.2	1.6515	.2	1.7512	.2	1.8638
.2	1.5625	.3	1.6534	.3	1.7533	.3	1.8662
.3	1.5642	.4	1.6553	.4	1.7554	.4	1.8686
.4	1.5659	.5	1.6571	.5	1.7576	.5	1.8710
.5	1.5676	.6	1.6590	.6	1.7597	.6	1.8734
.6	1.5693	.7	1.6609	.7	1.7618	.7	1.8758
.7	1.5710	.8	1.6628	.8	1.7640	.8	1.8782
.8	1.5727	.9	1.6459	.9	1.7661	.9	1.8807
.9	1.5744	58.0	1.6667	63.0	1.7683	68.0	1.8831
53.0	1.5761	.1	1.6686	.1	1.7705	.1	1.8856
.1	1.5778	.2	1.6705	.2	1.7726	.2	1.8880
.2	1.5795	.3	1.6724	.3	1.7748	.3	1,8905
.3	1.5812	.4	1.6744	.4	1.7770	.4	1.8930
.4	1.5830	.5	1.6763	.5	1.7791	.5	1.8954
.5	1.5847	.6	1.6782	.6	1.7813	.6	1.8979
.6	1.5864	.7	1.6802	.7	1.7835	.7	1.9004
.7	1.5882	.8	1.6821	.8	1.7857	.8	1.9029
.8	1.5899	.9	1.6841	.9	1.7879	.9	1.9054
.9	1.5917	59.0	1.6860	64.0	1.7901	69.0	1.9079
54.0	1.5934	.1	1.6880	.1	1.7923	.1	1.9104
.1	1.5952	.2	1.6900	.2	1.7946	.2	1.9129
.2	1.5969	.3	1.6919	.3	1.7968	.3	1.9155
.3	1.5987	.4	1,6939	.4	1.7990	.4	1.9180
.4	1.6004	.5	1.6959	.5	1.8012	.5	1.9205
.5	1.6022	.6	1.6979	.6	1.8035	.6	1.9231
.6	1.6040	.7	1.6999	.7	1.8057	.7	1.9256
.7	1.6058	.8	1.7019	.8	1.8080	.8	1.9282
.8	1.6075	.9	1.7039	.9	1.8102	.9	1.9308
.9	1.6093	60.0	1.7059	65.0	1.8125	70.0	1.9333
55.0	1.6111						

SPECIFIC GRAVITY AND CONTENT OF SULPHURIC ACID.

Specific Gravity $\frac{15°}{4°}$ in vacuo	100 parts by weight correspond to % SO_3	100 parts by weight correspond to % H_2SO_4	1 liter contains grams SO_3	1 liter contains grams H_2SO_4	Specific Gravity $\frac{15°}{4°}$ in vacuo	100 parts by weight correspond to % SO_3	100 parts by weight correspond to % H_2SO_4	1 liter contains grams SO_3	1 liter contains grams H_2SO_4
1.000	0.07	0.09	1	1	1.190	21.26	26.04	253	310
1.005	0.68	0.83	7	8	1.195	21.78	26.68	260	319
1.010	1.28	1.57	13	16	1.200	22.30	27.30	268	328
1.015	1.88	2.30	19	23	1.205	22.82	27.95	275	337
1.020	2.47	3.03	25	31	1.210	23.33	28.58	282	346
1.025	3.07	3.76	32	39	1.215	23.84	29.21	290	355
1.030	3.67	4.40	38	46	1.220	24.36	29.84	297	364
1.035	4.27	5.23	44	54	1.225	24.88	30.48	305	373
1.040	4.87	5.96	51	62	1.230	25.39	31.11	312	382
1.045	5.45	6.67	57	71	1.235	25.88	31.70	320	391
1.050	6.02	7.37	63	77	1.240	26.35	32.28	327	400
1.055	6.59	8.07	70	85	1.245	26.83	32.86	334	409
1.060	7.16	8.77	76	93	1.250	27.29	33.43	341	418
1.065	7.73	9.47	82	102	1.255	27.76	34.00	348	426
1.070	8.32	10.19	89	109	1.260	28.22	34.57	356	435
1.075	8.90	10.90	96	117	1.265	28.69	35.14	363	444
1.080	9.47	11.60	103	125	1.270	29.15	35.71	370	454
1.085	10.04	12.30	109	133	1.275	29.62	36.29	377	462
1.090	10.60	12.99	116	142	1.280	30.10	36.87	385	472
1.095	11.16	13.67	122	150	1.285	30.57	37.45	393	481
1.100	11.71	14.35	129	158	1.290	31.04	38.03	400	490
1.105	12.27	15.03	136	166	1.295	31.52	38.61	408	500
1.110	12.82	15.71	143	175	1.300	[illegible]	39.19	416	510
1.115	13.36	16.36	149	183	1.305	32.46	39.77	424	519
1.120	13.89	17.01	156	191	1.310	32.94	40.35	432	529
1.125	14.42	17.66	162	199	1.315	33.41	40.[illegible]	439	538
1.130	14.95	18.31	169	207	1.320	33.88	41.50	447	548
1.135	15.48	18.96	176	215	1.325	34.35	42.08	455	557
1.140	16.01	19.61	183	223	1.330	34.80	42.66	462	[illegible]
1.145	16.54	20.26	189	231	1.335	35.27	43.20	471	577
1.150	17.07	20.91	196	239	1.340	35.71	43.74	479	5[illegible]
1.155	17.59	21.55	203	248	1.345	36.14	44.28	486	596
1.160	18.11	22.19	210	257	1.350	36.58	44.82	494	605
1.165	18.64	22.83	217	266	1.355	37.02	45.35	502	614
1.170	19.16	23.47	224	275	1.360	37.45	45.88	509	624
1.175	19.69	24.12	231	283	1.365	37.89	46.41	517	633
1.180	20.21	24.76	238	292	1.370	38.32	46.94	525	643
1.185	20.73	25.40	246	301	1.375	38.75	47.47	533	653

SPECIFIC GRAVITY AND CONTENT OF SULPHURIC ACID—Continued.

Specific Gravity 15°/4° in vacuo	100 parts by weight correspond to % SO_3	100 parts by weight correspond to % H_2SO_4	1 liter contains grams SO_3	1 liter contains grams H_2SO_4	Specific Gravity 15°/4° in vacuo	100 parts by weight correspond to % SO_3	100 parts by weight correspond to % H_2SO_4	1 liter contains grams SO_3	1 liter contains grams H_2SO_4
1.380	39.18	48.00	541	662	1.675	61.20	74.97	1025	1256
1.385	39.62	48.53	549	672	1.680	61.57	75.42	1034	1267
1.390	40.05	49.06	557	682	1.685	61.93	75.86	1043	1278
1.395	40.48	49.50	564	692	1.690	62.29	76.30	1053	1289
1.400	40.91	50.11	573	702	1.695	62.64	76.73	1062	1301
1.405	41.33	50.63	581	711	1.700	63.00	77.17	1071	1312
1.410	41.76	51.15	589	721	1.705	63.35	77.60	1080	1323
1.415	42.17	51.66	597	730	1.710	63.70	78.04	1089	1334
1.420	42.57	52.15	604	740	1.715	64.07	78.48	1099	1346
1.425	42.96	52.63	612	750	1.720	64.43	78.92	1108	1357
1.430	43.36	53.11	620	759	1.725	64.78	79.36	1118	1369
1.435	43.75	53.59	628	769	1.730	65.14	79.80	1127	1381
1.440	44.14	54.07	636	779	1.735	65.50	80.24	1136	1392
1.445	44.53	54.55	643	789	1.740	65.86	80.68	1146	1404
1.450	44.92	55.03	651	798	1.745	66.22	81.12	1156	1416
1.455	45.31	55.50	659	808	1.750	66.58	81.56	1165	1427
1.460	45.69	55.97	667	817	1.755	66.94	82.00	1175	1439
1.465	46.07	56.43	675	827	1.760	67.30	82.44	1185	1451
1.470	46.45	56.90	683	837	1.765	67.65	82.88	1194	1463
1.475	46.83	57.37	691	846	1.770	68.02	83.32	1204	1475
1.480	47.21	57.83	699	856	1.775	68.49	83.90	1216	1489
1.485	47.57	58.28	707	865	1.780	68.98	84.50	1228	1504
1.490	47.95	58.74	715	876	1.785	69.47	85.10	1240	1519
1.495	48.34	59.22	723	885	1.790	69.96	85.70	1252	1534
1.500	48.73	59.70	731	896	1.795	70.46	86.30	1265	1549
1.505	49.12	60.18	739	906	1.800	70.94	86.90	1277	1564
1.510	49.51	60.65	748	916	1.805	71.50	87.60	1291	1581
1.515	49.89	61.12	756	926	1.810	72.08	88.30	1305	1598
1.520	50.28	61.59	764	936	1.815	72.69	89.05	1319	1621
1.525	50.66	62.06	773	946	1.820	73.51	90.05	1338	1639
1.530	51.04	62.53	781	957	1.821	73.63	90.20	1341	1643
1.535	51.43	63.00	789	967	1.822	73.80	90.40	1345	1647
1.540	51.78	63.43	797	977	1.823	73.96	90.60	1348	1651
1.545	52.12	63.85	805	987	1.824	74.12	90.80	1352	1656
1.550	52.46	64.26	813	996	1.825	74.29	91.00	1356	1661
1.555	52.79	64.67	821	1006	1.826	74.49	91.25	1360	1666
1.560	53.12	65.08	829	1015	1.827	74.69	91.50	1364	1671
1.565	53.46	65.49	837	1025	1.828	74.86	91.70	1368	1676
1.570	53.80	65.90	845	1035	1.829	75.03	91.90	1372	1681
1.575	54.13	66.30	853	1044	1.830	75.19	92.10	1376	1685
1.580	54.46	66.71	861	1054	1.831	75.35	92.30	1380	1690
1.585	54.80	67.13	869	1064	1.832	75.53	92.52	1384	1695
1.590	55.18	67.59	877	1075	1.833	75.72	92.75	1388	1700
1.595	65.55	68.05	886	1085	1.834	75.96	93.05	1393	1706
1.600	55.93	68.51	897	1096	1.835	76.27	93.43	1400	1713
1.605	56.30	68.97	904	1107	1.836	76.57	93.80	1405	1722
1.610	56.68	69.43	913	1118	1.837	76.90	94.20	1412	1730
1.615	57.05	69.89	921	1128	1.838	77.23	94.60	1419	1739
1.620	57.40	70.32	930	1139	1.839	77.55	95.00	1426	1748
1.625	57.75	70.74	938	1150	1.840	78.04	95.60	1436	1759
1.630	58.09	71.16	947	1160	1.8405	78.33	95.95	1441	1765
1.635	58.43	71.57	955	1170	1.8410	79.19	97.00	1458	1786
1.640	58.77	71.99	964	1181	1,8415	79.76	97.70	1469	1799
1.645	59.10	72.40	972	1192	1.8410	80.16	98.20	1476	1808
1.650	59.45	72.82	981	1202	1.8405	80.57	98.70	1483	1816
1.655	59.78	73.23	989	1212	1.8400	80.98	99.20	1490	1825
1.660	60.11	73.64	998	1222	1.8395	81.18	99.45	1494	1830
1.665	60.46	74.07	1007	1233	1.8390	81.39	90.70	1497	1834
1.670	60.82	74.51	1016	1244	1.8385	81.59	99.95	1500	1838

Percentage of Sulphur Trioxide and Sulphuric Acid in Fuming Sulphuric Acid.

Total SO_3 as found by titration	The acid contains %		Total SO_3 as found by titration	The acid contains %		Total as found by titration	The acid contains %	
	H_2SO_4	SO_3		H_2SO_4	SO_3		H_2SO_4	SO_3
81.8326	100	0	87.8775	66	34	93.9389	33	67
81.8163	99	1	88.0612	65	35	94.1224	32	68
82.0000	98	2	88.2448	64	36	94.3061	31	69
82.1836	97	3	88.4285	63	37	94.4897	30	70
82.3674	96	4	88.6122	62	38	94.6734	29	71
82.5510	95	5	88.7959	61	39	94.8571	28	72
82.7346	94	6	88.9795	60	40	95.0408	27	73
82.9183	93	7	89.1632	59	41	95.2244	26	74
83.1020	92	8	89.3469	58	42	95.4081	25	75
83.2857	91	9	89.5306	57	43	95.5918	24	76
83.4693	90	10	89.7142	56	44	95.7755	23	77
83.6530	89	11	89.8979	55	45	95.9591	22	78
83.8367	88	12	90.0816	54	46	96.1428	21	79
84.0204	87	13	90.2653	53	47	96.3265	20	80
84.2040	86	14	90.4489	52	48	96.5102	19	81
84.3877	85	15	90.6326	51	49	96.6938	18	82
84.5714	84	16	90.8163	50	50	96.8775	17	83
84.7551	83	17	91.0000	49	51	97.0612	16	84
84.9387	82	18	91.1836	48	52	97.2448	15	85
85.1224	81	19	91.3673	47	53	97.4285	14	86
85.3061	80	20	91.5510	46	54	97.6122	13	87
85.4897	79	21	91.7346	45	55	97.7959	12	88
85.6734	78	22	91.9183	44	56	97.9795	11	89
85.8571	77	23	92.1020	43	57	98.1632	10	90
86.0408	76	24	92.2857	42	58	98.3469	9	91
86.2244	75	25	92.4693	41	59	98.5306	8	92
86.4081	74	26	92.6530	40	60	98.7142	7	93
86.5918	73	27	92.8367	39	61	98.8979	6	94
86.7755	72	28	93.0204	38	62	99.0816	5	95
86.9591	71	29	93.2040	37	63	99.2753	4	96
87.1428	70	30	93.3877	36	64	99.4489	3	97
87.3265	69	31	93.5714	35	65	99.6326	2	98
87.5102	68	32	93.7551	34	66	99.8163	1	99
87.6938	67	33						

Sodium Hydroxide Solution at 15°C (Caustic Soda).

LUNGE.

Specific Gravity	Degrees Baume'	Degrees Twaddell	Per Cent Na_2O.	Per Cent NaOH.	1 Liter Contains Grams	
					Na_2O.	NaOH.
1.007	1.0	1.4	0.47	0.61	4	6
1.014	2.8	2.9	0.93	1.20	9	12
1.022	3.1	4.4	1.55	2.00	16	21
1.029	4.1	5.8	2.10	2.70	22	28
1.036	5.1	7.2	2.60	3.35	27	35
1.045	6.2	9.0	3.10	4.00	32	42
1.052	7.2	10.4	3.60	4.64	38	49
1.060	8.2	12.0	4.10	5.29	43	56
1.067	9.1	13.4	4.55	5.87	49	63
1.075	10.1	15.0	5.08	6.55	55	70
1.083	11.1	16.6	5.67	7.31	61	79
1.091	12.1	18.2	6.20	8.00	68	87
1.100	13.2	20.0	6.73	8.68	74	95
1.108	14.1	21.6	7.30	9.42	81	104
1.116	15.1	23.2	7.80	10.06	87	112
1.125	16.1	25.0	8.50	10.97	96	123
1.134	17.1	26.8	9.18	11.84	104	134
1.142	18.0	28.4	9.80	12.64	112	144
1.152	19.1	30.4	10.50	13.55	121	156
1.162	20.2	32.4	11.14	14.37	129	167
1.171	21.2	34.2	11.73	15.13	137	177
1.180	22.1	36.0	12.33	15.91	146	188
1.190	23.1	38.0	13.00	16.77	155	200
1.200	24.2	40.0	13.70	17.67	164	212
1.210	25.2	42.0	14.40	18.58	174	225
1.220	26.1	44.0	15.18	19.58	185	239
1.231	27.2	46.2	15.96	20.59	196	253
1.241	28.2	48.2	16.76	21.42	208	266
1.252	29.2	50.4	17.55	22.64	220	283
1.263	30.2	52.6	18.35	23.67	232	299
1.274	31.2	54.8	19.23	24.81	245	316
1.285	32.2	57.0	20.00	25.80	257	332
1.297	33.2	59.4	20.80	26.83	270	348
1.308	34.1	61.6	21.55	27.80	282	364
1.320	35.2	64.0	22.35	28.83	295	381
1.332	36.1	66.4	23.20	29.93	309	399
1.345	37.2	69.0	24.20	31.22	326	420
1.357	38.1	71.4	25.17	32.47	342	441
1.370	39.2	74.0	26.12	33.69	359	462
1.383	40.2	76.6	27.10	34.96	375	483
1.397	41.2	79.4	28.10	36.25	392	506
1.410	42.2	82.0	29.05	37.47	410	528
1.424	43.2	84.8	30.08	38.80	428	553
1.438	44.2	87.6	31.00	39.99	446	575
1.453	45.2	90.6	32.10	41.41	466	602
1.468	46.2	93.6	33.20	42.83	487	629
1.483	47.2	96.6	34.40	44.38	510	658
1.498	48.2	99.6	35.70	46.15	535	691
1.514	49.2	102.8	36.90	47.60	559	721
1.530	50.2	106.0	38.00	49.02	581	750

Table of Chloride of Calcium Solution.

Specific Gravity at 64 Degrees F.	Degree Beaume at 64 Degrees F.	Degree Salometer at 64 Degrees F.	Per Cent of $CaCl_2$	Freezing Point in Degrees F.	Ammonia Gauge Pressure Pounds per Square Inch
1.007	1	4	0.943	+31.20	46
1.014	2	8	1.886	+30.40	45
1.021	3	12	2.829	+29.60	44
1.028	4	16	3.772	+28.80	43
1.035	5	20	4.715	+28.00	42
1.043	6	24	5.658	+26.89	41
1.050	7	28	6.601	+25.78	40
1.058	8	32	7.544	+24.67	38
1.065	9	36	8.487	+23.56	37
1.073	10	40	9.430	+22.09	35.5
1.081	11	44	10.373	+20.62	34
1.089	12	48	11.316	+19.14	32.5
1.097	13	52	12.259	+17.67	30.5
1.105	14	56	13.202	+15.75	29
1.114	15	60	14.145	+13.82	27
1.122	16	64	15.088	+11.80	25
1.131	17	68	16.031	+ 9.96	23.5
1.140	18	72	16.974	+ 7.68	21.5
1.149	19	76	17.917	+ 5.40	20
1.158	20	80	18.860	+ 3.12	18
1.167	21	84	19.803	— 0.84	15
1.176	22	88	20.746	— 4.44	12.5
1.186	23	92	21.689	— 8.03	10.5
1.196	24	96	22.632	—11.63	8
1.205	25	100	23.575	—15.23	6
1.215	26	104	24.518	—19.56	4
1.225	27	108	25.461	—24.43	1.5
1.236	28	112	26.404	—29.29	1" vacuum
1.246	29	116	27.347	—35.30	5" vacuum
1.257	30	120	28.290	—41.32	8.5" vacuum
1.268	31	......	29.233	—47.66	12" vacuum
1.279	32	......	30.176	—54.00	15" vacuum
1.290	33	......	31.119	—44.32	10" vacuum
1.302	34	......	32.062	—34.66	4" vacuum
1.313	35	......	33.	—25.00	1.5 pounds

Table of Brine Solution.

(CHLORIDE OF SODIUM—COMMON SALT.)

Per Cent of Salt by Weight	Degrees on Salometer at 60 Degrees Fahr.	Specific Gravity at 60 Degrees Fahr.	Specific Heat	Weight of One Gallon	Pounds of Salt in One Gallon	Pounds of Water in One Gallon	Weight of One Cubic Foot	Pounds of Salt in One Cubic Foot	Pounds of Water in One Cubic Foot	Freezing Point Degrees Fahr.
0	0	1.	1.	8.35	0.	8.35	62.4	0	62.4	32.
1	4	1.007	0.992	8.4	0.084	8.316	62.8	0.628	62.172	31.8
5	20	1.037	0.96	8.65	0.432	8.218	64.7	3.237	61.465	25.4
10	40	1.073	0.892	8.95	0.895	8.055	66.95	6.605	60.253	18.6
15	60	1.115	0.855	9.3	1.395	7.905	69.57	10.435	59.134	12.2
20	80	1.150	0.829	9.6	1.92	7.68	71.76	14.352	57.408	6.86
25	100	1.191	0.783	9.94	2.485	7.455	74.26	18.565	55.695	1.00

The Metric System, Fundamental Equivalents.

The fundamental unit of the metric system is the Meter—the unit of length. From this the units of capacity (Liter) and of weight (Gram) were derived. All other units are the decimal subdivisions or multiples of these. These three units are simply related, e. g., for all practical purposes one Cubic Decimeter equals one Liter and one Liter of water weighs one Kilogram. The metric tables are formed by combining the words "Meter," "Gram," and "Liter" with the six numerical prefixes, as in the following tables:

Prefixes.	Meaning.			Units.
milli-	= one thousandth ..	1/1000	0.001	
centi-	= one hundredth ..	1/100	0.01	"meter" for length
deci-	= one tenth.	1/10	0.1	
Unit	= one.		1.	"gram" for weight or mass
deka-	= ten	10/1	10.	
hecto-	= one hundred	100/1	100.	"liter" for capacity
kilo-	= one thousand ...	1000/1	1000.	

All lengths, areas, and cubic measures in the following tables are derived from the international meter, the legal equivalent being 1 Meter = 39.37 Inches (law of July 28, 1866). In 1893 the United States Office of Standard Weights and Measures was authorized to derive the yard from the meter, using for the purpose the relation legalized in 1866, 1 Yard = 3600/3937 Meter.

The customary weights derived from the international kilogram are based on the value of 1 avoirdupois pound = 453.5924277 grams. This value is carried out farther than that given in the law, but is in accord with the latter as far as it is there given. The value of the troy pound is based upon the relation just mentioned and also the equivalent 5760/7000 avoirdupois pounds equal 1 troy pound.

In the following tables the metric unit has been selected as the common unit so that conversions may be made through the metric unit.

LINEAR DIMENSIONS—CONVERSION FACTORS.

Cm. to A.	A.	A. to Cm.
$1.0000 \cdot 10^{-5}$	KILOMETER = 0.62137 — U. S. miles = 3280.83 ft.	$1.0000 \cdot 10^{5}$
$1.0000 \cdot 10^{-2}$ (*a*)	METER = 3.28083 ft. = 39.37 inches (legal)	$1.0000 \cdot 10^{2}$
1.0000	CENTIMETER = 0.3937 inch = 10 millimeters	1.0000
$1.0000 \cdot 10$	MILLIMETER = 0.03937 inch = 1000 microns	$1.0000 \cdot 10^{-1}$
$1.0000 \cdot 10^{4}$	MICRON = 0.00003937 inch = 1000 millimicrons	$1.0000 \cdot 10^{-4}$
$1.0000 \cdot 10^{7}$	MILLIMICRON or MICROMILLIMETER = 10 A. U.	$1.0000 \cdot 10^{-7}$
$1.0000 \cdot 10^{8}$	ANGSTROM UNIT = 3.932×10^{-9} inch	$1.0000 \cdot 10^{-8}$
$6.2137 \cdot 10^{-6}$	MILE (Statute) = 5280 feet = 1.609347 kilom.	$1.6093 \cdot 10^{5}$
$1.9883 \cdot 10^{-3}$	ROD or PERCH = 16.5 feet	$5.029 \cdot 10^{2}$
$1.0936 \cdot 10^{-2}$	YARD = 3 feet	$9.144 \cdot 10$
$3.28083 \cdot 10^{-2}$	FOOT = 12 inches	$3.0480 \cdot 10$
$3.937 \cdot 10^{-1}$	INCH = 0.083333 ft.	2.5400
$3.937 \cdot 10^{2}$	MIL = 1/1000 inch	$2.5400 \cdot 10^{-3}$
$8.983 \cdot 10^{-8}$	1° LONGITUDE AT EQUATOR = 69.1713 Statute Miles	$1.1132 \cdot 10^{7}$
$2.0712 \cdot 10^{-6}$	LEAGUE = 3 Statute Miles	$4.8280 \cdot 10^{5}$
$5.3959 \cdot 10^{-6}$	KNOT, NAUTICAL MILE, SEA MILE = 6080.2 (Geographical Mile)	$1.85325 \cdot 10^{5}$
$5.3957 \cdot 10^{-6}$	BRITISH NAUTICAL MILE = 6080.4006466 + feet	$1.85319 \cdot 10^{5}$
$4.97 \cdot 10^{-5}$	FURLONG = 660 feet = 10 chains	$2.01168 \cdot 10^{4}$
$2.7340 \cdot 10^{-4}$	1 CABLE LENGTH = 120 feet	$3.6576 \cdot 10^{3}$
$5.468 \cdot 10^{-3}$	U. S. FATHOM = 6 feet	$1.8288 \cdot 10^{2}$
$4.9709 \cdot 10^{-4}$	CHAIN = 66 feet = 100 links	$2.01168 \cdot 10^{3}$
$4.97 \cdot 10^{-2}$	LINK = 7.92 inches	$2.01168 \cdot 10$
$1.118 \cdot 10^{-2}$	VARA = 33⅓ inches	$8.4760 \cdot 10$
$2.734 \cdot 10^{-4}$	BOLT = 40 yards	$3.7576 \cdot 10^{3}$
$1.1811 \cdot 10^{-1}$	BARLEY CORN = ⅓ inch	8.4667
$4.3744 \cdot 10^{-2}$	SPAN = 9 inches	$2.2860 \cdot 10$
$9.8425 \cdot 10^{-2}$	HAND = 4 inches	$1.0160 \cdot 10$
$1.312 \cdot 10^{-1}$	PALM = 3 inches	7.6200
1.7001	LINE = 1/12 inch	$2.1167 \cdot 10^{-1}$
$2.834 \cdot 10$	POINT = 1/72 inch	$3.5278 \cdot 10^{-2}$

(*a*) Note $10^{-5} = 1/10^{5} = 1/100000 = 0.00001$.

SQUARE MEASURE, SURFACES, AREAS.

Sq. cm. to A.	A.	A. to sq. cm.
$1.000 \cdot 10^{-8}$	HECTARE = 2.471043930 acres	$1.000 \cdot 10^{8}$
$1.000 \cdot 10^{-6}$ (*a*)	ARE or AR = 119.59852621 sq. yd.	$1.000 \cdot 10^{6}$
$1.000 \cdot 10^{-10}$	SQUARE KILOMETER = 0.386100614 sq. miles	$1.000 \cdot 10^{10}$
$1.000 \cdot 10^{-4}$	SQUARE METER = 10.76386735908 sq. ft.	$1.000 \cdot 10^{4}$
1.000	SQUARE CENTIMETER = 0.15499968997 sq. in.	1.000
$1.000 \cdot 10^{2}$	SQUARE MILLIMETER = 0.001550 sq. in.	$1.000 \cdot 10^{-2}$
$1.0725017 \cdot 10^{-12}$	1 TOWNSHIP = 36 square miles	$9.3239945 \cdot 10^{11}$
$3.86100614 \cdot 10^{-11}$	SQUARE MILE = 640 acres = 2.78784×10^{7} sq. in.	$2.58999847 \cdot 10^{10}$
$2.47104393 \cdot 10^{-8}$	ACRE = 10 sq. chains = 43560 sq. ft. = 0.0015625 sq. mi.	$4.0468726 \cdot 10^{7}$
$3.953670288 \cdot 10^{-6}$	SQ. ROD or POLE = 272.25 sq. ft. = 0.00625 A.	$2.52929537 \cdot 10^{5}$
$1.19598526 \cdot 10^{-4}$	SQUARE YARD = 9 sq. ft. = 1296 sq. in.	$8.3613 \cdot 10^{3}$
$1.0763867359 \cdot 10^{-3}$	SQUARE FOOT = 144 sq. in. = 3.58701×10^{-8} sq. mi.	$9.29034 \cdot 10^{2}$
$1.5499968 \cdot 10^{-1}$	SQUARE INCH = 0.0069444 sq. ft. = 2.491×10^{-10} sq. mi.	6.4516
$1.5499968 \cdot 10^{5}$	SQUARE MIL = 0.000001 sq. in.	$6.4516 \cdot 10^{-6}$
$1.2705 \cdot 10^{5}$	CIRCULAR MIL = (wire) = 0.00000122 sq. in.	$7.871 \cdot 10^{-6}$
$2.47104393 \cdot 10^{-7}$	SQUARE CHAIN = 4356 sq. ft. = 0.1 acres	$4.0468726 \cdot 10^{6}$
$2.47104393 \cdot 10^{-4}$	SQUARE LINK = 62.7264 sq. in. = 0.4356 sq. ft.	$4.0468726 \cdot 10^{3}$
$1.0764 \cdot 10^{-5}$	1 SQUARE (roofs and floors) = 100 sq. ft.	$9.29034 \cdot 10^{4}$

(*a*) $10^{-8} = 1/10^{8} = 1/100000000 = 0.00000001$

VOLUME, CAPACITY, CUBIC CONTENTS, SPACE.

Cubic centimeter to A.	A.	A. to cubic centimeter.
1.000	CUBIC CENTIMETER = 16.23 minims = 0.0610 cu. in.	1.0000
$1.000 \cdot 10^{-3}$	LITER = 1.056681868 U. S. Qt. = 61.023 cu. in.	$1.000 \cdot 10^{3}$
$1.000 \cdot 10^{-6}$	CUBIC METER = 264.4 U. S. Gal. = 35.3165 cu. ft. (Kiloliter) (stere) = 1.307942772 cu. yd.	$1.000 \cdot 10^{6}$
$6.1023377953 \cdot 10^{-2}$	CUBIC INCH = 0.553 fld. oz. = 0.00058 cu. ft.	$1.6387 \cdot 10$
$3.532 \cdot 10^{-5}$	CUBIC FOOT = 7.48 U. S. Gal. = 1728 cu. in.	$2.8317 \cdot 10^{4}$
$1.308 \cdot 10^{-9}$	CUBIC YARD = 20.197 U. S. Gal. = 27 cu. ft.	$7.64559 \cdot 10^{5}$

U. S. LIQUID AND APOTHECARY MEASURE.

$1.623 \cdot 10$	MINIM = about 1 drop = 0.00376 cu. in.	$6.16119 \cdot 10^{-2}$
$2.705 \cdot 10^{-1}$	FLUID DRAM = 60 minims = 0.2256 cu. in.	3.6967
$8.116 \cdot 10^{-1}$	SCRUPLE = 20 minims = 0.0752 cu. in.	1.2322
$3.3815 \cdot 10^{-2}$	FLUID OUNCE = 8 drams = 1.805 cu. in.	$2.9573 \cdot 10$
$8.454 \cdot 10^{-3}$	GILL = 4 ounces = 7.220 cu. in.	$1.1829 \cdot 10^{2}$
$2.113 \cdot 10^{-3}$	PINT = 16 ounces = 28.88 cu. in.	$4.73179 \cdot 10^{2}$
$1.056 \cdot 10^{-3}$	QUART = 2 pints = 57.76 cu. in.	$9.46358 \cdot 10^{2}$
$2.641704673 \cdot 10^{-4}$	GALLON = 4 quarts = 0.1337 cu. ft. = 231 cu. in.	$3.78543 \cdot 10^{3}$
$8.387 \cdot 10^{-6}$	BARREL (wine) = 31½ gallons = 4.205 cu. ft.	$1.1924 \cdot 10^{5}$
$4.193 \cdot 10^{-6}$	HOGSHEAD = 63 gallons = 8.410 cu. ft.	$2.3848 \cdot 10^{5}$
$6.297 \cdot 10^{-6}$	BARREL (petroleum) = 42 gal. = 5.615 cu. ft.	$1.58984 \cdot 10^{5}$
$6.297 \cdot 10^{-6}$	TIERCE = 42 gal. = 5.615 cu. ft.	$1.5898 \cdot 10^{5}$
$3.148 \cdot 10^{-6}$	PUNCHEON = 84 gallons = 11.23 cu. ft.	$3.176 \cdot 10^{5}$

U. S. DRY MEASURE.

Cubic centimeter to A.	A.	A. to cubic centimeter.
$1.816 \cdot 10^{-3}$	PINT = 33.6 cu. in.	$5.506 \cdot 10^{2}$
$9.08 \cdot 10^{-4}$	QUART = 1.101 liters = 67.2 cu. in.	$1.10123 \cdot 10^{3}$
$2.27 \cdot 10^{-4}$	GALLON = 4.4049 liters = 268.8 cu. in.	$4.40492 \cdot 10^{3}$
$1.13 \cdot 10^{-4}$	PECK = 8.8098 liters = 537.6 cu. in.	$8.80984 \cdot 10^{3}$
$2.837742299 \cdot 10^{-5}$	BUSHEL = 9.31 U. S. Gal. = 2150.4 cu. in.	$3.523928 \cdot 10^{4}$
$9.418 \cdot 10^{-4}$	BARREL (flour) 196 lbs. = 88.904 kgm. = 7056 cu. in. = 408 cu. ft.	$1.06180 \cdot 10^{5}$
$8.849 \cdot 10^{-5}$	BARREL (cement) = 376 lbs. = 170.551 kgm. = 4.0 cu. ft.	$1.13 \cdot 10^{5}$

BRITISH LIQUID AND DRY MEASURE.

$1.693 \cdot 10$	MINIMS = about 1 drop = 0.00361 cu. in.	$5.9192 \cdot 10^{-2}$
$2.8219 \cdot 10^{-1}$	DRACHM = 60 minims = 0.2166 cu. in.	3.54958
$3.527 \cdot 10^{-2}$	OUNCE = 8 drachms = 1.733 cu. in.	$2.839661 \cdot 10$
$1.7608 \cdot 10^{-3}$	PINT = 20 ounces = 34.67 cu. in.	$5.6793 \cdot 10^{2}$
$8.804 \cdot 10^{-4}$	QUART = 1.136 liters = 69.34 cu. in.	$1.13586 \cdot 10^{3}$
$2.201 \cdot 10^{-4}$	GALLON = 4.543 liters = 277.274 cu. in.	$4.54345797 \cdot 10^{3}$
$1.1005 \cdot 10^{-4}$	PECK = 2 gallons = 554.4 cu. in.	$9.08692 \cdot 10^{3}$
$2.75121 \cdot 10^{-5}$	BUSHEL = 8 gallons = 2218.2 cu. in.	$3.63477 \cdot 10^{4}$
$6.87802 \cdot 10^{-6}$	COOMB = 4 bushels = 5.1347 cu. ft.	$1.453908 \cdot 10^{5}$
$3.43901 \cdot 10^{-6}$	QUARTER = 8 bushels = 10.269 cu. ft.	$2.907816 \cdot 10^{5}$

MISCELLANEOUS.

$5.085 \cdot 10^{-3}$	BOARD FOOT (1′ × 1′ × 1″) = 144 cu. in.	$1.96642 \cdot 10^{2}$
$2.760 \cdot 10^{-7}$	CORD (4′ × 4′ × 8′) = 128 cu. ft.	$3.6246 \cdot 10^{6}$
$8.1034 \cdot 10^{-10}$	ACRE FOOT = 362000 U. S. Gal. = 43560 cu. ft.	$1.2335 \cdot 10^{9}$
$8.88 \cdot 10^{-7}$	U. S. SHIPPING TON = 40 cu. ft.	$1.13268 \cdot 10^{6}$
$8.409 \cdot 10^{-7}$	1 BRITISH SHIPPING TON = 42 cu. ft.	$1.1893 \cdot 10^{6}$

U. S. liquid measure × 1.2003 = British liquid and dry of same denomination.
U. S. dry measure × 1.032 = British liquid and dry of same denomination.

WEIGHTS—CONVERSION FACTORS.

Grams to A.	A.	A to grams.
1.000	GRAM (1 cc. water at 4°C.) = 15.432 grains	1.0000
$1.000 \cdot 10^{3}$	MILLIGRAM = 0.015432 grain	$1.0000 \cdot 10^{-3}$
$1.0000 \cdot 10^{-3}$	KILOGRAM = 2.679 T. lbs. = 2.204622341 Av. lbs	$1.0000 \cdot 10^{3}$
$1.000 \cdot 10^{-5}$ (*a*)	QUINTAL (100 kilograms) = 2.2046 cwt	$1.0000 \cdot 10^{5}$
$1.000 \cdot 10^{-6}$	METRIC TON = 1.1023 ton (short) = 2204.6 lbs	$1.0000 \cdot 10^{6}$
$1.5432 \cdot 10$	GRAIN (T. Ap. Av.) = 0.0020835 ounce (T.)	$6.4799 \cdot 10^{-2}$
$6.430 \cdot 10^{-1}$	PENNYWEIGHT (T.) = 24.0 grains	1.5552
$6.43 \cdot 10^{-2}$	CARET (T.) = 10.0 pwt	$1.5552 \cdot 10$
$7.716 \cdot 10$	SCRUPLE (Ap.) = 20.0 grains	1.2960
$2.572 \cdot 10$	DRAM (Ap.) = 60.0 grains	3.8879
$3.215 \cdot 10^{-2}$	OUNCE (T.) = 1.09714 + oz. Av. = 480 grains	31.1035
$2.68 \cdot 10^{-3}$	POUND (T.) = 0.822857 lb. Av. = 12 oz. Troy	$3.732714662 \cdot 10^{2}$
$3.5273990 \cdot 10^{-2}$	OUNCE (Av.) = 0.911450 oz. T. = 437.5 grains	$2.834952673 \cdot 10$
$2.2046244 \cdot 10^{-3}$	POUND (Av.) = 1.2153 lbs. T. = 16 oz. Av. = 7000 grains	$4.535924277 \cdot 10^{2}$
$2.2046244 \cdot 10^{-5}$	HUNDRED WEIGHT (short) = 100 lbs	$4.5359 \cdot 10^{4}$
$1.968414 \cdot 10^{-5}$	HUNDRED WEIGHT (long) = 112 lbs	$5.0802 \cdot 10^{4}$
$1.1023122 \cdot 10^{-6}$	TON (U. S. short) = 2000 lbs	$9.07184 \cdot 10^{5}$
$0.9845 \cdot 10^{-6}$	TON (British long) = 2240 lbs	$1.016 \cdot 10^{6}$
$3.937 \cdot 10^{-5}$	STONE = 14 lbs	$6.3503 \cdot 10^{3}$
$7.874 \cdot 10^{-5}$	QUARTER = 25 lbs	$1.13368 \cdot 10^{4}$
4.8665	CARAT (precious stones) = 3.1713 grains	$2.055 \cdot 10^{-1}$
0.03429	ASSAY TON (metallurgists) = oz. Av. = 0.885188 oz. Troy	$2.91667 \cdot 10$

T. = Troy. Ap. = Apothecary. Av. = Avoirdupois.

(*a*) $10^{-3} = 1/10^{3} = 1/1000 = 0.001$.

WORK CONVERSIONS.

	1. Erg.*	2. Joule.	3. Kilojoule.	4. Watt hour.	5. K. W. hour.	6. H. P. hour.
1. Erg	1.0000	10^{-7} (a)	$1.000 \cdot 10^{-10}$	$2.778 \cdot 10^{-11}$	$2.778 \cdot 10^{-14}$	$3.725 \cdot 10^{-14}$
2. Joule	10^{7}	1.0000	10^{-3}	$2.778 \cdot 10^{-4}$	$2.778 \cdot 10^{-7}$	$3.725 \cdot 10^{-7}$
3. Kilojoule	10^{10}	10^{3}	1.0000	$2.778 \cdot 10^{-1}$	$2.778 \cdot 10^{-4}$	$3.725 \cdot 10^{-4}$
4. Watt hour	$3.6 \cdot 10^{10}$	3600.00	3.600	1.000	$1.000 \cdot 10^{-3}$	$1.341 \cdot 10^{-3}$
5. Kilowatt hr	$3.6 \cdot 10^{13}$	$3.6 \cdot 10^{6}$	3600.000	1000.000	1.000	1.3411128
6. Horse-power hr	$2.684 \cdot 10^{13}$	$2.684 \cdot 10^{6}$	$2.684 \cdot 10^{3}$	745.6494	0.7456494	1.0000
7. Foot pound	$1.3544 \cdot 10^{7}$	1.3544	$1.3544 \cdot 10^{-3}$	$3.762 \cdot 10^{-4}$	$3.762 \cdot 10^{-7}$	$5.046 \cdot 10^{-7}$
8. Calorie (gm.)	$4.189 \cdot 10^{7}$	4.189	$4.189 \cdot 10^{-3}$	$1.163 \cdot 10^{-3}$	$1.163 \cdot 10^{-6}$	$1.500 \cdot 10^{-6}$
9. Brit. Thermal Units	$1.0553 \cdot 10^{10}$	1055.3	1.0553	$2.931 \cdot 10^{-1}$	$2.931 \cdot 10^{-4}$	$3.931 \cdot 10^{-4}$
10. Cu. ft. water fall— 1 ft. (4°C.)	8.463	84.63	0.08463	$2.351 \cdot 10^{-2}$	$2.351 \cdot 10^{-5}$	$3.153 \cdot 10^{-5}$
11. Kilogram-meter	$9.8062 \cdot 10^{7}$	9.8062	$9.8062 \cdot 10^{-3}$	$2.724 \cdot 10^{-3}$	$2.724 \cdot 10^{-6}$	$3.653 \cdot 10^{-6}$

*The work done by one dyne acting through one centimeter is an erg.
(a) $10^{7} = 1/10^{7} = 1/10{,}000{,}000 = 0.0000001$.

	7. Foot Lb.	8. Calorie (15°C).	9. B. T. U.	10. Cu. ft. H_2O 1 ft.	11. Kgm. meter
1. Erg	$7.384 \cdot 10^{-8}$	$2.387 \cdot 10^{-8}$	$9.476 \cdot 10^{-11}$	$1.1812 \cdot 10^{-9}$	$1.0197 \cdot 10^{-8}$
2. Joule	$7.384 \cdot 10^{-1}$	$2.387 \cdot 10^{-1}$	$9.476 \cdot 10^{-4}$	$1.1812 \cdot 10^{-2}$	$1.0197 \cdot 10^{-1}$
3. Kilojoule	$7.384 \cdot 10^{2}$	$2.387 \cdot 10^{2}$	$9.476 \cdot 10^{-1}$	$1.1812 \cdot 10$	$1.0197 \cdot 10^{2}$
4. Watt hour	$2.658 \cdot 10^{3}$	$8.594 \cdot 10^{2}$	3.4115	$4.2525 \cdot 10$	$3.671 \cdot 10^{2}$
5. K. W. hr	$2.658 \cdot 10^{6}$	$8.594 \cdot 10^{5}$	$3.411 \cdot 10^{3}$	$4.2525 \cdot 10^{4}$	$3.671 \cdot 10^{5}$
6. H. P. hr	$1.982 \cdot 10^{6}$	$6.407 \cdot 10^{5}$	$2.543 \cdot 10^{3}$	$3.170 \cdot 10^{4}$	$2.737 \cdot 10^{5}$
7. Ft. pound	1.000	$3.233 \cdot 10^{-1}$	$1.2835 \cdot 10^{-3}$	$1.600 \cdot 10^{-2}$	$1.381 \cdot 10^{-1}$
8. Calorie	3.093	1.0000	$3.969 \cdot 10^{-3}$	$4.948 \cdot 10^{-2}$	$4.272 \cdot 10^{-1}$
9. B. T. U.	$7.794 \cdot 10^{2}$	$2.520 \cdot 10^{2}$	1.000	$1.247 \cdot 10$	1.076 · 10[illegible]
10. Cu. ft. H_2O 1 ft.	$6.250 \cdot 10$	$2.021 \cdot 10$	$8.022 \cdot 10^{-2}$	1.0000	8.630
11. Kgm.-meter	7.241	2.341	$9.292 \cdot 10^{-3}$	$1.1582 \cdot 10^{-1}$	1.0000

PRESSURE CONVERSIONS.

	1. Cm. H_2O.	2. In H_2O.	3. Ft. H_2O.	4. Mm. Hg.	5. Cm. Hg.	6. In Hg.
1. Cm. water 4° C....	1.0000	0.3937	0.03281	0.7356	0.07356	0.02896
2. Inches of water...	2.540	1.0000	0.08333	1.8685	0.18685	0.07356
3. Feet of water.....	30.48	12.00	1.0000	22.42	2.242	0.8826
4. Mm. of mercury...	1.3595	0.5353	0.4461	1.0000	0.10000	0.03937
5. Cm. of mercury...	13.595	5.353	4.461	10.00	1.0000	0.39370
6. In. of mercury....	34.54	13.595	1.1330	25.40	2.540	1.0000
7. Gm. per sq. cm....	1.000	0.3937	0.03281	0.7356	0.07356	0.02896
8. Kg. per sq. cm....	1000.0000	393.7	32.81	735.6	73.56	28.96
9. Oz. per sq. in.....	4.394	1.7300	0.14416	3.232	0.3232	0.12725
10. Lbs. per sq. in.....	70.32	27.68	2.307	5.171	0.5171	2.036
11. Oz. per sq. ft.....	0.03052	0.012012	0.0010012	0.02245	$2.245 \cdot 10^{-3}$	$8.836 \cdot 10^{-4}$
12. Lbs. per sq. ft.....	0.4885	0.1923	0.01602	0.3591	0.03591	0.014137
13. Dynes per sq. cm..	$1.0197 \cdot 10^{-3}$	$4.0145 \cdot 10^{-4}$	$3.3455 \cdot 10^{-5}$	$7.500 \cdot 10^{-4}$	$7.500 \cdot 10^{-5}$	$2.952 \cdot 10^{-5}$
14. Atmospheres*	1033.29	406.806	33.9005	760.00	76.000	29.9212

Mercury at 0° C. Water at 4° C.

*Atmosphere is the pressure exerted by a column of mercury 76.0 cm. high at 0° C. at sea level and in a latitude of 45° upon the area of one square centimeter.

PRESSURE CONVERSIONS—Continued.

	7. Gms/cm.²	8. Kgm./gm².	9. Oz./in².	10. Lbs./in².	11. Oz./ft².	12. Lbs./ft².	13. Dynes/cm².	14. Atmospheres
1......	1.0000	0.001000	0.2276	0.01422	32.77	2.048	980.62	$9.679 \cdot 10^{-4}$
2......	2.540	0.002540	0.5780	0.036125	83.23	5.205	2492.0	0.002458
3......	30.48	0.03048	6.937	0.4335	998.8	62.43	29890.0	0.02950
4......	1.3595	0.0013595	0.3094	0.01934	44.56	2.785	1333.3	0.0013159
5......	13.595	0.013595	3.094	0.1934	445.6	27.85	13333.0	0.013159
6......	34.54	0.03454	7.860	0.4912	1131.7	70.73	33865.0	0.03342
7......	1.000	0.001	0.2276	0.014223	32.770	2.048	980.62	$9.679 \cdot 10^{-4}$
8......	1000.0	1.0000	227.6	14.223	32770.0	2048.0	980620.0	0.9679
9......	4.394	4.394	1.0000	0.06250	144.0	9.000	4309.5	0.0042525
		10^{-3}						
10......	70.32	0.07032	16.000	1.0000	2304.2	144.00	68950.0	0.06805
11......	0.03052	3.052	6.946	4.340	1.0000	0.06250	29.93	$2.9533 . 10^{-5}$
		$\cdot 10^{-5}$	$\cdot 10^{-3}$	$\cdot 10^{-4}$				
12......	0.4885	4.885	0.11112	0.006944	16.000	1.000	478.9	$4.725 \cdot 10^{-4}$
		$. 10^{-4}$						
13......	$1.0197 \cdot 10^{-3}$	1.019	2.3208	1.4504	$3.3410 \cdot 10^{-2}$	$2.088 \cdot 10^{-3}$	1.0	$9.868 \cdot 10^{-7}$
		$\cdot 10^{-6}$	$\cdot 10^{-4}$	10^{-5}				
14......	1033.29	1.03329	235.152	14.697	33861.9	2116 37	1013295.0	1.00000

COMPARATIVE TEMPERATURE DEGREES.

	Degrees Absolute	Degrees Cent.	Degrees Fahr.	Degrees Reaumur.
Degrees Absolute	1.0	1.0	$^9/_5$	$^4/_5$
Degrees Centigrade	1.0	1.0	$^9/_5$	$^4/_5$
Degrees Fahrenheit	$^5/_9$	$^5/_9$	1.0	$^4/_9$
Degrees Reaumur	$^5/_4$	$^5/_4$	$^9/_4$	1.0

COMPARATIVE TEMPERATURE POINTS.

Absolute zero = —273° Centigrade = —459.4° Fahr. = —218.4° Reaum.
Freezing water = 0° C. = 273° A. = 32° F. = 0° R.
Boiling water = 100° C. = 373° A. = 212° F. = 80° R.

HEAT QUANTITY CONVERSION FACTORS.

One British Thermal Unit = 251.995 × calories (gm.) = 0.251995 × Cal. Large.
One gram caloric = 0.00396832 British Thermal Units.
One B. T. U. per pound = $^5/_9$ calorie per gram.
One calorie per gram = 1.8 B. T. U. per pound.

TIME CONVERSION FACTORS.

One year = 365 days, 5 hours, 48 minutes, 48 seconds = 12 calendar months.
= 52.1693 + weeks = 8765.8133 + hrs. = 525948.8 minutes = 31556928 seconds.
One week 7 days = 168 hrs. = 10080 minutes = 604800 seconds.
One day = 24 hours = 1440 minutes = 86400 seconds.
One hour = 60 minutes = 3600 seconds.
One minute = 60 seconds.

VELOCITY CONVERSION FACTORS.

	Mi./hr. 1.	Ft./sec. 2.	Km./hr. 3.	M./sec. 4.	Mi./da. 5.	Km./da. 6.
1. Miles per hour.......	1.0000	1.4667	1.6093	0.44704	24.00	38.62
2. Feet per second.......	0.6819	1.0000	1.0973	0.30480	16.37	26.33
3. Kilometers/hour ..	0.6214	0.9114	1.0000	0.2778	14.913	24.00
4. Meters per second.	2.237	3.281	3.600	1.0000	53.69	86.40
5. Miles per day.........	0.04167	0.06112	0.06706	0.01863	1.0000	1.609
6. Kilometers/day	0.02589	0.03797	0.04167	0.01157	0.6214	1.0000

CONVERSION FACTORS FOR MONEY.

$ to A.	A.		A. to $
1.000	Dollar (U. S.)		1.000
100.000	Cent (U. S.)		0.010
0.196	Guinea (English)	= 21 shillings	5.10972
0.2055	Pound Sterling (Sovereign)	= 20 shillings	4.8665
4.11	Shilling (s)	= 12 pence	0.24331
40.93	Penny (d)	= 4 farthings	0.02028
163.72	Farthing	= ¼ penny	0.00507
0.822	Crown	= 5 shillings	1.21660
4.200	Mark (Germany)	= 100 pfennigs	0.238
420.0	Pfennig		0.00238
5.182	Franc (France)	= 100 centimes	0.193
518.2	Centime		0.00193

CLASSIFICATION OF U. S. PATENTS ON PETROLEUM REFINING.

A. Water separation, dehydration, de-emulsification, heating and physical purification of oil and bottom settlings.

B. Cracking, conversion, and decomposition processes.

C. Paraffin and wax.

D. Chemical treatment of petroleum.
   1. Acid or alkali.
   2. Other than acid or alkali.

E. Asphalt.
   1. Compositions.
   2. Production.
   3. Refining.

F. Simple distillation.
   1. Fire.
   2. Steam.
   3. Gas.
   4. Air.
   5. Vacuum.
      I. Batch.
      II. Continuous.

G. Coal oil, Kerosene and Illuminating oils.

H. Oil-fire prevention, extinction and storage.

I. Recovery of acid-sludge and alkali-sludge.

J. Gasoline production and treatment.

K. Gas.
   1. Production.
   2. Treatment.
   3. Production of carbon black.

L. Chemical products.

M. Patented blends and compounds.

N. Testing apparatus.

O. Lubricating oils.

P. Electrical processes.

Q. Transporting oil.

R. Methods of removing carbon and coke.

S. Mechanical appliances in oil refining, and processes. (Not covering any particular operation.)

T. Plastics.

U. Condensers and condensing.

V. Desulphurizing and deodorizing.

W. Oil shales, oil sands and coals.

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922).

NAME	Number	Date	Class
Aab, Geo. and S. K. Campbell	369,902	Sep. 13, 1887	C
Abbott, L. S	1,332,018	Feb. 24, 1920	B, D
Adair, Jas	35,497	June 10, 1862	U
Adair, Jas., and Tweddle, H. W. C	56,343	July 17, 1866	F
Adair, Thos. D	1,106,352	Aug. 4, 1914	A
Adams, Chas	52,509	Feb. 13, 1866	C
Adams, J. H	1,320,354	Oct. 28, 1919	B
Adams, J. H	1,320,726–7	Nov. 4, 1919	B
Adams, J. H	976,975	Nov. 29, 1910	B
Adams, Jos. H	1,327,263	Jan. 6, 1920	B
Adams, Henry W	12,614	Apr. 3, 1855	O
Adamson, Wm	45,007	Nov. 15, 1864	D 1
Adiassewich, Alexander	629,536	July 25, 1899	F
Alberger, J. L	37,798	March 3, 1863	B, G
Alexander, Clive M	1,230,975	June 26, 1917	B
Alexander, Clive M	1,387,677	Aug. 16, 1920	B
Alexander, C. M., and Taber, G. H., Jr	1,381,098	June 14,1921	B
Alexander, Jas. H	229,287	June 29, 1880	F
Alexander, Jas. H. and Eberhard	156,265	Oct. 27, 1874	F
Alexander, Robt	435,198	Aug. 26, 1890	E 3
Alkemade, J. von R	1,076,000	Oct. 14, 1913	C
Allan, Hugh Logie	1,390,742	Sept. 13, 1921	F
Allan, D. M., Jr	1,187,797	June 20, 1916	D 1
Allen, Geo	182,625	Sept. 26, 1876	A, O
Allen, W. H	1,167,966	Jan. 11, 1916	
Allison, Wm	1,395,694	Nov. 1, 1921	J
Alter, David, and Hill, S. A	20,026	April 27, 1858	F
Alvord, Clark	213,157	Mar. 11, 1879	R
Ambruson, H. J	1,252,642	Jan. 8, 1918	K1
Amend, Otto	480,311	Aug. 9, 1892	B
Amend, Otto	480,312	Aug. 9, 1892	B
Amend, Otto	747,348	Dec. 22, 1903	D 1, V
Amend, Otto	551,941	Dec. 24, 1895	V, D 1
Amend, Otto	601,331	Mar. 29, 1898	V, D 1
Amend, Otto	747,347	Dec. 22, 1903	V, D 1
Andrews & Averill	1,319,828	Oct. 28, 1919	B
Andrews, B., and Averill, W. C., Jr	1,329,739	Feb. 3, 1920	B
Andrews, B., and Averill, W. C., Jr	1,312,467	Aug. 5, 1919	S
Andrews, Samuel	58,197	Sept. 25, 1866	F 1, I
Andrews, Samuel	69,745	Oct. 15, 1867	S
Angus, H. R	407,274	July 16, 1889	F
Anthony, C. E	620,082	Feb. 21, 1899	B, T
Archbold, Geo	503,028	Aug. 8, 1893	E 1
Archer, Wm	44,137	Sept. 6, 1864	F
Ard, L. B	1,373,698–9	April 5, 1921	W
Artmann, Carl	1,031,227	July 2, 1912	E 1
Arvine, Freeling W	629,059	July 18, 1899	A
Arvine, Freeling W	431,795	July 8, 1890	G N
Ash, Horace W	779,197	Jan. 8, 1905	E 2, F
Ash, Horace W	779,198	Jan. 8, 1905	E 2, F
Ash, Horace W	757,387	April 12, 1904	F 1
Ashworth, A. A	1,300,547	April 15, 1919	S
Ashworth, A. A	1,300,548	April 15, 1919	S
Atwood, Luther	27,767	April 10, 1860	F 2
Atwood, Luther	21,805	Oct. 19, 1858	B
Atwood, Luther	22,406	Dec. 28, 1858	B
Atwood, Luther	22,407	Dec. 28, 1858	B
Atwood, Luther	23,006	Feb. 22, 1859	B
Atwood, Luther	23,337	Mar. 29, 1859	G
Atwood, Luther	28,246	May 29, 1860	G B
Atwood, Luther	28,448	May 29, 1860	F
Atwood, Luther	27,768	April 10, 1860	F
Atwood, Luther	31,858	Mar. 26, 1861	B, D 1
Atwood, L. and W	15,506	Aug. 12, 1856	W, F
Atwood, L. and W	15,505	Aug. 12, 1856	G
Atwood, W	226,151	April 16, 1880	A
Aukerman, Cal M	672,882	April 30, 1901	B
Averill, W. C., Jr	1,375,245	April 19, 1921	F

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Bacon, Brooks & Clark	1,131,309	Mar. 9, 1915	J B
Bacon, Brooks & Clark	1,334,731	Mar. 23, 1920	B
Bacon & Clark	1,101,482	June 23, 1914	B
Backhaus, Arthur A	1,271,114	July 2, 1918	M
Backhaus, Arthur A	1,271,115	July 2, 1918	M
Backhaus, A. A	1,296,902	Mar. 11, 1919	M
Baillard, Chas. L	340,411	April 20, 1886	D 1
Baker, Leslie A	299,611	June 3, 1884	A
Ballard, A. M	1,327,691	Jan. 13,1920	K
Barber, Guy M	1,251,952	Jan. 1, 1918	S
Barbet, E. A	1,319,319	Oct. 21, 1919	F
Barnes, Wm. T	24,920	Aug. 2, 1859	U
Barnes, Wm. T	24,921	Aug. 2, 1859	G
Barrett, Michael	59,531	Nov. 6, 1866	I
Barron, Thos. J	46,987	Mar. 28, 1865	M
Barnickel, W. S	1,093,092	April 14, 1914	A D 1
Barnickel, W. S	1,223,659	April 24, 1917	A D 1
Barnickel, W. S	1,223,660	April 24, 1917	A
Bartels, E	1,115,887	Nov. 3, 1914	H
Barstow, Frank Q	181,814	Sept. 5, 1876	C
Barthel, Peter	135,879	Feb, 18, 1873	E 1, 3
Baskerville, Chas	1,231,985	July 3, 1917	I
Bassett, R. D	1,120,669	Dec. 15, 1914	J
Bassett, R. D	1,120,670	Dec. 15, 1914	J
Bates, H. F	1,046,541	Dec. 10, 1912	K 1
Baum, E. P	1,109,103	Sept. 1, 1914	A
Baynes, R., and Fearenside, J	299,324	May 27, 1884	D 2
Beckley. R. E	1,127,722	Feb. 9, 1915	B
Bell, A. F. L	1,231,695	July 3, 1917	B R
Bell, A. F. L	581,451	April 27, 1897	E 3, 2
Bell, A. F. L	617,712	Jan. 17, 1899	E 2, 3
Bell, A. F. L	580,592	April 13, 1897	E 3
Bell, A. F. L	655,430	Aug. 7, 1900	E 2, 3
Bell, A. F. L	505,416	Sept. 19, 1893	E 2, 3
Bellingrath, Leonard, Jr	20,465	June 1, 1858	F 1, 4
Bending, Wm. P	998,670	July 25, 1911	A
Benham, E. B	1,262,576	April 9, 1918	K 1
Benham. E. B	1,040,124	Oct. 1, 1912	B
Benton, G. L	342,564	May 25, 1886	B
Benton, G. L	342,565	May 25, 1886	B
Bending, Wm. P	1,144,522	June 29, 1915	D 1
Benhoff, G. F., Jr., and Jensen, J. O	1,181,564	May 2, 1916	F 2
Berend, Ludwig	1,167,373	Jan. 11, 1916	D 1
Berg, Friedrich	645,743	Mar. 20, 1900	F 2, 1
Berg, Friedrich	560,463	May 19, 1896	D 1
Berg, F	736,479	Aug. 18, 1903	V, D 1
Berg, F	736,480	Aug. 18, 1903	V
Berg, F	623,066	April 11, 1899	D 1
Berg, H. J	93,952	Aug. 24, 1869	F 1
Bergius, Friedrich	1,344,671	June 29, 1920	B
Bergius, Friedrich	1,391,664	Sept. 27, 1921	D 3
Bibby, John, and Lapham, A	48,896	July 25, 1865	F 1
Bicknell, John E	313,979	Mar. 17, 1885	F 2
Bicknell, John E	400,042	Mar. 26, 1889	C
Bicknell, John E	400,043	Mar. 26, 1889	C
Biddison, P. McD., and Boyd, H. T	1,345,740	July 6, 1920	B
Bielouss, Elias	1,384,423	July 12, 1921	L D
Biggins, Jas. E	1,274,976	Aug. 6, 1918	B
Blacher, L., and Sztencel, S	956,276	April 26, 1910	I
Black, J. C	968,640	Aug. 30, 1910	D 1
Black, J. C	1,152,478	Sept. 7, 1915	F 3
Black, J. C	1,164,162	Dec. 14, 1915	D 2, F 3
Black, John C	1,275,648	Aug. 13, 1918	J
Blakeman, Wm. N., Jr	1,385,035–6	July 19, 1921	M
Blakeman, Wm. N., Jr	1,385,037	July 19, 1921	D 3
Blowski, Jno. and A	1,186,373	June 6, 1916	I
Born, Sidney	1,234,124	July 24, 1917	F 1, II, S
Borrman, C. H	1,220,067	Mar. 20, 1917	F 2, II

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Bostick, J. W., and Homer, Chas. H.	1,380,863	June 7, 1921	A
Bowman, F.	12,852	May 15, 1855	F 1
Bowman, Levi M	1,347,932	July 27, 1920	S O
Boyd & Hapgood	1,363,833	Dec. 28, 1920	O
Boyle, Alex. M	1,276,866	Aug. 27, 1918	W
Brace, H. B., and Swart, W. T.	54,495	May 8, 1866	M G
Brackebusch, Hans	275,565	April 10, 1883	D 1
Bradford, Geo	805,116	Nov. 21, 1905	F 1, 5
Bragg, John	604,515	May 24, 1898	V, D 1
Braggins, Edw	46,633	Mar. 7, 1865	F 5
Brander, G. A	1,361,005	Dec. 7, 1920	W
Bransky, Oscar E	1,396,399	Nov, 8, 1921	D
Braun, Otto	243,496	June 28, 1881	U
Breinig, Revere	306,897	Oct. 21, 1884	I
Brickman, Saml	1,279,506	Sept. 24, 1918	F
Brooks, Essex & Smith	1,191,916	July 18, 1916	L
Brooks & Smith	1,231,123	June 26, 1917	L
Brown, Arthur L	1,234,862	July 31, 1917	D 2
Brown, Ernest	1,225,569	May 8, 1917	D 2
Brown, D. P., and Neeley, J. W.	361,671	April 26, 1887	F 1, 2
Brown, E. G., Cammann, O. N., and Wilcox, O.	510,672	Dec. 12, 1893	F 1, 2
Brown, L. W.	994,100	May 30, 1911	A
Brown, W. A.	1,309,794	July 15, 1919	A
Brown, Wm.	10,055	Sept. 27, 1853	C W
Brownlee, R. H., and Uhlinger	1,265,043	May 7, 1918	K 3, B
Brownlee, R. H.	1,325,927	Dec. 23, 1919	B
Brownlee, R. H.	1,308,161	July 1, 1919	F
Brucke, Otto	963,510	July 5, 1910	A
Brundred, Wm. J	148,806	Mar. 24, 1874	F 2
Buerger, C. B	1,302,761	May 6, 1919	S
Bullard, John	34,195	Jan. 21, 1862	G
Burcey, Chas. J. T	122,810	Jan. 16, 1872	F
Burch, Eli F.	1,396,249	Nov. 8, 1921	F
Burch, Eli F.	1,238,101	Aug. 28, 1917	O T
Burdon, J. W. M. and M. M	1,112,051	Sept. 29, 1914	K 1
Burghardt, C. A	309,027	Dec. 9, 1884	U
Burk, H. R.	284,811	Sept. 11, 1883	G
Burke, A. M., and Wright, S.	65,999	June 25, 1867	D 1
Burke, C. R.	1,344,258	June 22, 1920	
Burket, D. M., and Gray, J. C.	57,285	Aug. 21, 1866	O
Burrell, G. A., Voress, C. L., and Canter, V. C.	1,382,890	June 28, 1921	K J
Burke, Chas. R.	1,389,934	Sept. 6, 1921	B
Burgess, Louis	1,401,113	Dec. 20, 1921	B
Burrows, H. G.	998,837	July 25, 1911	F 2, 11
Burton, W. M.	1,055,707	Mar. 11, 1913	B, E 2
Burton, W. M.	1,049,667	Jan. 7, 1913	B. J
Burton, W. M.	1,105,961	Aug. 4, 1914	J. B
Burton, W. M.	1,112,113	Sept. 29, 1914	C B
Burton, W. M.	1,167,884	Jan. 11, 1916	B
Burwell, A. W., and Sherman, L. O.	738,656	Sept. 8, 1903	V, D 1
Bush, Asa A.	269,382	Dec. 19, 1882	F 1
Busse, Heinrich	376,289	Jan. 10, 1888	T
Byerley, Francis X.	347,288	Aug. 10, 1886	C F
Byerley, F. X.	524,130	Aug. 7, 1894	E 2, 3, F
Byerley, F. X.	547,329	Oct. 1, 1895	F 1, 2
Byerley, F. X.	241,431	July 19, 1881	C
Byerley, F. X.	132,353	Oct. 22, 1872	C
Byerley, F. X.	164,672	June 22, 1875	C
Calkins, A. C.	779,398	Jan. 3, 1905	B
Calkins, A. C.	769,681	Sept. 6, 1904	D 1
Campbell, Andrew	999,628	Aug. 1, 1911	C
Campbell, Jas. R.	1,384,990	July 19, 1921	I. D
Cantour, David	553,206	Jan. 14, 1896	F
Carman, F. J.	501,988	July 25, 1893	V
Carpenter, Calvin, Jr.	82,083	Sept. 15, 1868	O

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Carter, G. F.	680,639	Aug. 13, 1901	S
Carthesy, J. H.	1,316,770	Sept. 23, 1919	F
Cassal, N. C., and Gerrans, B. H.	1,330,844	Feb. 17, 1920	B
Catlin, Robt. M.	1,272,377	July 16, 1918	W
Cazin, Francis F. M.	400,634	April 2, 1889	F
Cazin, F. M. F.	400,633	April 2, 1889	V, G
Chamberlain, H. P.	1,221,790	April 3, 1917	B
Chemin, Jean C. O.	297,766	April 29, 1884	F D
Cheney, Samuel	230,239	July 20, 1880	F 2
Cherry, Cummings	15,642	Sept. 2, 1856	A
Cherry, C.	15,643	Sept. 2, 1856	W
Cherry, Louis Bond	1,229,886	June 12, 1917	B. P
Cherry, L. B.	1,327,023	Jan. 6, 1920	P
Chesebrough, Robt. A.	127,568	June 4, 1872	M
Chesebrough, Robt. A.	237,484	Feb. 8, 1881	M
Chesebrough, R. A.	49,502	Aug. 22, 1865	G. S
Chesebrough, R. A.	48,367	June 27, 1865	S
Chesebrough, R. A.	51,557	Dec. 19, 1865	S
Chesebrough, R. A.	51,558	Dec. 19, 1865	S
Chesebrough, R. A.	524,704	Aug. 21, 1894	F 2, II
Chevrier, Gervais	106,915	Aug. 30, 1870	I
Childs, Samuel	11,059	June 13, 1854	F 1, 2, I
Clark, C. E.	1,147,608	July 20, 1915	K 1
Clark, Edward M.	1,119,496	Dec. 1, 1914	B
Clark, E. M.	1,129,034	Feb. 16, 1915	B
Clark, E. M.	1,388,514	Aug. 23, 1921	B
Clark, E. M.	1,132,163	March 16, 1915	B
Clark, Frank W.	547,332	Oct. 1, 1895	F 3, 4
Clark, R. C., and Beecher, W. F.	275,589	April 10, 1883	F 1, 4
Clark, R. C., and Warren, M. H.	298,825	May 20, 1884	F
Clark, R. C., and Warren, M. H.	318,698	May 26, 1885	F
Clark, S. G.	34,816	April 1, 1862	G, F 2, II
Clarke, Edw.	232,685	Sept. 28, 1880	I
Clifford, Victor	1,266,407	May 14, 1918	H
Coast, John W., Jr.	1,250,798	Dec. 18, 1917	B
Coast, John W., Jr.	1,250,800	Dec. 18, 1917	B
Coast, John W., Jr.	1,250,801	Dec. 18, 1917	B
Coast, John W. ,Jr.	1,207,724	June 24, 1919	S
Coast, John W., Jr.	1,252,401	Jan. 8, 1918	B
Coast, John W., Jr.	1,253,000	Jan. 8, 1918	B
Coast, John W., Jr.	1,258,190	Mar. 5, 1918	B
Coast, John W., Jr.	1,252,999	Jan. 8, 1918	B
Coast, John W., Jr.	1,291,414	Jan. 14, 1919	B
Coast, John W., Jr.	1,250,799	Dec. 18, 1917	B
Coast, John W., Jr.	1,258,191	Mar. 5, 1918	B
Coast, John W., Jr.	1,388,629	Aug. 23, 1921	B
Coast, John W., Jr.	1,400,800	Dec. 20, 1921	B
Coast, John W., Jr.	1,370,881	Mar. 8, 1921	B
Coast, John W., Jr.	1,372,937	Mar. 29, 1921	B
Coast, John W., Jr.	1,374,357	Aug. 12, 1921	B
Coast, John W., Jr.	1,379,333	May 24, 1921	B R
Coast, John W., Jr.	1,333,964	Mar. 16, 1920	B
Coast, John W., Jr.	1,345,132–3–4	June 29, 1920	B
Coast, John W., Jr.	1,348,264–5–6	Aug. 3, 1920	B
Coast, John W., Jr.	1,348,267–8	Aug. 3, 1920	B
Coast, John W., Jr.	1,349,815–6–7	Aug. 17, 1920	B
Coast, John W., Jr.	1,355,311–2	Oct. 12, 1920	B
Coast, John W., Jr.	1,353,316	Sept. 21, 1920	B
Coast, John W., Jr.	1,374,357	April 12, 1921	F
Cobb, J. O.	1,201,558	Oct. 17, 1916	A
Cobb, E. B.	1,387,835	Aug. 16, 1921	D
Cobb, E. B.	1,315,623	Sept. 9, 1919	I, D
Cobb, E. B.	1,322,762	Nov. 25, 1919	B, D
Cobb, Ernest B.	1,388,517	Aug. 23, 1921	D
Cobb, Ernest B.	1,357,224–5	Nov. 2, 1920	D
Cobb, Ernest B.	1,300,816	April 15, 1919	D
Cochran, A.	1,296,367	Mar. 4, 1919	B
Cole, Jas., Jr.	182,169	Sept. 12, 1876	F 2, 4 II

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Coleman, John T	191,406	May 29, 1877	F
Colin, T. F	607,017	July 12, 1898	V, D 1
Colin, T. F	723,368	Mar. 24, 1903	V, D
Colin, T. F	744,720	Nov. 24, 1903	V, D
Colin, T. F	685,907	Nov. 5, 1901	V, D
Collins, Jacob	1,028,439	June 4, 1912	A
Collins, John F	59,334	Oct. 30, 1866	F 4, I
Collins, Jos. G	32,557	June 18, 1861	S
Connelly, Martin	240,093	April 12, 1881	D 1, V
Connelly, Martin	240,094	April 12, 1881	D 1, V
Cook & Price	1,190,633	July 11, 1916	E 3
Cooper, A. S	617,226	Jan. 3, 1899	E 2, 3
Cooper, H. C	1,323,837	Dec. 21, 1919	J
Cooper, Isaac N	1,349,048	Aug. 10, 1920	H
Corfield, Wm	54,061	April 17, 1866	M
Corfield, Wm	54,060	April 17, 1866	M
Cornell, Sidney	1,202,969	Oct. 31, 1916	F 2
Cosden, J. S	981,176	Jan. 10, 1911	F 2, 11
Cosden, J. S., and Coast, J. W., Jr	258,196	Mar. 5, 1918	B
Cosden, J. S., and Coast, J. W., Jr	1,261,215	April 2, 1918	B
Cottrell & Wright	987,117	Mar. 21, 1911	P
Cottrell & Speed	987,115	Mar. 21, 1911	P A
Cottrell & Speed	987,116	Mar. 21, 1911	P
Cottrell, F. G	987,114	Mar. 21, 1911	P
Courtois, F. A	788,250	April 25, 1905	N
Cowan, Wm. P	558,358	April 14, 1896	C
Crane, Frederick D	1,223,153	April 17, 1917	M D
Crane, Adolphus G	1,276,879	Aug. 27, 1918	F
Crane, Gerard	231,280	Aug. 17, 1880	E 1
Crawford, Benjamin	113,023	Mar. 28, 1871	B
Crocker, Samuel H	129,463	July 16, 1872	B
Cronemeyer, A. H	718,318	Jan. 13, 1903	A
Cronenberger, W. M	1,152,399	Sept. 7, 1915	M
Cronin, C. J	150,465	May 5, 1874	F
Cross, A. B	1,327,906	Jan. 13, 1920	J K
Cross, Jas. P	57,095	Aug. 14, 1866	M
Cross, Roy	1,255,138	Feb. 5, 1918	B
Cross, Walter M	1,203,312	Oct. 31, 1916	B
Cross, W. M	1,326,851	Dec. 30, 1919	B
Culmer, Geo., and Geo. C. K	635,429	Oct. 24, 1899	F
Culmer, Geo., and Geo. C. K	635,430	Oct. 24, 1899	W
Culmer, F. W	217,995	July 29, 1879	G
Cunningham, Christopher	158,042	Dec. 22, 1874	C
Danckwardt, P	1,141,529	June 1, 1915	J, F 1, 11
Danckwardt, P	1,373,653	April 5, 1921	B, D
Danckwardt, P	1,317,077	Sept. 23, 1919	B, P
Daugherty, Alvin A	1,353,638	Sept. 21, 1920	B
Daul, John	213,395	Mar. 18, 1879	F 2
Daul, Louis	258,284	May 23, 1882	F 2
Davidson, J. G., and Ford, R. W	1,229,042	June 5, 1917	P
Davidson, Samuel	1,238,644	Aug. 28, 1917	J, K 2
Davis, C. S	1,369,787-8	Mar. 1, 1921	B
Davis, John T	671,078	April 2, 1901	F 1, 11
Davis, John T	1,159,186	Nov. 2, 1915	F 2, 11
Davis, Samuel	65,884	June 18, 1867	S
Day, D. F	1,323,681	Dec. 2, 1919	W
Day, David T	826,089	July 17, 1906	V, D
Day, David T	1,221,698	April 3, 1917	B, D
Day, David T	1,004,632	Oct. 3, 1911	B
Day, David T	1,280,178	Oct. 1, 1918	W
Day, David T	1,365,894	Jan. 18, 1921	D 2
Day, David T	1,342,741	June 8, 1920	W
Day, David T	1,386,768	Aug. 9, 1921	B
Day, Roland B	1,280,179	Oct. 1, 1918	B
Day, Roland B	1,357,276-7 8	Nov. 2, 1920	B
Dayton, W. C	1,174,970-1	Mar. 14, 1916	K 1
Dean, Daniel A	1,398,587	Nov. 29, 1921	F

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Dean, Richard	290,866	Dec. 25, 1883	F 2, II
Dean, Richard	305,056	Sept. 16, 1884	F 1, 2, II
Dean, Richard	310,497	Jan. 6, 1885	F
Dean, Richard	314,368	Mar. 24, 1885	F 1, 2, 3, II
Dean, Richard	342,500	May 25, 1886	F 2, II
Dehnst, Julius	1,112,602	Oct. 6, 1914	V, D
DeSmedt, Edw. J	236,995	Jan. 25, 1881	E 1, 2
DeSmedt, Edw. J	237,662	Feb. 8, 1881	E 1, 2
Dewar & Redwood	419,931	Jan. 21, 1890	B
Dewar & Redwood	426,173	April 22, 1890	B
Dewitt, Henry C	63,299	Mar. 26, 1867	M
Dickey, Julius C	166,349	Aug. 3, 1875	F 1
Diehl, H. A	469,777	Mar. 1, 1892	E 2, 3
Dieterichs, E. F	253,990	Feb. 21, 1882	F 1, 2
Ditmar, Peter	246,096	Aug. 23, 1881	M
Divine, S. ., and Seely, C. A	55,071	May 29, 1866	F 2
Divine, R. E	1,303,662-3	April 22, 1919	K
Divine, R. E	1,303,779	May 13, 1919	I
Doe, Wm	174,789	Mar. 14, 1876	S
Dow, Allan W	688,073	Dec. 3, 1901	E 1, 2, B
Downard, J. S., and Roloson, B. A	722,500	Mar. 10, 1903	E 2
Downer, Wm. P	44,519	Oct. 4, 1864	D 1
Drake, Thos	471,963	Mar. 29, 1892	L
Draper, Henry V. P	238,867	Mar. 15, 1881	G D
Drayton, Thos	11,239	July 4, 1854	D
Dubbs, C. P	1,231,509	June 26, 1917	B
Dubbs, C. P	1,392,629	Oct. 4, 1921	B
Dubbs, J. A	1,100,717	June 2, 1914	B
Dubbs, J. A	1,135,506	April 13,1915	E 2, B
Dubbs, J. A	470,911	Mar. 15, 1892	V
Dubbs, J. A	646,639	April 3, 1900	F 2, 4
Dubbs, J. A	1,002,570	Sept. 5, 1911	A, F
Dubbs, J. A	1,057,227	Mar. 25, 1913	E 2
Dubbs, J. A	694,621	Mar. 4, 1902	F 4, II
Dubbs, J. A	694,622	Mar. 4, 1902	F 4
Dubbs, J. A	407,182	July 16, 1889	V, D
Dubbs, J. A	1,123, 502	Jan. 5, 1915	A
Dubbs, Henry	161,672	April 6, 1875	D, S
Dubbs, L. A	1,319,053	Oct. 21, 1919	B
Dubler, John B	251,770	Jan. 3, 1882	F
Dubler, J. B	283,471	Aug. 21, 1883	F 1, II
Dubreuil, A	48,265	June 20, 1865	F 2
Duffus, G. H. S	46,088-9-90.	Jan. 31, 1865	F, S
Duffy, J. T	1,356,196	Oct. 19, 1920	J. K
Duncan, W. M	1,342,947	June 8, 1920	F
Dundas, R. C	1,056,980	Mar. 25, 1913	E 2, B
Dundas, R. C	1,120,039	Dec. 8, 1914	F 1, II
Dundas, R. C	1,257,199	Feb. 19, 1918	B
Dunham, F. H	1,003,040	Sept. 12, 1911	E
Dunham, F. H	1,013,283	Jan. 2, 1912	E 2
Dunkle, Allen H	530,300	Dec. 4, 1894	U
Dunscomb, Edward	62,739	Mar. 12, 1867	S
Dupias, A. C. G., and Fell, W. S	749,368	Jan. 12, 1904	F, S
Durant, C. W., and Griffith, J	132,263	Oct. 15, 1872	U
Dvorkovitz, Paul	546,697	Sept. 24, 1895	F 2
Dyar, N. A., and Augustus, J. F	25,362	Sept. 6, 1859	M
Dyer, E. I	1,207,381	Dec. 5, 1916	A
Dyer, E. I	1,220,504	Mar. 27, 1917	A
Dyer, E. I., and Heise, A. R	1,242,784	Oct. 9, 1917	A
Dyer, Frank L	579,360	Mar. 23, 1897	F 2, 5
Dyer, Walter	1,256,535	Feb. 19, 1918	D
Dyer, Walter and W. E	1,256,536	Feb. 19, 1918	D
D'Yarmett, E. C	1,376,713	May 3, 1921	J, B
Earle, G. W.	1,221,038	April 3, 1917	H
Eastlake, Lewis S	1,352,502	Sept. 14, 1920	O
Eaton, Richard	110,638	Jan. 3, 1871	O
Edeleanu, Lazar	911,553	Feb. 2, 1909	D

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Edgerton, Henry H	159,655	Feb. 9, 1875	K 1
Edwards, E. A	439,745	Nov. 4, 1890	F 2, 4, H
Edwards, Jos. B	100,874	Mar. 15, 1870	F 2
Edwards, Jos. B	1,277,884	Sept. 3, 1918	B
Eggleston, J. E	1,018,040	Feb. 20, 1912	F, V
Ekstrand, Chas	1,388,415	Aug. 23, 1921	B
Eldred, B. E., and Mersereau, G	1,234,886	July 31, 1917	B
Elliott, W. S	1,242,667	Oct. 9, 1917	A, D
Ellis, Carleton	1,089,359	Mar. 3, 1914	O
Ellis, Carleton	1,191,880	July 18, 1916	D, L
Ellis, Carleton	1,216,971	Feb. 20, 1917	B
Ellis, Carleton	1,249,278	Dec. 4, 1917	J, B
Ellis, Carleton	1,318,060–1	Oct. 7, 1919	B
Ellis, Carleton	1,365,044	Jan. 11, 1921	L
Ellis, Carleton	1,365,046	Jan. 11, 1921	L
Ellis, Carleton	1,345,589	July 6, 1920	D 3
Ellis, Carleton	1,341,975	June 1, 1920	B
Ellis, Carleton	1,396,999	Nov, 15, 1921	B
Ellis, C., and Cohen, M. J	1,365,048	Jan. 11, 1921	L
Ellis, C., and Cohen, M. J	1,365,050	Jan. 11, 1921	L
Ellis, C., and Cohen, M. J	1,365,051–2	Jan. 11, 1921	L
Ellis, C., and Wells, Alfred A	1,365,053	Jan. 11, 1921	L
Ellis, John, and Kattell, E. C	68,789	April 16, 1867	F 2, H
Ellis, John, and Kattell, E. C	68,860	Sept. 17, 1867	F 2, H
Ellithorpe, S. B	52,277	Jan. 30, 1866	U
Emerson, Victor Lee	1,346,797–8	July 13, 1920	B
Emerson, Victor Lee	1,367,806–7	Feb. 8, 1921	B
Emerson, V. L	1,356,057	Oct. 19, 1920	F
Emerson, V. L	1,337,831	April 20, 1920	F
Emory, F. F	1,148,834	Aug. 3, 1915	S
Engle, Jacob P	481,391–2	Aug. 23, 1892	A
Erickson, Emil T	1,281,320	Oct. 15, 1918	W
Erwin, J. B., and O. R	1,085,805	Feb. 3, 1914	H
Eva, Gray and Christy	1,100,126	June 16, 1914	O
Evans, Edward	1,257,829	Feb. 26, 1918	V
Evans, G. P	1,366,642–3	Jan. 25, 1921	F
Everest, H. B	212,914	Mar. 4, 1879	F
Everest, H. B	68,426	Sept. 3, 1867	F 2, 5, H
Ewing, Chas. R	1,083,998	Jan. 13, 1914	S
Ewing, M. P	56,852	July 31, 1866	F 2, 5 H
Ewing, M. P., and Everest, H. B	58,021	Sept. 11, 1866	F 2, 5 H
Fagan, John G	1,148,763	Aug. 3, 1915	H
Fairchild, J. H	53,528	Mar. 27, 1866	U
Fales, Levi S	49,740	Sept. 5, 1865	S
Fales, Levi S	52,151	Jan. 23, 1866	F, U
Fales, Levi S	49,739	Sept. 5, 1865	F 4, I
Fales, Levi S	97,182	Nov. 23, 1869	I
Farrar, Alonzo	96,097	Oct. 26, 1869	D
Farrar, A	100,876	Mar. 15, 1870	I
Farrar, F. F., and Gill, F. P	206,309	July 23, 1878	I
Faucett, H. W., and McGowan, T	133,426	Nov. 26, 1872	S, F
Faucett & McGowan	133,425	Nov. 26, 1872	S, D
Faucett & McGowan	117,873	Aug. 8, 1871	U
Faust, Samuel D	1,340,532	May 18, 1920	F
Fazi, Romolo de	1,108,351	Aug. 25, 1914	M
Felizat, Louis	1,070,135	Aug. 19, 1913	D
Felton, D. F	1,179,296	April 11, 1916	K 1
Fenton, Jas. T	1,394,481	Oct. 18, 1921	B
Fenton, Jas. T	1,396,174	Nov. 8, 1921	B
Fichet, L. V	53,964	April 17, 1866	F 2, H
Field, John K	408,472	Aug. 6, 1889	D 1
Fleming, J. C	956,065	April 26, 1910	S, A
Fleming, R	1,324,766	Dec. 9, 1919	B
Fleming, R	1,325,668	Dec. 23, 1919	I
Fleury, Huot	50,571	Oct. 24, 1865	F 5, D
Flowers, G. W., and Happersett, J. C. and D. W	74,756	Feb. 24, 1868	M

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Fordred, John	54,267	April 24, 1866	W, D 1
Forrest, Chas. N	1,163,593	Dec. 7, 1915	E 1, 3
Forward, C. B	1,189,083	June 27, 1916	B, J
Forward, C. B	1,181,301	May 2, 1916	F 2, II
Forward, C. B	1,202,823	Oct. 31, 1916	B
Forward, C. B	998,569	July 18, 1911	E 2, B
Forward, C. B	1,100,966	June 23, 1914	B
Forward, C. B	1,088,693	Mar. 3, 1914	B
Forward, C. B	1,088,692	Mar. 3, 1914	E 2, B
Forward, C. B	1,247,808	Nov. 27, 1917	U
Forward, C. B	1,255,149	Feb. 5, 1918	B
Forward, C. B	1,274,405	Aug. 6, 1918	B
Forward, C. B	1,299,449	April 8, 1919	F
Forward, C. B., and Davidson, J. M	611,620	Oct. 4, 1898	E 2, 3, D 1
Foster, Arthur B	1,394,486	Oct. 18, 1921	B
Foubert, Andre	71,156	Nov. 19, 1867	F 2
Foubert, Andre	118,602	Aug. 29, 1871	F
Foubert, Andre	60,166	Dec. 4, 1866	F 1
Fowler, David W	75,147	Mar. 3, 1868	M
Frances & Morgan	1,313,629	Aug. 19, 1919	D
Franke, A. H	1,142,512	June 8, 1915	A
Frasch, Hans A	488,628	Dec. 27, 1892	I
Frasch, Hans A	640,292	Jan. 2, 1900	F 2, II
Frasch, Hans A	525,811	Sept. 11, 1894	D 1
Frasch, Hans A	581,546	April 27, 1897	E 2, 3
Frasch, Hans A	1,212,620	Jan. 16, 1917	B
Frasch, H. A	1,318,657	Oct. 14, 1919	F
Frasch, Herman	845,735	Feb. 26, 1907	F 2, II
Frasch, Herman	968,760	Aug. 30, 1910	F 1
Frasch, Herman	487,216	Nov. 29, 1892	V
Frasch, Herman	564,920	July 28, 1896	V
Frasch, Herman	490,144	Jan. 17, 1893	V
Frasch, Herman	553,191	Jan. 14, 1896	S
Frasch, Herman	561,216	June 2, 1896	D 1
Frasch, Herman	564,921	July 28, 1896	V
Frasch, Herman	448,480	March 17, 1891	V
Frasch, Herman	378,246	Feb. 21, 1888	V, D
Frasch, Herman	951,729	Mar. 8, 1910	G, D
Frasch, Herman	951,272	Mar. 8, 1910	G, D
Frasch, Herman	622,799	April 11, 1899	V
Frasch, Herman	190,483	May 8, 1877	F 2, 4
Frasch, Herman	630,496	Aug. 8, 1899	V
Frasch, Herman	500,252	June 27, 1893	V
Frasch, Herman	572,676	Dec. 8, 1896	V, D
Frasch, Herman	231,420	Aug. 24, 1880	U
Frasch, Herman	205,792	July 9, 1878	F
Frasch, Herman	649,047	May 8, 1900	O, V
Frasch, Herman	340,499	April 20, 1886	F
Frasch, Herman	487,119	Nov. 29, 1892	V
Frasch, Herman	281,045	July 10, 1883	F 2, 3
Frasch, Herman	564,922–3	July 28, 1996	V
Frasch, Herman	564,924	July 28, 1896	V, F
Frasch, Herman	649,048	May 8, 1900	V, D
Frasch, Herman	542,849	July 16, 1895	V, D 1
Frasch, Herman	543,619	July 30, 1895	V
Fraser, Wm. M	1,259,223	Mar. 12, 1918	E 1, 2
Fraser, Wm. M	1,258,103	Mar. 5, 1918	E 1, 2
Frederici, C. F	48,672	July 11, 1865	F
Freel, John	504,917	Sept. 12, 1893	S, F
French, Edw. H	1,394,488	Oct. 18, 1921	D
Gaggin, Richard	118,359	Aug. 22, 1871	D 2, V
Gallsworthy, Benjamin	1,234,327	July 24, 1917	F 2, II
Galloupe, J. H	1,283,723	Nov. 5, 1918	W
Galloupe, J. H	1,365,822	Jan. 18, 1921	W
Gardner, H. A., and Bielouss, E	1,384,447	July 12, 1921	L, D
Gardner, J., and Harris, J. F	442,802	Dec. 16, 1890	V, F

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)— Continued.

NAME	Number	Date	Class
Herber, Samuel M	1,183,457	May 16, 1916	F, 2, 3 D
Hibbert, Harold	1,270,759	June 25, 1918	B, K 2
Hicks, Enoch O	1,378,229	May 17, 1921	B
Higbie, M. S., and Dougherty, A	387,358	Aug. 7, 1888	C, E, 1
Higbie, M. S., and Dougherty, A	387,357	Aug. 7, 1888	C, E. 1, 3
Higgins, Chas. S	309,718	Dec. 23, 1884	N
Higham, A. D	54,157	April 24, 1866	F
Hill, R. L	1,269,439	June 11, 1918	B
Hill, S., and Thumm, C. F	101,364	Mar. 29, 1870	F 1, II
Hill, S., and Thumm, C. F	101,364	Mar. 29, 1870	F 1, II
Hill, S., and Thumm, C. F	102,819	May 10, 1870	F 1, II
Hill, S., and Thumm, C. F	114,293	May 2, 1871	F 1, 3 II
Hird, Harold Pearson	1,368,149	Feb. 8, 1921	F
Hirshberg, Leon	1,042,915	Oct. 29, 1912	D
Hirt, Leon E	1,222,402	April 10, 1917	B, F
Hirt, Leon E	1,250,879	Dec. 18, 1917	B, P
Hirt, Leon E	1,264,796	April 30, 1918	K, 3
Hodkinson, M	26,326	Nov. 29, 1859	G, W
Hofferberth, John	105,683	July 26, 1870	F 1, I
Hoffman, Bernhard	641,962	Jan. 23, 1900	M
Hoffman, Ross J	405,738	June 25, 1889	S
Hoffman, Wm. John	1,367,968	Feb. 8, 1921	M
Holmes, F. W., and Blasdell, E	1,055,747	Mar. 11, 1913	B
Hoge, Daniel W	1,382,727	June 28, 1921	
Holmes, Fletcher B	1,276,219	Aug. 20, 1918	D
Holmes, Jos. E	23,427	Mar. 29, 1859	G. W
Holmes, Jos. E	1,241,979	Oct. 2, 1917	B, J
Holmes, J. E	24,212	May 31, 1859	W
Hood, J. J., and Salamon, A. G	962,840	June 28, 1910	D 2
Hopkins, A. S	1,199,463	Sept. 26, 1916	B
Hopkins, A. S	1,199,464	Sept. 26, 1916	B
Horner, E. N	22,727	Jan. 25, 1859	W, D
Houlehan, Arthur Earl	1,334,033	Mar. 16, 1920	
Houlehan, Arthur Earl	1,337,317	April 20, 1920	
Houlker, Christopher	110,364	Dec. 20, 1870	O
Hout, F., and Rogers, John	71,619	Dec. 3, 1867	F 4
Hout, F., and Rogers, John	63,051	Mar. 19, 1867	S
Howard, F A	1,284,687	Nov. 12, 1918	F
Howarth, John	42,772	May 17, 1864	W, F
Howe, Ephriam	7,667	Sept. 24, 1850	M
Howell, ——	1,294,909	Feb. 18, 1919	S
Howell, C. G	66,841	July 16, 1867	F 1, 2
Howell, H. F	216,518	June 17, 1879	L
Hudson, Chas. R	681,170	Aug. 20, 1901	A
Hudson, Samuel	123,907	Feb. 20, 1872	G
Huglo, Victor	953,952	April 5, 1910	B
Hubbard, P	1,326,056	Dec. 23, 1919	B
Humason, G. A	1,291,899	Jan. 21, 1919	S
Humphreys, R. E	1,122,002	Dec. 22, 1914	B, S
Humphreys, R. E	1,122,003	Dec. 22, 1914	B
Humphreys, R. E	1,119,700	Dec. 1, 1914	B
Humphreys, R. E.–	1,286,179	Nov. 26, 1918	I
Humphreys & Burton	1,343,674	June 15, 1920	B
Huntington, John	62,750	Mar. 12, 1867	F
Hussey, John S	1,277,935	Sept. 3, 1918	C
Huston, John B	297,603	April 29, 1884	S
Huston, John B	486,406	Nov. 15, 1892	A
Hyde, Burrows	281,999	July 24, 1883	T
Ihart, J. P	654,258	July 24, 1900	A
Ilges, R. W	968,478	Aug. 23, 1910	F 2, II
Isom, Edward W	1,285,200	Nov. 19, 1918	B
Jaeger, W. G. W	24,217	May 31, 1859	W
Jaeger, W. G. W	24,561	June 28, 1859	W, S
Jaeger, W. G. W	54,358	May 1, 1866	F 1, 2, II

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
James, C. M	86,232	Jan. 26, 1869	F 1, 2 II
Jann, John	52,574	Feb. 13, 1866	M
Jann, John	57,727	Sept. 4, 1866	M
Jenkins, U. S	1,226,526	May 15, 1917	J, B
Jenkins, U. S	1,321,749	Nov. 11, 1919	
Jenney, W. P	190,762	May 15, 1877	I
Jenney, W. P	178,061	May 30, 1876	I
Jenney, W. P	178,154	May 30, 1876	I, T
Jennings, Isaiah	1,453	Dec. 31, 1839	M
Jensen, J. O	1,388,718	Aug. 23, 1921	W
Jensen, J. O	1,268,721	June 4, 1918	A
Johansen, E. M	1,373,661	April 29, 1921	I
Johnson, John	54,917	May 22, 1866	S
Johnson, Walter	1,354,257	Sept. 21, 1920	B, P
Johnson & Snodgrass	1,283,202	Oct. 29, 1918	S
Johnston, Jas. J	117,425	July 25, 1871	F
Johnston, Jas. J	117,426	July 25, 1871	A
Johnston, Jas. J	48,285	June 20, 1865	F 4, 5
Johnston, Jas. J	31,982	April 9, 1861	S
Johnston, Jas. J	50,935	Nov. 14, 1865	F 2
Johnston, Jas. J	91,448	June 15, 1869	F 2, II
Jones, Albert R	1,328,522	Jan. 20, 1920	
Jones, Frank	1,373,890	April 5, 1921	W
Jones, Harry Wagenseller	1,336,357	April 6, 1920	
Jones, Harry Wagenseller	1,347,543	July 27, 1920	
Jones, Harry Wagenseller	1,347,544	July 27, 1920	
Jones, Philip	1,255,018	Jan. 28, 1918	K 2, S
Jones, E. C., and Jones, L. B	1,089,926	Mar. 10, 1914	K 1, 2
Jones & Jones	1,157,225	Oct. 19, 1915	K 1
Jones, R. G	1,166,375	Dec. 28, 1915	F 2, II
Jones, R. G	1,005,977	Oct. 17, 1911	A
Jordery, Chas. A	126,552	May 7, 1872	M
Joseph, Irwin S	1,362,105	Dec. 14, 1920	A
Just, John A	658,988	Oct. 2, 1900	M
Kasson, H. R., and Saxton, S. S	998,691	July 25, 1911	E 1, 2
Kattell, E. C	222,408	Dec. 9, 1879	F 2, 4
Kayser, Adolf	508,479	Nov. 14, 1893	D 1, V
Kayser, A	640,918	Jan. 9, 1900	V, D 1
Keen, Morris L	25,552	Sept. 20, 1859	F 1
Kelley, E. G	67,988	Aug. 20, 1867	F 1, II
Kelley, E. G., and Tait, A. H	32,568	June 18, 1861	F 1, 2 II
Kelley, E. G	84,195	Nov. 17, 1868	F 1, II
Kells, Edw	298,210	May 6, 1884	F
Kells, Edw	374,838	Dec. 13, 1887	F 1, I
Kelsey, S. E	1,029,366	April 7, 1914	B
Kelsey, S. E	1,302,669	May 6, 1919	S
Kendall, Edw. D	413,187	Oct. 22, 1889	D
Kendall, Edw. D	359,357	Mar. 15, 1887	D 1
Kendall, Edw. D	284,437	Sept. 4, 1883	D, M
Kendall, Edw. D	451,660	May 6, 1891	D 1, 2
Kendall, Edw. D	1,192,529	July 25, 1916	K 2, J
Kendall, Edw. D	1,154,517	Sept. 21, 1915	D 1, S
Kendall, Edw. D	1,154,516	Sept. 21, 1915	D 1
Kennard, Harold J	1,394,771	Oct. 25, 1921	P
Kennedy, C. F	1,356,631	Oct. 26, 1920	O, D
Kennedy, D. McD	370,950	Oct. 4, 1887	V
Kennedy, J. S	1,339,112	May 4, 1920	
Kerr, Arthur Neal	1,371,427	Sept. 5, 1918	K 2
Kerr, A. N	1,199,903	Oct. 3, 1916	J
Keyt, A. N	1,262,808	April 16, 1918	D
Kipper, H. B	1,253,048	Jan. 8, 1918	D 1
Kirchoffer, G. W	32,373	May 21, 1861	G. W
Kirk, Arthur	78,878	June 16, 1868	F 1, II
Kirk, J. L	215,756	May 27, 1879	F 1, II
Kirk, Solomon W	267,752	Nov. 21, 1882	C
Kirschbraun, L	1,940,750	Aug. 15, 1916	E 1, 2

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Garner, J. B., and Clayton, H. D	1,262,769	April 16, 1918	L
Garner, J. B	1,299,455	April 8, 1919	J, K
Garner, J. B., and Cooper, H. C	1,332,290	Mar. 2, 1920	K, J
Garrity, W. F., and Jarvais, A	1,190,538	July 11, 1916	O, A
Garvey, Benjamin	29,218	July 17, 1860	G
Gathmann, Louis	768,796	Aug. 30, 1904	F 1, 5
Gathmann, Louis	755,760	Mar. 29, 1904	F
Gay, Cassius M	1,179,001	April 11, 1916	J
Gearing, C. M	212,084	Feb. 4, 1879	F 1, 11
Gellen, A	1,063,025	May 27, 1913	I
Gengembre, H. P	52,283	Jan. 30, 1866	A
Gengembre, H. P	52,284	Jan. 30, 1866	A
Gengembre, H. P	24,454	June 21, 1859	G
Gengembre, H. P	25,109	Aug. 16, 1859	G, B
Gengembre, H. P	27,542	Mar. 20, 1860	G, W
Gengembre, H. P	33,699	Nov. 12, 1861	G
Gerbeth, F. L. de	81,071	Aug. 18, 1868	L, P
Gesner, Abraham	11,205	June 27, 1854	G
Gesner, A	11,203	June 27, 1854	G
Gesner, A	11,204	June 27, 1854	G
Gesner, Abraham	12,612	Mar. 27, 1855	G
Gibbons, Samuel	87,485	Mar. 2, 1869	O
Gibbons, S	87,658	Mar. 9, 1869	F
Gibbons, S	85,810	Jan. 12, 1869	F 2, 11
Gibbons, S	68,974	Sept. 17, 1867	F 1, 2 11
Gilchrist, V. T	1,386,467	Aug. 2, 1921	F
Gillespie, Jas	23,362	Mar. 29, 1859	G, F
Gillons, G. H	1,084,080	Jan. 13, 1914	F 1, 11
Goldwater, Henry	366,720	July 19, 1887	F 1, 2, 11
Goldwater, Henry	432,525	July 22, 1890	S
Goodaire, Wm., and Stead, Geo	101,003	Mar. 22, 1870	I
Gordon, Thos	451,724	May 5, 1891	D
Govers, F. X	1,297,833	Mar. 18, 1919	W
Gracie, John	114,802	May 16, 1871	F 4
Gracie, John	114,803	May 16, 1871	F
Gracie, John	117,405	July 25, 1871	F
Gracie, John	117,406	July 25, 1871	F 1, 1
Gracie, John	99,081	Jan. 26, 1870	F 1, 11
Grady, Chas. F	556,412	Mar. 17, 1896	F 2, 11
Graham, C. B	732,937	July 7, 1903	D 1
Grannis, C. W	36,403	Sept. 9, 1862	U, G
Grant, H. F	1,303,292	May 13, 1919	O
Grant, Jas. B	57,311	Aug. 21, 1866	F
Grant, J. B., and Mason, A	339,545	April 6, 1886	F 1, 2, 5, 11
Grant & Mason	339,546	April 6, 1886	F 2, 5, 11
Grant & Mason	339,545	April 6, 1886	A
Gray, A, McD	663,235	July 10, 1900	C
Gray, Daniel T	250,524	Dec. 6, 1881	C
Gray, D. T	248,735	Oct. 25, 1881	C
Gray, D. T	281,491	July 17, 1883	C, S
Gray, E. B	1,005,425	Oct. 10, 1911	I
Gray, G. W	1,193,540	Aug. 8, 1916	B, J
Gray, G. W	1,193,541	Aug. 8, 1916	B
Gray, J. L	923,429	June 1, 1909	I
Gray, J. L	923,428	June 1, 1909	I
Gray, J. L	1,192,889	Aug. 1, 1916	F
Gray, J. L	923,427	June 1, 1909	I
Gray, John Lathrop	1,331,909	Feb. 24, 1920	
Gray, Thos. T	1,340,889	May 25, 1920	D
Gray, T. T	1,158,205	Oct. 25, 1915	P
Gregory, Ralph and Winton	1,271,511	July 2, 1918	S, 1, 2, 7, 1, 61
Green, Joel	46,791	Mar. 14, 1865	K 2
Greene, H. J	1,252,000	Jan. 1, 1918	K 1
Greenstreet, Chas. J	1,110,924	Oct. 26, 1915	B
Greenstreet, Chas. J	1,110,923	Sept. 15, 1914	B
Greenstreet, C. J	1,110,025	Sept. 15, 1914	B
Greenstreet, C. J	1,166,982	Sept. 16, 1914	B

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Greenstreet, C. J.	1,299,172	Jan. 1, 1916	B
Grieg, A., and Smith, Jas.	42,171	Mar. 29, 1864	K 1
Griffin, Jonathan	23,167	Mar. 8, 1859	M
Groble, J. C.	1,283,502	Nov. 5, 1918	K
Grogan, Henry	94,409	Aug. 31, 1869	F 2
Grogan, H., and Lape, G. T.	89,988	May 11, 1869	F 2, 5 II
Grousilliers, Hector de	378,774	Feb. 28, 1888	I
Guillaume, Emile	996,081	June 27, 1911	B
Gulick, W. R.	1,187,061	June 13, 1916	M
Gumpoldt, Emil	616,838	Dec. 27, 1898	M
Hadley, B. E.	1,300,230	April 8, 1919	S
Hague, S. L.	775,448	Nov. 22, 1904	W, S
Hague, S. L.	759,988	May 17, 1904	W, S
Hall, C. H.	86,535	Feb. 2, 1869	F 2
Hall, C. H.	55,855	June 26, 1866	F 1, 2 II
Hall, C. H., and Ellis, John	58,813	Oct. 16, 1866	F 1, II
Hall, T. G.	372,672	Nov. 8, 1887	V
Hall, Wm. A.	1,175,909	Mar. 14, 1916	B
Hall, Wm. A.	1,105,772	Aug. 4, 1914	B, K 1
Hall, Wm. A.	1,194,289	Aug. 8, 1916	B
Hall, Wm. A.	1,239,099	Sept. 4, 1917	B
Hall, Wm. A.	1,175,910	Mar. 14, 1916	B, K 1
Hall, Wm. A.	1,247,671	Nov. 27, 1917	B
Hall, Wm. A.	1,242,795	Oct. 9, 1917	B
Hall, Wm. A.	1,242,796	Oct. 9, 1917	B
Hall, Wm. A.	1,239,100	Sept. 4, 1917	B
Hall, Wm. A.	1,261,930	April 9, 1918	B
Hall, Wm. A.	1,242,746	Oct. 9, 1917	B
Hall, Wm. A.	1,242,795	Oct. 9, 1917	B
Hall, Wm. A.	1,285,136	Nov. 19, 1918	B
Hall, Wm. C.	266,990	Nov. 7, 1882	F 2
Halvorson, Halvor	305,182	Sept. 16, 1884	S
Halvorson, H.	305,180	Sept. 16, 1884	F
Hamilton, T. S.	1,018,971	Feb. 27, 1912	A
Hand, Harry W.	596,874	Jan. 4, 1898	U, S
Handy, Jas. O.	1,281,355	Oct. 15, 1918	O
Handy, Jas. O.	1,281,354	Oct. 15, 1918	O
Hansen, Julius	1,084,738	Jan. 20, 1914	C
Hardy, C. A.	51,042	Nov. 21, 1865	F
Hardy, C. A.	40,168	Oct. 6, 1863	F 2, 4
Hardy, C. A.	46,899	Mar. 21, 1865	F
Harris, Ford W.	1,281,952	Oct. 15, 1918	A, P
Harris, John	1,283,508	Nov. 5, 1918	K 2
Harris, Milo	170,730	Dec. 7, 1875	U
Harrison, Poole	1,355,554	Oct. 12, 1920	N
Hart, Thos. M.	1,252,433	Jan. 8, 1918	A, E 2, 3
Hartshorn, H. M.	91,843	June 29, 1869	N
Hastings, D., and Brink, A. W.	867,505	Oct. 1, 1907	K, 2, J
Hatch, N. B.	22,798	Feb. 1, 1859	G
Hawes, Benj. N.	444,833	Jan. 20, 1891	V
Hazlett, R. W., and Hobbs, J. H.	24,211	May 31, 1859	G, S
Hebard, Benj. F.	31,457	Feb. 19, 1861	M
Heckenbleikner & Gilchrist	1,310,078	July 15, 1919	I
Hedges, E. E.	1,383,205	June 28, 1921	W
Helbing, H., and Passmire, F. S.	666,010	Jan. 15, 1901	D 1
Hempel, H.	621,338	Mar. 21, 1899	M
Hempel, H.	621,411	Mar. 21, 1899	M
Henderson, Geo. A.	1,266,261	May 14, 1918	E 1
Henderson, N. M.	490,199	Jan. 17, 1893	C
Henderson, N. M.	340,878	April 27, 1886	F
Henderson, H.	1,335,438	Mar. 30, 1920	B, F
Hennebutte, H.	1,165,878	Dec. 28, 1915	F
Hennebutte, H.	1,165,877	Dec. 28, 1915	F 4, 1
Hense, Rudolf	1,073,233	Sept. 16, 1913	M
Herber, Samuel M.	1,111,580	Sept. 22, 1914	F, D 1

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Kitchen, J. M. W.	1,008,273	Nov. 7, 1911	F 1, 2 H
Klauber, Laurence M	1,371,378	July 25, 1919	N
Klein, John S	306,837	Oct. 21, 1884	S
Kline, Geo. H	253,362	Nov. 30, 1886	F 1, H S
Klosterman, Robt	152,650	June 30, 1874	F
Knottenbelt, H. W	1,194,033	Aug. 8, 1916	W
Knottenbelt, H. W	1,277,605	Sept. 3, 1918	D 1
Koch, G. T., and Stallkamp, A. L	1,380,067	May 31, 1921	D, L
Koehler, Herman	507,441	Oct. 24, 1893	V
Koehler, W. C., and Kink, L	1,084,016	Jan. 13, 1914	O
Koetchaw, R	1,325,299	Dec. 16, 1919	B
Koppers, H	1,098,723	June 2, 1914	F 2, H
Kormann, Frederick A	1,332,849	Mar. 2, 1920	F
Kotschevar, H. J	1,357,998	Nov. 9, 1920	B, K
Kreiser, J. M	384,768	June 19, 1888	S
Kresier, J. M	366,487	July 12, 1887	F
Kreusler, A	50,368	Oct. 10, 1866	F
Kroll, C	1,373,251	Mar. 29, 1921	F
Lachman, W	1,363,659	Dec. 28, 1920	S
Lackmen, A	1,171,524	Feb. 15, 1916	F 2, H
Lacy, B. S	1,263,906	April 23, 1918	L
Laing, John	471,291	Mar. 22, 1892	B
Laing, John	488,767	Dec. 27, 1892	B
Laird, Robt. H	507,230	Oct. 24, 1893	F 2, H
Laird, Robt. H	498,518	May 30, 1893	F
Laird, R. E., and Raney, Jos. H	1,116,299	Nov. 3, 1914	A, P
Laird, W. G	1,320,396	Oct. 4, 1919	F
Laird & Raney	1,142,761	June 8, 1915	A, P
Laird & Raney	1,142,760	June 8, 1915	A, P
Laird & Raney	1,142,759	June 8, 1915	A, P
Lamb, D. M	183,401	Oct. 17, 1876	D, 1
Lambe, Frederick	102,135	April 19, 1870	C
Lambert, Chas. G	1,245,930	Nov. 6, 1917	B
Lamplough, F	1,229,098	June 5, 1917	B
Landes, Wm	1,199,909	Oct. 3, 1916	B
Landsberg, L	1,211,721	Jan. 9, 1917	I
Lane, Edw	172,131	Jan. 11, 1876	F 1, H
Lang, J. S	954,575	April 12, 1910	B
Lapham, Allen	59,317	Oct. 30, 1866	F
Lapp, C. E	1,266,281	May 14, 1918	B
Lasher, D. F	1,075,481	Oct. 14, 1913	D 1
Lawrence, W P	1,315,632	Sept. 9, 1919	K
Lee, A. K	162,394	April 20, 1875	E 1
Leete, H. C	1,288,934	Dec. 24, 1918	D
Leman, Wm. T	727,391	May 5, 1903	U
Lennard, F	459,123	Sept. 8, 1891	F 2, H
Lennard, F	499,557	June 13, 1893	F 2
Lennard, F	659,076	Oct. 2, 1900	T
Lepley, Clyde E	1,261,410	April 2, 1918	F
Leslie, E. H	1,310,164	July 15, 1919	S
Leslie, E. H., and Barbre, C	1,337,523	April 20, 1920	D
Lessing, Rudolf	1,281,597	Oct. 15, 1918	K 2
Letchford, R. M., and Nation, W	133,042	Nov. 12, 1872	C
Levy, E. D., and Jacobs, H. W	1,251,978	Jan. 1, 1918	Q
Lewis, Jos. W	1,364,443	Jan. 4, 1921	B
Lewis, F. B., and Cooke, T. S	1,392,584	Oct. 4, 1921	B
Lewis, Sylvester	35,527	June 10, 1862	M
Lewis, S	42,671	May 10, 1864	V
Lewis, S	43,156	June 14, 1864	M
Linderborg, G., and Scott, W. B	1 220,651	Mar. 27, 1917	K 2, B
Lindsy, Wm. J	1,256,340	Feb. 12, 1918	K 1
Linn, S. S	1,284,117	Nov. 5, 1918	M
Livesay, Jas., and Kidd, Jas	258,778	May 30, 1882	F
Livingston, Julius I	239,260	Mar. 22, 1881	T
Livingston, Max	237,560	Feb. 8, 1881	F
Livingston, Max	728,257	May 19, 1903	F H

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Lockhart, Chas., and Gracie, J	40,632	Nov. 17, 1863	F
Lockhart & Gracie	80,294	July 28, 1868	F
Loew, Oscar	101,284	Mar. 29, 1870	D 1
Lofhjelm, Karl	546,018	Sept. 10, 1895	F
Loftus, Robt. G	113,782	April 18, 1871	D 1
Loftus, Robt. G	81,654	Sept. 1, 1868	K 2
Loftus, Robt. G	43,157	June 14, 1864	I
Long, F. R	1,256,146	Feb. 12, 1918	S
Loomis, C. C	1,280,612	Oct. 1, 1918	L
Loomis, Wells, Hitchcock & Stryker	66,364	July 2, 1867	M
Looney, John J	139,009	May 20, 1873	D 1
Lorch, H. D	1,264,668	April 30, 1918	F 2, 5
Lorraine, David G	1,396,860	Nov. 15, 1921	B-D-3
Lossen, Clemens	537,121	April 9, 1895	V
Low, Frank S	1,192,653	July 25, 1916	J, B
Lowe, L. P., and Ruff, F. C	1,351,859	Sept. 7, 1920	B
Lowe, W. P., and Bilfinger, C. W	556,155	Mar. 10, 1896	B
Lucas, Owen D	1,168,404	Jan. 18, 1916	B
Lucas, Owen D	1,183,091	May 16, 1916	B
Lugo, Orazio	51,843	Jan. 2, 1886	F 3
Lugo, Orazio	60,757	Jan. 1, 1867	V, D 1
Lugo, Orazio	58,113	Sept. 18, 1866	F 3, 4, I
Lugo, O., and Schrade, T. O. L	60,396	Dec. 11, 1866	F 3, 4, I
Lupton, Geo	110,054	Dec. 13, 1870	D
Lutz, H. E	240,914	May 3, 1881	F 1, II
Maag, G. C	1,142,525	June 8, 1915	B
McAfee, Almer M	1,277,092	Aug. 27, 1918	C
McAfee, A. M	1,099,096	June 2, 1914	B
McAfee, A. M	1,127,465	Feb. 9, 1915	B
McAfee, A. M	1,144,304	June 22, 1915	B
McAfee, A. M	1,202,081	Oct. 24, 1916	B
McAfee, A. M	1,277,329	Aug. 27, 1918	D
McAfee, A. M	1,277,328	Aug. 27, 1818	D
McAfee, A. M	1,235,523	July 31, 1917	B
McAfee, A. M	1,326,072	Dec. 23, 1919	B
McAfee, A. M	1,326,073	Dec. 23, 1919	B
McArthur, D. R	1,119,974	Dec. 8, 1914	B
McAig, D. C	1,255,449	Feb. 5, 1918	S
McCabe, J. R	1,376,713	May 3, 1921	B, P
McCarty, F	91,953	June 29, 1869	F 2, II
McCarty, Wm. F. M	1,274,912	Aug. 6, 1918	B
McCarty, W. F. M	1,274,913	Aug. 6, 1918	B
McCaskell, J. A	1,317,514	Sept. 30, 1919	W
McComb, Wm. F	1,374,858	April 12, 1921	B
McComb, Wm. M	1,337,144	April 13, 1920	B
McCue, J. and W. B	21,143	Aug. 10, 1858	W
McElroy, Karl P	1,259,757	Mar. 19, 1918	K 2, B
McElroy, Karl P	1,259,758	Mar. 19, 1918	K 2
McGinnis, Walter R	1.328,680	Jan. 20, 1920	K J
McGowan, Thompson	492,421	Feb. 28, 1893	F
McGowan, T	454,061	June 16, 1891	F
McGowan, T	443,328	Dec. 23, 1890	F
McGowan, T	658,857	Oct. 2, 1900	V
McGowan, T	257,961	May 16, 1882	F 3, D 1
McGowan, T	431,386	July 1, 1880	F
McGowan, T	166,285	Aug. 3, 1875	F 2
McGowan, T	492,419	Feb. 28, 1893	S
McGowan & Van Syckel, S	154,700	Sept. 1, 1874	S
McGowan & Van Syckel, S	156,229	Oct. 27, 1874	F 1
McHenry, C. D	1,154,869	Sept. 28, 1915	B, K 1
McKee, Ralph H	1,244,444	Oct. 23, 1917	L
McKibben, Chas. W	1,327,835	Jan. 13, 1920	A
McKibben, Chas. W	1,299,589	April 8, 1919	A
McKibben, Chas. W	1,299,590	April 8, 1919	A
McKissack, R. I	1,113,029	Oct. 6, 1914	K 1
McManus, H	305,097	Sept. 16, 1884	I

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
McMillan, F. M	215,471	May 20, 1879	C
McOmber, L. W	1,345,452	July 6, 1920	B
McSwinney, Daniel J	1,384,805	July 19, 1921	M
MacBeth, A	1,325,448	Dec. 16, 1919	H
MacDougall, A J	1,381,319	June 14, 1921	D
Macalpine, Thos	655,500	Aug. 7, 1900	D 1, 2
Macalpine, Thos	686,663	Nov. 12, 1901	D 1, 2
Macalpine, Thos	684,813	Dec. 25, 1900	F 2, 5, 1
Macalpine, Thos	741,517	Oct. 13, 1903	D
Maitland, H. T	1,188,961	June 27, 1916	O, D
Maitland, H. T	1,272,979	July 16, 1918	D 1
Mann, F. W	619,593	Feb. 14, 1899	B
Mann, M. D	1,365,045	Jan. 11, 1921	D
Mann & Chappell, M. L	1,163,025	Dec. 7, 1915	D
Mann & Chappell	1,183,094	May 16, 1916	L
Mann & Chappell	1,214,204	Jan. 30, 1917	B
Mann & Chappell	1,249,444	Dec. 11, 1917	B
Mann & Chappell	1,257,906	Feb. 26, 1918	B
Mann, Matthew D., Jr	1,365,043	Jan. 11, 1921	L
Mann, Matthew D, Jr	1,365,043	Jan. 11, 1921	L
Mann, Stephen S	204,235	May 28, 1878	N
Mann, Stephen S	152,855	July 7, 1874	N
Mann & Williams	1,365,043	Jan. 11, 1921	K, L
Mansfield, David	55,880	June 26, 1866	M
Marrin, Thos	211,762	Jan. 28, 1879	C
Marrin, Thos	243,930	July 5, 1881	F
Martin, J. N	254,990	Mar. 14, 1882	F
Martini, Dan	892,378	June 30, 1908	B, P
Mason, Allan	444,203	Jan. 6, 1891	F 1, 2, H
Mason, Allan	444,202	Jan. 6, 1891	F 1, 2, H
Mason, F. B	1,294,136	Feb. 11, 1919	M
Mathieu, Jean A	374,077	Nov. 29, 1887	F 2, 5, H
Maybury, Wm	737,756	Sept. 1, 1903	F 1, 2, H
Meeds, Wilber R	266,859	Oct. 31, 1882	M
Meeds, W. R	250,830	Dec. 13, 1881	M
Meigher, Jas. D	224,301	Feb. 10, 1880	F 1, 4, H
Mellen, G. H., and Hazelton, J. C	57,749	Sept. 4, 1866	M
Mengel, Chas. C	116,852	July 11, 1871	F
Mengel, C. C	465,703	Dec. 22, 1891	F 1, 3
Mengel, C. C	452,578	May 19, 1892	F 3, V
Meriam, J. B	61,946	Feb. 12, 1867	C
Meredith, S	13,358	July 31, 1855	W
Merriam, E. S	1,304,587	May 27, 1919	J-K
Merrick, Thos. E	91,654	June 22, 1869	O, D
Merrill, Francis B	761,315	May 31, 1904	F
Merrill, Joshua	33,955	Dec. 17, 1861	S
Merrill, Joshua	32,951	July 30, 1861	S
Merrill, Joshua	32,706	July 2, 1861	S
Merrill, Joshua	32,704	July 2, 1861	D 1
Merrill, Joshua	32,705	July 2, 1861	D 1
Merrill, Joshua	90,284	May 18, 1869	F 1, 2
Merrill, Joshua	43,325	June 28, 1864	D 1
Merrill, Willis C	1,252,376	Jan. 1, 1918	E 3
Meriz, Josef	339,201	April 6, 1886	F 2, H
Mesereau, G	1,282,906	Oct. 29, 1918	K
Mesereau, G	1,308,802	July 8, 1919	K
Meucci, Antonio	36,419	Sept. 9, 1862	D 1
Midgely, T., Jr	1,296,832	Mar. 11, 1919	M
Mieschke-Smith, W	1,327,247	Jan. 6, 1920	F
Mijs, Jan	1,178,532	April 11, 1916	C
Miles, George	205,407	June 25, 1878	F, S
Miles, George W	1,168,534	Jan. 18, 1916	C
Miller, Jas	77,070	April 21, 1868	F 5, H
Miller, Jas. Roys	1,359,614	Nov. 24, 1920	O
Miller, J. R	1,312,265	Aug. 5, 1919	B
Millochau, Adolph	38,641	May 19, 1863	D 1
Millochau, A	37,918	Mar. 17, 1863	D 1

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Millochau, A	53,167	Mar. 13, 1866	F 1
Millochau, A	46,923	Mar. 21, 1865	F 1
Millochau, A	41,085	Jan. 5, 1864	D 1
Millochau, A	49,777	Sept, 5, 1865	N
Mills, E. N	1,007,788	Nov. 7, 1911	Q
Millspaugh, Pethuel	127,259	May 28, 1872	M
Mims, John C	713,475	Nov. 11, 1902	D 1, E 3
Minshall, F. W	415,876	Nov. 26, 1889	F 2, 3, V
Mitchell, Willis	1,141,072	May 25, 1915	K 1
Montague, H. E	1,227,551	May 22, 1917	B
Mooney, L	1,174,888	Mar. 7, 1916	R
Moore, E. A	786,828	April 11, 1905	A
Moore, George H	586,520	July 13, 1897	V, D 1
Moore, E. S., and Thomas, H. H	1,281,808	Oct. 15, 1918	S
Moore, J. B	1,130,318	Mar. 2, 1915	B
Morehouse, C. L	55,426	June 5, 1866	D 1, C
Morehouse, C. L	174,921	Mar. 21, 1876	G
Morfit, Clarence	66,243	July 2, 1867	U
Morris, W. L	1,137,075	April 27, 1915	C
Morris, W. L	1,305,735	June 3, 1919	O
Mott, Leander M	54,192	April 24, 1866	O
Mowbray, George M	25,575	Sept. 27, 1859	F 1, 4, II
Mueller, C. L. E	1,297,388	Mar. 18, 1919	M
Mumford, Russell Wm	1,377,021	May 3, 1921	O, P
Munson, A. L	440,830	Nov. 18, 1890	D
Murray, Thos. E	1,273,523	July 23, 1918	S
Murray, T. E., and Ricketts, E. B	1,293,866	Feb. 11, 1919	F
Murray, T. E	1,302,200	April 29, 1919	S
Myers, Geo. W	147,783	Feb. 24, 1874	K 2, S
Navin, F	1,312,266	Aug. 5, 1919	W
Neahous, Herman	242,554	June 7, 1881	C
Neal, Stephens	1,036,306	Aug. 20, 1912	F 2
Neilson, Albert	232,618	April 5, 1881	F
Nelson, John	1,391,568	Sept. 20, 1921	B
Newton, Daniel L	1,330,490	Feb. 10, 1920	K
Newton, D. F., and Anderson, N. H	1,376,631	May 3, 1921	F
Newton, D. L	1,356,878	Oct. 26, 1920	K, J
Newall, Robert	53,656	April 3, 1866	V, D
Newsome, Thos. J	405,047	June 11, 1889	A
Nichols, H. M	1,302,832	May 6, 1919	S
Nichols, H. M	1,356,550	Oct. 26, 1920	C
Nicholson, John	22,973	Feb. 15, 1859	W
Nicolai, J. H. and W. F	224,037	Feb. 3, 1880	G, S
Nicolai, Pierre	225,635	Mar. 16, 1880	F 2
Nikiforoff, A	755,309	Mar. 22, 1904	B
Noad, James	985,053	Feb. 21, 1911	B, W
Nomi, Konosuke	1,386,945	Aug. 9, 1921	F
Nordenson, Carl O	1,218,575	Mar. 6, 1917	K 1
Norton, J. W., and Rouse, F. H	313,514	Mar. 10, 1885	S
Norton & Rouse	336,941	Mar. 2, 1886	F 2, 4, D 1
Noteman, Alonzo	512,894	Jan. 16, 1894	D
Noyes, John E	82,151	Sept. 15, 1868	G, M
Ogilvy, David J	1,268,142	June 4, 1918	W
O'Hara, Jas	22,573	Jan. 11, 1859	K 3
Olsen, Geo	1,199,491	Sept. 26, 1916	J, A
O'Neall, J. M	754,687	Mar. 15, 1904	F 1, 2 II
Opl, Karl	1,128,494	Feb. 16, 1915	C
Origet, Maurice	1,370,476	Mar. 1, 1921	F
Paine, Henry M	9,119	July 13, 1852	M
Palmer, Chas. S	1,187,380	June 13, 1916	B
Palmer, Chas. S	1,268,763	June 4, 1918	K 1
Palmer, Chas. S	1,313,009	Aug. 12, 1919	B
Paris, Auguste Jean, Jr	1,367,828	Feb. 8, 1921	B
Parker, J. H	958,820	May 24, 1910	B

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)— Continued.

NAME	Number	Date	Class
Parker, R. B	1,252,481	Jan. 8, 1918	K 2
Parker, W. C	169,189	Oct. 26, 1875	O
Parker, W. M	1,226,990	May 22, 1917	B
Parsons, Chas. C	88,978	April 13, 1869	F 2, 5
Parsons, C. Chauncey	93,739	Aug. 17, 1869	C
Parsons, H. E	214,946	April 29, 1879	F, K 2
Pease, Francis S	226,187	April 6, 1880	N
Pemberton, Henry	24,952	Aug. 2, 1859	W, I
Pennissat, Andre	204,244	May 28, 1878	I
Perkins, A. H	36,632	Oct. 7, 1862	T
Perkins, George H	399,073	Mar. 5, 1889	F
Perkins, Geo. H	240,923	May 3, 1881	S
Perkins, J., and Burnet, Wm. H	47,125	April 4, 1865	F 2, 11
Perkins, W. D	731,943	June 23, 1903	F 1, 2, 11
Perrier, Odilon	544,516	Aug. 13, 1895	F 1, 2, 11
Perrine, Robt. M	419,347	Jan. 14, 1890	V, D
Peterson, F. P	1,031,664	July 2, 1912	J, K 2
Petroff, Grigori	1,087,888	Feb. 17, 1914	I
Petroff, G	1,233,700	July 17, 1917	D 1
Petty, T. K., and Warden, W. G	37,263	Dec. 23, 1862	S
Peucben, S. C	531,560	Dec. 25, 1894	P
Pfiefer, F	1,296,115	Mar. 4, 1919	K
Pfiefer, F	1,296,116	Mar. 4, 1919	K
Phillip, A	1,286,091	Nov. 26, 1918	Q
Phillips, Joseph	98,883	Jan. 18, 1870	G, M
Pictet, Raoul P	1,228,818	June 5, 1917	B
Pielsticker, Carl M	186,951	Feb. 6, 1877	D 1
Pielsticker, Carl M	477,153	June 14, 1892	F 2, 11
Pizel, Daniel	1,070,730	Aug. 19, 1913	C
Pinckney, T. DeWitt	221,421	Nov. 11, 1879	N
Pine, J. A. W., and Ruggles, Wm. B	1,057,667	April 1, 1913	E 3
Pinkham, C. W	34,772	Mar. 25, 1862	M, G
Pitt, Wm. H	379,492	Mar. 13, 1888	F, V.
Pitt, Wm. H	411,394	Sept. 17, 1889	F, V
Place, Chas. T	243,080	June 21, 1881	F
Poisat, A. M., and Knab, D. C	7,124	Feb. 26, 1850	F 2, 11
Pollak, R. R	1,254,271	Jan. 22, 1918	A
Ponton, John	165,612	July 13, 1875	N
Poole, Willard B	1,340,793	May 18, 1920	B
Porges, P., and Neumann, R	1,017,587	Feb. 13, 1912	C
Porter, Alonzo W	146,778	Jan. 27, 1874	G
Poterie, George	453,386	June 2, 1891	W
Pray, Lyman	61,098	Jan. 8, 1867	S, F
Prentiss, E. F., and Robertson, R. A	48,435	June 27, 1865	U
Prentiss & Robertson	41,858	Mar. 8, 1864	F 2, 11
Price, C. P	1,273,091	July 16, 1918	F 2, 1
Price, Walter B	548,391	Oct. 22, 1895	D 1
Price, W. B., and Dietz, Ernest	1,349,294	Aug. 10, 1920	B
Price, W. B	522,028	June 26, 1894	G, D 1
Prichard, Geo. I	1,264,435	April 30, 1918	F 2, 11
Prichard, G. L	1,290,345	Jan. 7, 1919	I
Primose, John	1,389,978	Sept. 6, 1921	F
Propfe, H	478,265	July 5, 1892	F 1, 11
Prutzman, Paul W	1,397,113	Nov. 15, 1921	D
Prutzman, Paul W	1,238,331	Aug. 28, 1917	A
Prutzman, Paul, and Goodwin, G. L	1,339,792	Dec. 13, 1921	F
Puening, Franz	1,176,094	Mar. 21, 1916	K 2, S
Puening, Franz	1,358,174	Nov. 9, 1920	B
Pyzel, Daniel	1,040,408	Oct. 8, 1912	C
Puzel, Daniel	1,276,690	Aug. 20, 1918	S
Pyzel, Daniel	1,383,024	June 28, 1921	F 2
Quinby, Henry R	1,382,234	June 21, 1921	A P
Quinn, Abraham	31,998	April 9, 1861	F
Quinn, A	36,481	Sept. 16, 1862	F
Ramage, Alexander S	1,365,849	Jan. 18, 1921	D 1

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Rand, Alonzo C	62,362	Feb. 26, 1867	S
Rave, Chas	425,905	April 15, 1890	I, P
Reese, Jacob	38,602	May 19, 1863	S
Reese, Jacob	150,614	May 5, 1874	S
Reeves, S. H	1,302,090	April 29, 1919	T
Reeves, W. P	1,283,559	Nov. 5, 1918	S
Reilly, P. C	1,310,164	July 15, 1919	F, S
Rensink, G. C	1,134,419	April 6, 1915	A
Requa, Chas. W	77,094	April 21, 1868	F 1, 2, I
Restieux, Thos	63,749	April 9, 1867	V, D 1
Reynolds, F. R	1,119,453	Dec. 1, 1914	F 2
Rial, Wirt D	1,390,386	Sept. 13, 1921	F
Rice, L. M., and Adams, S. E	90,392	May 25, 1869	S
Richardson, Clifford	551,294	Dec. 10, 1895	E 3, A
Richardson, Wm. D	1,257,397	Feb. 26, 1918	P
Richardson, John E	65,275	May 28, 1867	C
Richter, Felix	1,098,763	June 2, 1914	D
Richter, Felix	1,098,764	June 2, 1914	D
Rites, F. M	1,167,021	Jan. 4, 1916	K 1, B
Rites, F. M	1,144,788	June 29, 1915	K 1, B
Rites, F. M	1,144,789	June 29, 1915	K 1, B
Rittman, Walter F	1,352,916–7	Sept. 14, 1920	B
Rittman, Walter F	1,330,008	Feb. 3, 1920	B
Rittman, Walter F	1,365,602	Jan. 11, 1921	B
Rittman, Walter F., and Dutton, Clarence B	1,365,603	Jan. 11, 1921	B
Rittman, Walter F., and Dutton, Clarence B	1,365,604	Jan. 11, 1921	B
Roberts, A. E., and Emery, A. L	1,016,958	Feb. 13, 1912	Q
Robertson, J. H	1,238,339	Aug. 28, 1917	B, P
Robinson, Clarence I	1,387,868	Aug. 16, 1921	D
Robinson, C. I	1,014,520	Jan. 9, 1912	I
Robinson, C. I	1,018,374	Feb. 20, 1912	F 1
Robinson, C. I	968,692	Aug. 30, 1910	D 1
Robinson, C. I	910,584	Jan. 26, 1909	V, D
Robinson, J. C	218,901	Aug. 26, 1879	F 2, II
Rodman, Hugh	1,209,336	Dec. 19, 1916	B
Rogers, Allen	1,378,424	May 17, 1921	B
Rogers, Davenport	211,055	Dec. 17, 1878	F 2, 4, II
Rogers, D	284,331	Sept. 4, 1883	F
Rogers, F. M	1,299,385	April 1, 1919	A
Rogers, F. M., and Cooke, T. S	1,122,220	Dec. 22, 1914	J
Rogers, Henry H	120,539	Oct. 31, 1871	F
Rogers, John	50,276	Oct. 3, 1865	F
Rogers, Lebbeus H	1,269,747	June 18, 1918	W
Rogers, M. C	1,148,990	Aug. 3, 1915	S
Rogers, Wm. B	60,559	Dec. 18, 1866	M
Roots, James	340,522	April 20, 1886	M, G
Rose, H. C	182,775	Oct. 3, 1876	F 1, 2, II
Rose, James R	1,252,033	Jan. 1, 1918	B, K 1
Rosen, Jean	1,165,909	Dec. 28, 1915	O
Rosen, Jean	1,162,654	Nov. 30, 1915	B
Rosenbaum, R. R	1,324,983	Dec. 16, 1919	B
Rosenbaum, R. R	1,332,359	Mar. 2, 1920	E
Rosenbaum, R. R	1,278,023	Sept. 3, 1918	C, E 2
Ross, S. J., and Schofield, H	1,204,492	Nov. 14, 1916	B
Roth, P., and Venturino, M. E	1,208,378	Dec. 12, 1916	B
Roth & Venturino	1,208,214	Dec. 12, 1916	B
Roth & Venturino	1,208,378	Dec. 12, 1916	B
Rowlands, P. O	1,252,955	Jan. 8, 1918	S
Rowsell, John	299,167	May 27, 1884	D 1
Rowsey, G. L	1,316,511	Sept. 16, 1919	F
Rudigier, Edw. A	1,386,077	Aug. 2, 1921	F
Ruff, F. C	1,263,289	April 16, 1918	D 1
Ruff, F. C	1,319,420	Oct. 21, 1919	B
Ruff, F. C	1,325,582	Dec. 23, 1919	B
Ryan, H. D	1,327,572	Jan. 6, 1920	W

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Ryder, Henry	142,515	Sept. 2, 1873	F, S
Ryder, Watson	214,199	April 8, 1879	F 1, H
Ryder, W., and Qualey, J. A	739,757	Sept. 22, 1903	F
Sabatier, P., and Malihe, A	1,124,333	Jan. 12, 1915	B, P
Sabatier, P., and Malihe, A	1,152,765	Sept. 7, 1915	B
Salathe, Frederick	452,764	May 19, 1891	T
Salathe, F.	564,341	July 21, 1896	T
Sampson, C. E., and Woods, W	1,177,816	April 4, 1916	B
Sangster, W. H	54,414	May 1, 1866	S, D
Sangster, W. H., and Spencer, T. C	56,276	July 10, 1866	F
Sargent, Thos. D	20,587	June 15, 1858	W
Saunders, H. F., and Sutherland, L. T	1,362,355	Dec. 14, 1920	L
Savage, Wallace	1,279,918	Sept. 24, 1918	E 1
Sawyer, G. T., Howland, W., Jr., and Hatch, T. C	33,905	Dec. 10, 186[illegible]	S
Saybolt, Geo. M	565,039	Aug. 4, 1896	D 1
Saybolt, G. M	989,927	April 18, 1911	J, K 2
Saybolt, G. M	218,066	July 29, 1879	N
Saybolt, G. M	245,658	Aug. 9, 1881	N
Schalk, Emil	146,405	Jan. 13, 1874	D
Schalk, Emil	133,598	Dec. 3, 1872	D, S
Schesch, H. A	54,218	April 24, 1866	F
Scheuffgen, Robert	1,118,952	Dec. 1, 1914	H
Schieffelin, S	1,381,936	June 21, 1921	W
Schildhaus, G., and Condrea, C	956,184	April 26, 1910	I
Schill, E	1,100,260	June 16, 1914	F, K 2
Schill, E	1,142,275	June 8, 1915	J, K 2
Schiller, Max	580,652	April 13, 1897	V
Schmidt, A. T	164,694	June 22, 1875	D
Schmidt, W. A., and Wolcott, E. R	1,307,930	June 24, 1919	B
Schubert, Julius	156,600	Nov. 3, 1874	A
Schwartz, Stephen	1,247,883	Nov. 27, 1917	B
Scott, John B	58,180	Sept, 18, 1866	M
Seeger, Robt	1,394,688	Oct. 25, 1921	B
Seeger, Robert	1,259,786	Mar. 19, 1918	B
Seely, E. D	57,390	Aug. 21, 1866	M
Seely, C. A	87,207	Feb. 23, 1869	F
Seibert, N. M., and Brady, J. D	1,290,369	Jan. 7, 1919	A
Seidenschur, F., and Dehnst, J	1,162,729	Nov. 30, 1915	B
Seigle, A	567,751	Sept. 15, 1896	F 1, H
Seigle, A	567,752	Sept. 15, 1896	F
Sellers, H. L., and Conyngton, H. R	549,499	Nov. 5, 1895	E 3
Setzler, H. B	1,292,966	Jan. 28, 1919	B
Sewell, B. F. Brooke	781,045	Jan. 31, 1905	F
Sexton, Wm. A	1,248,730	Dec. 4, 1917	A
Seymour, M. J	306,965	Oct. 21, 1884	A
Shapter, J. S	61,474	Jan. 22, 1867	F 1, 2, 5
Sharples, P. T	1,352,265	Aug. 31, 1920	C
Sharples, P. T	1,373,773	April 5, 1921	A
Shaw, F. D	1,098,412	June 2, 1914	K 1
Shaw, G. E	61,572	Jan. 29, 1867	N
Shaw, G. E	56,107	July 3, 1866	N
Sheets, Earl H	1,273,191	July 23, 1918	K 2, J
Sherman, L. O	968,088	Aug. 23, 1910	B
Sherman, L. O	1,260,584	Mar. 26, 1918	B, J
Sherman, L. O	1,288,711	Dec. 24, 1918	B
Shiner, O. J	1,099,622	June 9, 1914	D 1
Shively, Martin	613,728	Nov. 8, 1898	S
Shreves, F. G	1,297,022	Mar. 11, 1919	W
Shroder, Richard	16,255	Dec. 16, 1856	W
Simonson, Walter H., and Mantius, O	1,384,978	July 19, 1921	I
Skidmore, C. J., and Conerty, P. F	1,302,094	April 29, 1919	O
Slater, Wm. A	1,263,950	April 23, 1918	I
Slemmer, Henry T	52,897	Feb. 27, 1866	O
Sloane, W. M	109,772	Nov. 29, 1870	A
Sloane, W. M., and Potter, B. M	223,519	Jan. 13, 1880	C
Sloane, W. M., and Bell, Wm	235,057	Nov. 30, 1880	C

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Slocum, F. L., and Stutz, C. C	1,304,211	May 20, 1919	B
Slocum, F. L., and Stutz, C. C	1,304,212	May 20, 1919	B
Small, H. J., and Stillman, H	595,788	Dec. 21, 1897	D 1, F 2
Smedley, J. D	37,709	Feb. 17, 1863	S
Smith, A. D	1,239,423	Sept. 4, 1917	J, B
Smith, A. D	1,374,402	April 12, 1921	F, B
Smith, A. D	1,324,075	Dec. 9, 1919	B
Smith, C. A	558,747	April 21, 1896	V, D
Smith, H. C	300,811	June 24, 1884	F, II
Smith, Hamilton L	60,585	Dec. 18, 1866	S
Smith, H. L	60,076	Nov. 27, 1866	F 2, 4, I
Smith, H. J., and Jones, W	35,184	May 6, 1852	N
Smith, Rolin H	306,653	Oct. 14, 1884	C
Smith, Wm	23,719	April 19, 1859	G, S
Smith, Wm. A	596,437	Dec. 28, 1897	V
Smothers, H. F., and Norquist, E. E	1,261,337	May 14, 1918	Q
Snee, J. A	1,165,458	Dec. 28, 1915	K 2
Snelling, Walter O	1,371,268	Mar. 15, 1921	B
Snelling, Walter O	1,056,845	Mar. 25, 1913	J, K, 2, B
Snelling, Walter O	1,186,855	June 13, 1916	F 1
Snelling, W. O	1,215,732	Feb. 13, 1917	V
Snow, Wm. B	130,668	Aug. 20, 1872	S
Snow, Wm. B	137,496	April 1, 1873	S
Soderlund & Boberg	1,252,962	Jan. 18, 1918	F 2
Sommer, Adolph	525,696	Sept. 11, 1894	V
Sommer, Adolph	523,716	July 31, 1894	V
Southey, A. W	1,120,857	Dec. 15, 1914	K 1
Spangle, George W	58,905	Oct. 16, 1866	D
Sparie, & Masland	695,123	Mar. 11, 1902	M
Spears, Wm	107,734	Sept. 27, 1870	F, G
Spier, Robert, and Mather, J	168,060	Sept. 21, 1875	U
Speller, F. N	774,341	Nov. 8, 1904	N
Squires, Frederick	1,249,232	Dec. 5, 1917	J, K 2
Squire, F. B	197,197	Nov. 13, 1877	N
Stafford, Jas. B	10,813	April 25, 1854	U
Stapp, A. A	1,324,212–13	Dec. 9, 1919	B
Stanley, A. M	1,177,904	April 4, 1916	K 1
Starke, Eric A	597,920	Jan. 25, 1898	D 1
Starke, E. A	781,240	Jan. 31, 1905	E 3, B
Starke, E. A	913,780	Mar. 2, 1909	D, F 2
Starke, E. A	1,109,187	Sept. 1, 1914	D 1
Stearns, H. A	103,385	May 24, 1870	F 2, II
Steenbergh, B. Van	1,124,364	Jan. 12, 1915	K 1, B
Steinschneider, ——	1,302,988	May 6, 1919	S
Steinschneider, Leo	981,953	Jan. 17, 1919	F 5
Steinschneider, Leo	1,192,581	July 25, 1916	F 5
Stelwagon, W. H	503,996	Aug. 29, 1893	S
Stephens, Sam F	1,375,427	April 19, 1921	B
Stevens, E. W	1,374,199	April 5, 1921	B, P
Stevens, Levi	363,432	May 24, 1887	F 2
Stevens, Levi	414,601	Nov. 5, 1889	B
Stevens, Wm. H	1,165,462	Dec. 28, 1915	M
Stewart, John	24,587	June 28, 1859	W
Stewart, J. L	162,965	May 4, 1875	F 2, II
Stewart, J. L., and Logan, J. P	113,811	April 18, 1871	F
Stewart, J. L., and Dubler, J. B	136,557	Mar. 4, 1873	S
Stewart, Lyman	1,163,570	Dec. 7, 1915	B
Still, Carl	1,080,177	Dec. 2, 1913	S
Stombs, D. S., and Brace, J	27,842	April 10, 1860	G
Stone, C. W	1,070,555	Aug. 19, 1913	A
Stott, Chas	68,257	Aug. 19, 1867	F 1, 2
Strache, H., and Porges, P	1,205,578	Nov. 21, 1916	B
Straight, Halver R	1,330,014	Feb. 3, 1920	W
Straight, H. R	1,323,204	Nov. 25, 1919	W
Strain, E. W	311,543	Feb. 3, 1885	F 1, 2, II
Strather, W. P	1,326,618	Dec. 30, 1919	O
Street, G. E. J	695,123	Mar. 11, 1902	M

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Stringfellow, John H. W	454,777	June 23, 1891	D
Stuber, John, Stuber, Jacob, and Mager, John W	123,741	Feb. 13, 1872	F 1, 2, H
Stutz, C. C	1,359,931	Nov. 23, 1920	B
Suckert, Julius	534,295	Feb. 19, 1895	V
Suhr, C. L	1,122,169	Dec. 22, 1914	F 2, H
Swan, O. C	1,250,526	Dec. 18, 1917	A
Swan, O. C	1,284,945	Nov. 12, 1918	S
Swaton, J. A	1,260,731	Mar. 26, 1918	B
Sylvester, F	68,669	Sept. 10, 1867	A
Symmes, H. K	26,000	Nov. 1, 1859	G
Symonds, D	65,136	May 28, 1867	V
Symonds, D	65,137	May 28, 1867	V
Taber, Geo. H., Jr	1,363,487	Dec. 28, 1920	K, J
Tagliabue, Chas. J	265,462	Oct. 3, 1882	F 1, 2, 3, 4, H
Tagliabue, Chas. J	254,176	Feb. 28, 1882	F 1, 2, H
Tagliabue, Chas. J	1,263,145	April 16, 1918	N
Tagliabue, Giuseppe	36,826	Oct. 28, 1862	N
Tagliabue, Giuseppe	38,427	May 5, 1863	N
Tagliabue, John	38,488	Sept. 16, 1862	N
Tait, A. H	96,997	Nov. 16, 1869	S
Tait, E. W	1,069,908	Aug. 12, 1913	J, K 2
Tait, G. M. S	1,128,549	Feb. 16, 1915	K 1, B
Tait, A. H., and Avis, J. W	53,359	Mar. 20, 1866	F 2, 3, H
Tait & Avis	63,115	Mar. 19, 1867	F 1
Tait & Avis	135,673	Feb. 11, 1873	F 2, H
Tatro, Jos. A	99,728	Feb. 8, 1870	D 1
Tatro, Jos. A	106,233	Aug. 9, 1870	D 1
Taveau, Rene de M	1,271,387	July 2, 1918	I, E 1
Taylor, H. K., and Graham, D. M	54,978	May 22, 1866	D 1
Taylor & Graham	59,751	Nov. 20, 1866	D 1
Tempere, Albert J	557,291	Mar. 31, 1896	V, D
Testellin, A., and Renard, G	1,138,260	May 4, 1915	B
Theisen, Eduard	552,456	Dec. 31, 1895	F
Thiesen, Eduard	552,456	Dec. 31, 1895	F
Thiele, Felix Co	683,354	Sept. 24, 1901	D 1
Thiele, Felix Carl	1,254,866	Jan. 29, 1918	L
Thirault, A	61,120	Jan. 8, 1867	F 4, H
Thirault, A	41,871	Mar. 8, 1864	
Thirault, A	63,963	April 16, 1867	F 2
Thomas, John J	178,889	June 20, 1876	S
Thomas, Joshua	282,239	July 31, 1883	F, H
Thomas, Joshua	314,490	Mar. 24, 1885	F 2
Thomas, Richard	781,854	Feb. 7, 1905	S
Thompson, N. W	1,298,602	Mar. 25, 1919	S
Thompson, W. P	1,160,670	Nov. 16, 1915	B
Thumm, Chas. F	389,988	Sept. 25, 1888	F 2, 4
Thurlow, E. W	1,343,100	June 8, 1920	W
Thursby, John	3,067	May 2, 1843	M
Tiemann, Julius H	321,165	July 7, 1885	D 1
Tiemann, J. H	330,637	Nov. 17, 1885	D 1
Tienen, W. O. Th. van	1,000,646	Aug. 15, 1911	I
Tilton, Ole	204,943	Nov. 12, 1878	F 2, 4
Timmons, J. R	1,105,383	July 28, 1914	F 1, H
Timmons, and Swain, O	1,179,243	April 11, 1916	F 1
Timmons, J. R	1,279,611	Sept. 24, 1918	A
Tokheim, J. J	1,248,951	Dec. 4, 1917	A
Travers, W. J	1,604,219	Sept. 26, 1911	A
Treneer, J. M., and Benjamin, C. S	1,392,370	Oct. 1, 1921	D
Trewby, G. C., and Fenner, H. W	252,981	Jan. 31, 1882	F 2
Trotter, Jas. Wilson	1,339,727	May 11, 1920	B
Trumble, Milton J	996,736	July 4, 1911	S, F
Trumble, M. J	1,349,794	Aug. 17, 1920	B
Trumble, M. J	1,002,474	Sept. 5, 1911	F 1, H
Trumble, M. J	1,070,361	Aug. 12, 1913	F 2, H
Trumble, M. J	1,182,601	May 9, 1916	E 2, F 2, H

UNITED STATES PETROLEUM PATENTS (TO JANUARY, 1922)—Continued.

NAME	Number	Date	Class
Trumble, M. J	1,250,052	Dec. 11, 1917	F, S
Trumble, M. J	1,259,171	Mar. 12, 1918	F 2, A
Trumble, M. J	1,260,598	Mar. 26, 1918	F
Trumble, M. J	1,262,875	April 16, 1918	F
Trumble, M. J	1,269,134	June 11, 1918	K 2, S
Trumble, M. J	1,304,125	May 20, 1919	B
Trumble, M. J	1,304,124	May 20, 1919	A
Trumble, M. J	1,281,884	Oct. 15, 1918	B
Tschudy, Frederick	1,348,606	Aug. 3, 1920	F
Turner, C. W	1,046,683	Dec. 10, 1912	B
Turner, C. W	1,151,422	Aug. 24, 1915	B
Turner, R. D	194,275	Aug. 14, 1877	A, V
Turner, R. D	154,430	Aug. 25, 1874	A
Turner, R. D	156,899	Nov. 17, 1874	S, F
Tweedle, Herbert W. C	120,349	Oct. 24, 1871	D
Tweedle, Herbert W. C	189,401	April 10, 1877	T
Tweedle, Herbert W. C	189,402	April 10, 1877	T
Tweedle, Herbert W. C	45,363	Dec. 6, 1864	K 2
Tweedle, Herbert W. C	72,125	Dec. 10, 1867	F 2, 5, II
Tweedle, Herbert W. C	72,126	Dec. 10, 1867	F 2, 5, II
Tweedle, Herbert W. C	34,324	Feb. 4, 1862	G, F 2, 5, II
Tyler, Cbas. N	38,015	Mar. 24, 1863	M
Ujhely, Heinrich	289,788	Dec. 4, 1883	D
Ujhely, H., and Buerie, C	131,137	Sept. 3, 1872	C
Upham, Ricbard D	512,494	Jan. 9, 1894	E 3
Van Devort, C., and Van Fleet, C	168,542	Oct. 5, 1875	F 2
Van Dyke, J., and Irish, Wm	1,095,438	May 5, 1914	B
Van Dyke & Irish	1,073,548	Sept. 16, 1913	B
Van Dyke & Irisb	1,143,466	June 15, 191	B
Van Dyke & Irish	1,130,862	Mar. 9, 1915	B
Van Syckel, Samuel	191,203	May 22, 1877	F, II
Van Syckel, Samuel	140,801	July 15, 1873	F 2
Van Syckel, Samuel	152,440	June 23, 1874	F, II
Van Syckel, Samuel	126,503	May 7, 1872	S
Van Syckel, Samuel	154,772	Sept. 8, 1874	F, II
Van Syckel, Samuel	154,771	Sept. 8, 1874	U
Van Syckel, Samuel	143,945	Oct. 21, 1873	K 2
Van Syckel, Samuel	110,516	Dec. 27, 1870	F 2, I
Van Syckel, Samuel	191,204	May 22, 1877	F, II
Van Tine, Henry C	60,290	Dec. 4, 1886	D
Van Vliet, L., and O'Neill, F	1,094,762	April 28, 1914	K 1
Van Wyck, C. I	27,603	Mar. 20, 1860	W
Van Wyck, William	65,313	May 28, 1867	S
Vander Weyde, Peter H	104,798	June 28, 1870	N
Vander Weyde, P. H	61,125	Jan. 8, 1867	A
Vander Weyde, P. H	58,005	Sept. 11, 1866	F 2, 4, 5, II
Vander Weyde, P. H	53,062	Mar. 6, 1866	F
Vaughan, Aaron C	53,709	April 3, 1866	G
Vaughan, John Ives	49,689	Aug. 29, 1865	F 1, 2, II
Van Boyen, Edgar	689,381	Dec. 24, 1901	C
Van Boyen, Edgar	690,693	Jan. 7, 1902	C
Von Groeling, A. J	1,295,088	Feb. 18, 1919	B
Von Groeling, A. J	1,327,184	Jan. 6, 1920	F
Von Groeling, A. J	1,378,066	May 17, 1921	F
Von Tilburg, F. E	1,326,230	Dec. 30, 1919	B
Vuilleumier, Rudolph	1,038,691	Sept. 17, 1912	K 1, B
Waddell, Alexander	1,249,864	Dec. 11, 1917	K 1
Wade, Henry Clay	1,336,450	April 13, 1920	B
Waitz, J. W	1,105,727	Aug. 4, 1914	J, K 2
Walker, Henry V	972,953	Oct. 18, 1910	D 1
Walker, H. V	955,372	April 19, 1910	V
Walker, W. E	1,037,280	June 17, 1919	L, K
Wallace, Geo. W	1,283,000	Oct. 29, 1918	W
Wallace, Geo. W	1,382,001	Oct. 29, 1918	F, W

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NAME	Number	Date	Class
Wallace, John Stewart, and Cowell, W. B.	716,132	Dec. 16, 1902	D
Wardell, H. R.	1,385,511	July 26, 1921	E
Warden, Henry	266,929	Oct. 31, 1882	C
Warden, Wm. G	240,937	May 3, 1881	S
Warden, Wm. G	240,036	May 3, 1881	S, D
Warden, Wm. G	110,806	Jan. 3, 1871	F 1, II
Warden, Wm. G	112,751	Mar. 14, 1871	F 1
Warfield, R. N	40,068	Sept. 22, 1863	V
Waring, Richard S	284,098	Aug. 28, 1883	T
Waring, Wilson	643,578	Feb. 13, 1900	I
Warren, Cyrus M	248,074	Oct. 11, 1881	T
Warren, Cyrus M	47,235	April 11, 1865	U
Warren, John	97,998	Dec. 14, 1869	F
Warren, John	102,186	April 19, 1870	S
Warren, John W	705,168	July 22, 1902	V
Warren, John W	666,446	Jan. 22, 1901	V
Warren, M. H.	1,110,361	Sept. 15, 1912	B
Warth, C. H.	1,131,880	Mar. 16, 1915	F 2, II, G
Washburn, C. H.	1,138,266	May 4, 1915	B
Webster & Boynton	1,361,940	Dec. 14, 1920	I
Wehr, Austin A.	1,340,427	May 18, 1920	H, J
Weisenberger, P.	54,984	May 22, 1866	D 1
Weiser, Josef	1,127,951	Feb. 9, 1915	S
Weizmann, Chas., and Leff, D. A.	1,395,620	Nov. 1, 1921	L
Welles, Wm. C.	61,291	Jan. 15, 1867	S
Wellman, Frank E.	1,390,002	Sept. 6, 1921	B
Wellman, Frank E.	1,328,468	Jan. 20, 1920	B
Wellman, Frank E.	1,362,160	Dec. 14, 1920	B
Wellman, Frank E.	1,335,767	April 6, 1920	B
Wellman, Frank E.	1,335,769	April 6, 1920	B
Wellman, Frank E.	1,347,664	July 27, 1920	B
Wellman, Frank E.	1,347,567	July 27, 1920	B
Wellman, Frank E.	1,347,568	July 27, 1920	B
Wellman, F. E.	1,275,337	Aug. 13, 1918	B
Wellman, F. E.	1,245,291	Nov. 6, 1917	B, S
Wells, A. A.	1,232,454	July 3, 1917	B
Wells, A. A.	1,187,874	June 20, 1916	B
Wells, A. A.	1,248,225	Nov. 27, 1917	B, J
Wells, Raymond	1,267,611	May 28, 1918	A
Wells, Raymond	1,357,365	Nov. 2, 1920	A
Wells, W. C., and Wells, F. E.	1,350,482	Aug. 24, 1920	O, C
Wells, W. C., and Wells, F. E.	877,620	Jan. 28, 1908	F 1, 3, II
Wells, W. C., and Wells, F. E.	1,296,244	Mar. 4, 1919	F
Welsh, M. J.	1,159,450	Nov. 9, 1915	C
Wemple, H. R.	1,262,886	April 16, 1918	K 1
Wendtland, August	618,307	Jan. 24, 1899	C
Weston, Elijah	219,546	Sept. 9, 1879	S
Wetmore, I. W.	39,978	Sept. 15, 1863	U
Wheeler, Milloughby MacBain	1,387,876	Aug. 16, 1921	B
Wheeler, Norman W	52,477	Feb. 6, 1866	S
Whitall, Frank M	768,101	Aug. 23, 1904	T
Whitall, Samuel	734,482	July 21, 1903	T
White, Carter	1,226,041	May 15, 1917	B
Whiting, Jas. R.	622,936	April 11, 1890	S
Whlting, J. R., and Lawrence, W. A.	583,779	June 1, 1897	V
Whitman, J. C.	1,312,375	Aug. 5, 1919	O, S
Whitmore, Samuel W	1,125,422	Jan. 19, 1915	F 1, II
Wickersham	1,376,180	April 26, 1921	B, P
Wiegand, S. Lloyd	39,607	Aug. 18, 1863	F 2
Wiegand, S. Lloyd	62,583	Mar. 5, 1867	C
Wiggins, Isaac B.	63,777	April 9, 1867	M
Wilber, William	23,210	Mar. 8, 1859	M
Wilcox, L. N.	49,020	July 25, 1865	F
Wilkinson, Asa W	115,707	Dec. 16, 1873	F 3
Wilkinson, Walter S.	512,348	Jan. 9, 1894	E 3
Wilkinson, Walter S.	597,892	Jan. 25, 1898	E 3
Willard, Franklin W	26,739	Jan. 3, 1860	G, S

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NAME	Number	Date	Class
Willard, Franklin W	27,503	Mar. 13, 1860	F
Willard, Franklin W	27,327	Feb. 28, 1860	G, S
Williams, R. A., and Bragg, J	304,390	Sept. 2, 1884	S
Willis, Geo. M	918,628	April 20, 1909	E 3
Wilson, R. J	379,090	Mar. 6, 1888	F 4
Wingett, John N	1,229,189	June 5, 1917	P
Wintz, Jas. P	807,983	Dec. 19, 1905	D
Wirkner, George von	783,916	Feb. 28, 1905	D 1
Wohle, Salo	1,081,801	Dec. 16, 1913	K 1
Wolf, Herman	604,280	May 17, 1898	D 1
Wolf, Linus	1,265,573	May 7, 1918	K 1
Wolff, Albert	1,240,523	Sept. 28, 1917	D
Wright, E. H., and Atwood, E. H	1,278,280	Sept. 10, 1918	F
Wright, R. K	1,316,214	Sept. 16, 1919	F
Wingett, J. N	1,384,878	July 19, 1921	W
Wynne, Edward W	901,411	Oct. 20, 1908	D
Wynne, Edw. William	1,351,458	Aug. 31, 1920	P, F
Yaley, Theodore E	1,329,450	Feb. 3, 1920	B
Yaryan, Homer T	300,185	June 10, 1884	F 2, 5, II
Yates, Robert	1,395,075	Oct. 25, 1921	B
Young, Alex V	1,378,643	May 17, 1921	B
Young, W. H	62,798	Mar. 12, 1867	O
Young, Wm. Herbert	1,378,307	May 17, 1921	B
Yunck, John A	1,345,656	July 6, 1920	B
Zerning, Herman	1,183,266	May 16, 1916	J, K 2, B
Zimmering, August F	313,795	Mar. 10, 1885	M

BOOKS ON PETROLEUM, ASPHALT AND NATURAL GAS.

Abady—Gas Analyst's Manual	$ 6.50
Abraham—Asphalts and Allied Substances	5.00
Aisinmann—Taschenbuch fur die Mineralol-Industrie. 8 vo. Berlin, 1896	....
Allen—Modern Power Gas Producer	2.50
American Society for Testing Materials—1921 Berky Standard	5.00
Archbutt and Deeley—Lubrication and Lubricants. 8 vo. London, 1912	....
Arnold & Darnell—Manual for the Oil and Gas Industry	2.50
Bacon and Hamor—The American Petroleum Industry	12.00
Baker—Roads and Pavements	5.00
Battle—Lubricating Engineer's Handbook	4.00
Battle—Industrial Oil Engineering	....
Berlinerblau—Das Erdwachs, Ozokerit und Cerestin. 8 vo. Brunswick, 1917	....
Booth—Liquid Fuel	3.00
Boorman—Asphalts: Their Sources and Utilizations	2.60
Brannt—Petroleum: Its History, Origin, Occurrence, Production, Physical and Chemical Constitution, Technology, Examination and Uses. Philadelphia and London, 1895	....
Butler—Oil Fuel: Its Supply, Composition and Application	2.25
Campbell—Petroleum Refining	8.50
Clowes and Redwood—The Detention and Measurement of Inflammable Gas and Vapor in the Air. 8vo. London, 1916	....
Cooper-Key—Storage of Petroleum Spirit. London, 1914	....
Coste—Calorific Power of Gas	2.00
Cox—Field Methods	4.00
Craig—Oil Finding	2.40
Crew—A Practical Treatise on Petroleum. 8vo. Philadelphia, 1887	....
Danby—Natural Rock Asphalts and Bitumens	2.50
Day—Handbook of the Petroleum Industry 1922	....
Delano—Twenty Years' Practical Experience of Natural Asphalt and Mineral Bitumen. 8vo. London and New York, 1893	....
Dennis—Gas Analysis	2.10
Deutsch (De la Meurthe)—Le Petrole et ses Application. Paris, N. D.	....
Dowson and Larter—Producer Gas	3.00
Dunn—Industrial Uses of Fuel Gas	3.00
Ellis & Meigs—Gasoline and Other Motor Fuels	6.00
Emmons—Geology of Petroleum	1.00
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Gas Chemist's Handbook	
Gibbings—Oil Fuel Equipment for Locomotives and Principles of Application	2.50
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Gregorius—Mineral Waxes: Preparation and Uses	2.50
Hager—Oil Field Motors	3.00
Hager—Practical Oil Geology	

BOOKS ON PETROLEUM, ASPHALT AND NATURAL GAS—Continued.

Hamor & Padgett—Examination of Petroleum.......................$ 6.00
Hempel—Methods of Gas Analysis....................... 2.25
Hicks—Laboratory Book of Mineral Oil Testing....................... 1.00
Hofer—Das Erdol (Petroleum) und Steine Verwandten. Brunswick, 1888 ....
Holde-Muller—Examination of Hydrocarbon Oils....................... 5.00
Hubbard—Laboratory Manual of Bituminous Materials....................... ....
Hubbard—Dust Preventives and Road Binders....................... 3.00
Jaccard—Le Petrole, L'Asphalte, et le Bitume au Point de vue Geologigue. Paris, 1895....................... ....
Guttentag, W. E.—Petrol and Petroleum Spirits, Sources, Preparation, Examination, Uses....................... 3.40
Johnson and Huntley—Principles of Oil and Gas Production.... 4.50
Judson—City Roads and Pavements....................... 2.00
Road Preservation and Dust Prevention....................... 1.50
King-Knight Co.—Oil Flow in Pipe Lines (San Francisco)........ 3.00
Lewes—Liquid and Gaseous Fuels....................... 2.00
Lunge—Technical Gas Analysis....................... 4.00
Marvin—The Petroleum Industry of Southern Russia. 4to. London, 1884 ....
The Region of the Eternal Fire; An Account of a Journey to the Petroleum Region of the Caspian in 1883. 8vo. London, 1884 ....
The Petroleum of the Future. Baku, the Petrolia of Europe. 8vo. London, 1883....................... ....
The Moloch of Paraffin. 8vo. London, 1886....................... ....
The Coming Deluge of Russian Petroleum, and its Bearings on British Trade. 1887....................... ....
England As a Petroleum Power, or the Petroleum Fields of the British Empire. London, 1887....................... ....
Our Unappreciated Petroleum Empire. 8vo. London, 1889 ....
The Coming Oil Age: Petroleum—Past, Present, and Future. 8vo. London, 1889....................... ....
Mills—Destructive Distillation: A Manualette of the Paraffin, Coal-Tar, Rosin Oil, Petroleum, and Kindred Industries. London, 1887 ....
Neuberger—Technology of Petroleum 9.00
Neuberger and Noalhat—Technology of Petroleum. Paris........ 10.00
North-Oil Fuel 2.00
Paine and Stroud—Oil Production Methods 3.00
Panvity—Prospecting for Oil and Gas....................... 3.25
Peckham—Solid Bitumens 5.00
Pforzheimer & Co., 25 Broad St., New York City—Independent Oil Stocks, 1921....................... ....
Pogue—Economics of Petroleum, 1921....................... 6.00
Redwood—Mineral Oils and Their By-Products....................... 5.40
Petroleum and Its Products. (3 vol.)....................... 13.50
Redwood and Eastlake—Petroleum Technologist's Pocketbook.... 3.00
Richardson—Asphalt Construction for Pavements and Highways 2.00

BOOKS ON PETROLEUM, ASPHALT AND NATURAL GAS—Continued.

Riche-Halphin—Le Petrole. Paris, 1896	$ ....
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Singer—Beitrage zur Theorie der Petroleum-bildung. Zurich, 1892	....
Southcombe—Chemistry of the Oil Industries	3.00
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Tecklenburg—Handbuch der Tiefbohrkunde. 6 Bde. Leipzig, 1886-1896	....
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Thomson and Redwood—Handbook on Petroleum	2.70
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Vieth—Das Erdol und seine Verarbeitung. Brunswick, 1892	....
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Westcott—Handbook of Natural Gas	....
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U. S. Government Publications on Petroleum, Asphalt and Natural Gas.

BUREAU OF MINES TECHNICAL PAPERS.

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No. 134. The use of mud-laden fluid in oil and gas wells.
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No. 206. Petroleum laws.

BUREAU OF STANDARDS.

Action of sunlight and air upon some lubricating oils. 1911. (Standards Reprint 153.) 5c.

Behavior of high-boiling mineral oils on heating in air. 1911. (Standards Reprint 160.) 5c.

Data on oxidation of automobile cylinder oils. 1916. (Standards Technologic Papers 73.) 5c.

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Effect of adding fatty and other oils upon carbonization of mineral lubricating oils. 1911. (Standards Technologic Papers 4.) 5c.

Evaporation test for mineral lubricating and transformer oils. 1913. (Standards Technologic Papers 13.) 5c.

Fluorescent test for mineral and rosin oils. 1911. (Chemistry Circular 84.) 5c.

Iodine number of linseed and petroleum oils. 1914. (Standards Technologic Papers 37.) 10c.

Modification of Herzfeld-Bohme method for detection of mineral oil in other oils. 1912. (Chemistry Circular 85.) 5c.

Oil films on water and on mercury. (In Smithsonian Report 1913, pages 261-273, illus.) Cloth $1.10.

United States standard tables for petroleum oils. 1916. (Standards Circular 57.) 15c.

Determination of ammonia in illuminating gas. 1914. (Standards Technologic Papers 34.) 10c.

Determination of sulphur in illuminating gas. 1913. (Standards Technologic Papers 20.) 10c.

Industrial gas calorimetry. 1914. 150 pages illus. (Standards Technologic Papers 36.) 40c.

Lead acetate test for hydrogen sulphide in gas. 1914. 46 pages, illus. (Standards Technologic Papers 41.) 25c.

Legal specifications for illuminating gas. 1913. (Standards Technologic Papers 14.) 10c.

London sliding scale for gas. 1909. (60th Congress, S. Doc. 696.) 5c.

On definition of ideal gas. 1910. (Standards Reprint 136.) 5c.

Standard methods of gas testing. 1917. 202 pages, illus. (Standards Circular 48.) 40c.

Standards for gas service. 3d edition. 1915. 197 pages. (Standards Circular 32.) 35c.

Supersedes 1st edition with title, "State and municipal regulations for gas," and 2d edition entitled, "Standard regulations for manufactured gas and gas service."

U. S. GEOLOGIC SURVEY.

Annual Reports of Geological Survey. 22d. 1901. Part 1 Director's Report and paper on asphalt and bituminous rock deposits. 464 pages, illus., maps. $1.60.

Bulletin No. 365. Fractionation of crude petroleum by capillary diffusion. 1908. 10c.

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Water Supply Papers 113. Disposal of strawboard and oil-well wastes. 1905. 5c.
Mineral Resources of U. S.—Non-metals. Part II (yearly).
Asphalt and Bituminous rock deposits of United States. (In Geological Report 1901, pt. 1, pp. 209-452, 52 plates, illus. maps.) Cloth, $1.60.
Asphaltum deposits of California. (In Mineral Resources, 1883-4, pp. 938-948.) Cloth, 60c.
Asphaltum, production, importation, commercial applications, history of paving industry, etc. (In Mineral Resources, 1893, pp. 627-669.) Cloth, 50c.

AGRICULTURAL DEPARTMENT.

Effect of controllable variables upon penetration test for asphalts and asphalt cements. (In Journal of Agricultural Research, Jan. 24, 1916, pp. 805-818.) 10c.
Bitumens and their essential constituents for road construction and maintenance. 1911. (Roads Circular 93.) 5c.
Methods for examination of bituminous road materials. 1915. (Agricultural Bulletin No. 314.) 10c.
Macadam roads. Construction of macadam roads. 1907. (Roads Bulletin No. 29.) 10c.
Macadam Roads. 1908. (Farmer's Bulletin No. 338.) 5c.
Use of mineral oil in road improvement. (In Agricultural Yearbook, 1902, pp. 439-454, illus.) Cloth, 85c.

SMITHSONIAN INSTITUTION—U. S. NATIONAL MUSEUM.

Bulletin No. 102, part 6. Petroleum. A resource interpretation.

PETROLEUM TRADE JOURNALS.

	Published at
California Derrick.	San Francisco, Calif.
The California Oil World	Bakersfield, Calif.
Coalinga Oil Record	Coalinga, Calif.
Gulf Coast Oil News	Houston, Texas
Journal du Petrole	Paris
National Petroleum News	Cleveland, Ohio
Natural Gas and Gasoline Journal	New York
Mining and Oil Bulletin	San Francisco

PETROLEUM TRADE JOURNALS—Continued.

Oil Weekly	Houston, Tex.
Oil News	Chicago, Ill.
Oil Age	Los Angeles, Cal.
Journal Inst. Pet. Technologists	
Oil Trade Journal	New York
Oil City Derrick	Oil City, Pa.
Oil & Gas Journal (The Oil Investors' Journal)	Tulsa, Okla.
Oil and Gas News	Kansas City, Mo.
Oildom	New York City, N. Y.
The Oil Industry	Los Angeles, Calif.
Oil News	London, Chicago
Petroleum Reporter	New York
International Petroleum Refiner	Kansas City, Mo.
Petroleum Age	Chicago, Ill.
The Petroleum Gazette	Titusville, Pa.
The Petroleum Review	London
The Petroleum World—PetroleumTimes	London
Journal of Gas Lighting	Chicago, Ill.
Gas Record	Chicago, Ill.
Gas Engineering	New York City, N. Y.

IMPORTANT SCIENTIFIC JOURNALS AND SOCIETY PUBLICATIONS.

(With articles on Petroleum, Asphalt and Natural Gas.)

Chemical Abstracts of American Chemical Society	Easton, Pa.
Journal of Industrial and Engineering Chemistry	New York City, N. Y.
Journal of American Chemical Society	Easton, Pa.
Chemical and Metallurgical Engineering	New York City, N. Y.
Engineering and Mining Journal	New York City, N. Y.
Engineering News Record	New York City, N. Y.
Journal of the Society of Chemical Industry	London
American Society for Testing Materials	Philadelphia, Pa.
Journal of the Franklin Institute	
International Society for Testing Materials	Philadelphia, Pa.
Institute of Mining Engineers	New York City, N. Y.

State Geological Survey Publications on Petroleum, Asphalt and Natural Gas.

ALABAMA.

Circular No. 3. Concerning oil and gas in Alabama, by E. A. Smith.
Bulletin No. 10. The Fayette Gas Field.
Bulletins Nos. 20, 22, 23, 28, 31, 33, 35.

CALIFORNIA.

Petroleum Resources of California.

KANSAS.

Vol. IX. Oil and Gas.
Bulletin No. 3. Oil and Gas Resources of Kansas.

KENTUCKY.

Vol. I, Series V, No. 1. Oil and Gas

MICHIGAN.

Publication No. 14, Series No. 11. Occurrence of oil and gas in Michigan.
Publication No. 19, Series No. 16.

MINNESOTA.

Bulletin No. 5, 1889. Natural Gas in Minnesota. N. H. Winchell. 39 p.

MISSISSIPPI.

No. 15. Oil and Gas Prospecting in Mississippi. By E. N. Lowe.

MISSOURI.

Vol. III, No. 4. Missouri School of Mines—Production of Oils and Tars from Bituminous Materials.

NEBRASKA.

Vol. 4, Part 25. Natural Fuels of Nebraska.

NEW YORK.

Vol. 6, No. 30. Petroleum and Natural Gas in New York, by Edward Orton.

OHIO.

Bulletin No. 1. Oil and Gas.
A New Geological Map of Ohio.
Bulletin No. 12. The Bremen Oil Field.
Vol. VI. Geology and Petroleum and Natural Gas.

OKLAHOMA.

Circular No. 8. Methods of exploring for oil and gas.
Handbook of Natural Resources of Oklahoma.
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Bulletin No. 19. Part I, 1915. Petroleum and Natural Gas.
Part II, 1917. Petroleum and Natural Gas.

PENNSYLVANIA.

Reports I, 12, 13, 14 and J. Bituminous coal fields.
Report L for the Pittsburgh gas well and the use of gas in iron manufacture.
Reports Q, Q2, Q3 and Q4 for reference to oil rocks in Beaver, Lawrence, Mercer, Crawford, Erie and S. Butler Counties.
Report K for the Dunkard Creek oil wells of Green County.
Reports R, R2 for description of oil rocks in McKean, Elk and Forest County.
Reports V. V2 for notes on the oil rocks of N. Butler and Clarion County.
Report H2 for oil boring at Cherry Tree, Cambria County.
Report G5 for oil boring in Wayne County.
Annual Report, 1885, for report of the progress in oil and gas region, with special facts relating to the geology and physics of natural gas.
Grand Atlas Div. III, Part I, under Bituminous Coal Fields.
Annual Reports, 1886, Part II.

SOUTH DAKOTA.

Circular No. 4. Possibilities of oil and gas in Harding County.
Circular No. 1. Oil in South Dakota.

TENNESSEE.

Vol. II. No. 2, No. 7.
Vol. V. No. 4.
Vol. VI. No. 1.
Vol. VII. No. 1, No. 4.
Vol. VIII. No. 3.

TEXAS.

Texas University Bulletin 246. Geology of Oil and Gas fields of Wichita and Clay Counties.
Texas University Bulletin No. 66. Thrall Oil field.
Texas University Bulletin No. 44. Review of Geology of Texas.

WEST VIRGINIA.

Coal, oil, gas, limestone and iron ore map.
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Vol. Ia. Petroleum and Natural Gas.

WYOMING.

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