

• N76 12482

PHOTOVOLTAIC APPLICATIONS OF
COMPOUND PARABOLIC CONCENTRATOR (CPC)

GRANT: 31-109-ENG-38

ORGANIZATION PERFORMING WORK: ARGONNE NATIONAL
LABORATORY

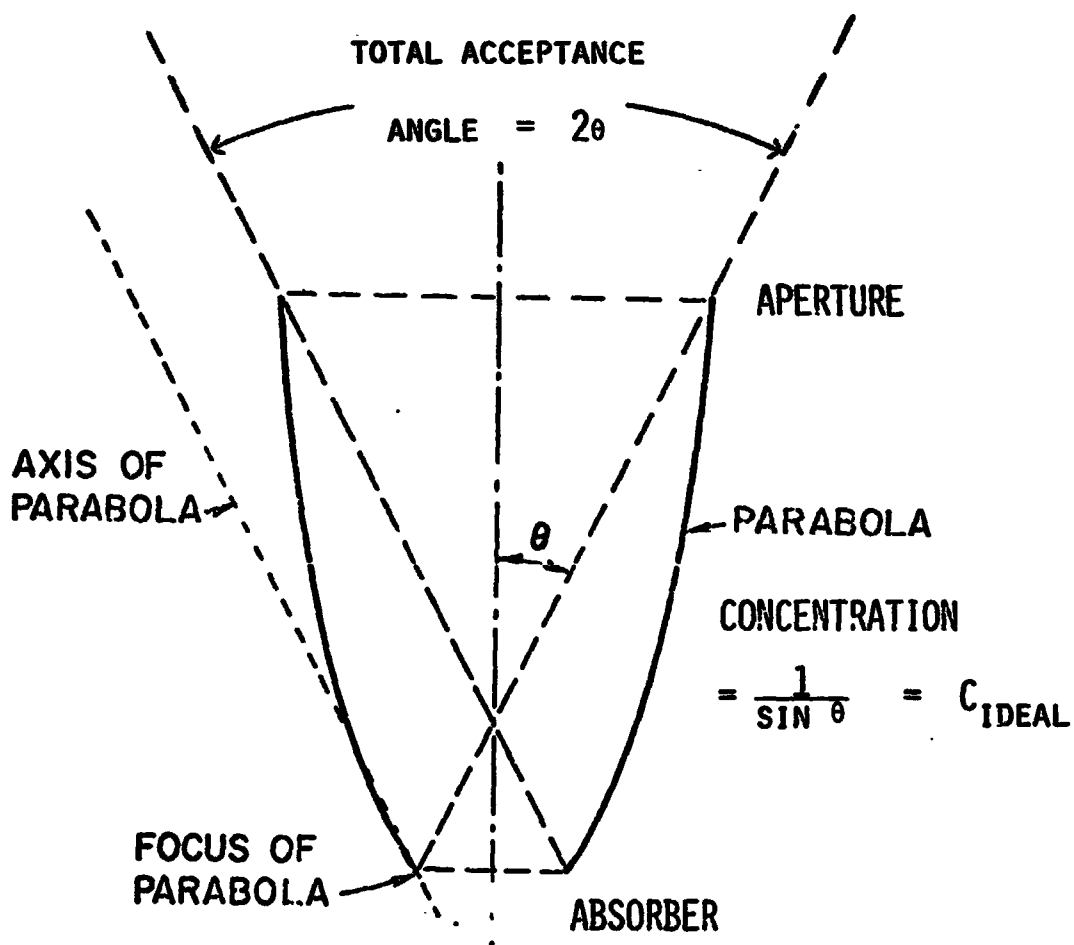
PERIOD OF GRANT: 26 MARCH -- 30 JUNE

AMOUNT OF AWARD: \$30,000

PRINCIPAL INVESTIGATOR: ROLAND WINSTON

COMPOUND PARABOLIC CONCENTRATOR

CPC



REPORTS

- A. RABL, "OPTICAL AND THERMAL PROPERTIES OF COMPOUND PARABOLIC CONCENTRATORS", ARGONNE REPORT SOL 75-01
- A. RABL, "COMPARISON OF SOLAR CONCENTRATORS", ARGONNE REPORT SOL 75-02.
- A. RABL, ET AL., "REPORT ON CONCENTRATING FLAT PLATE COMPOUND PARABOLIC COLLECTORS".
- R. GIUGLER, ET AL., "X 10 COMPOUND PARABOLIC CONCENTRATORS", ALSO PROGRESS REPORTS NSF/RANN/SE-AER-74-01065/PR/74/4 AND 75-01065/PR/75/1.

OVERALL OBJECTIVE OF PROJECT

**DETERMINE SUITABILITY OF CPC FOR PHOTOVOLTAIC
APPLICATIONS, IN PARTICULAR**

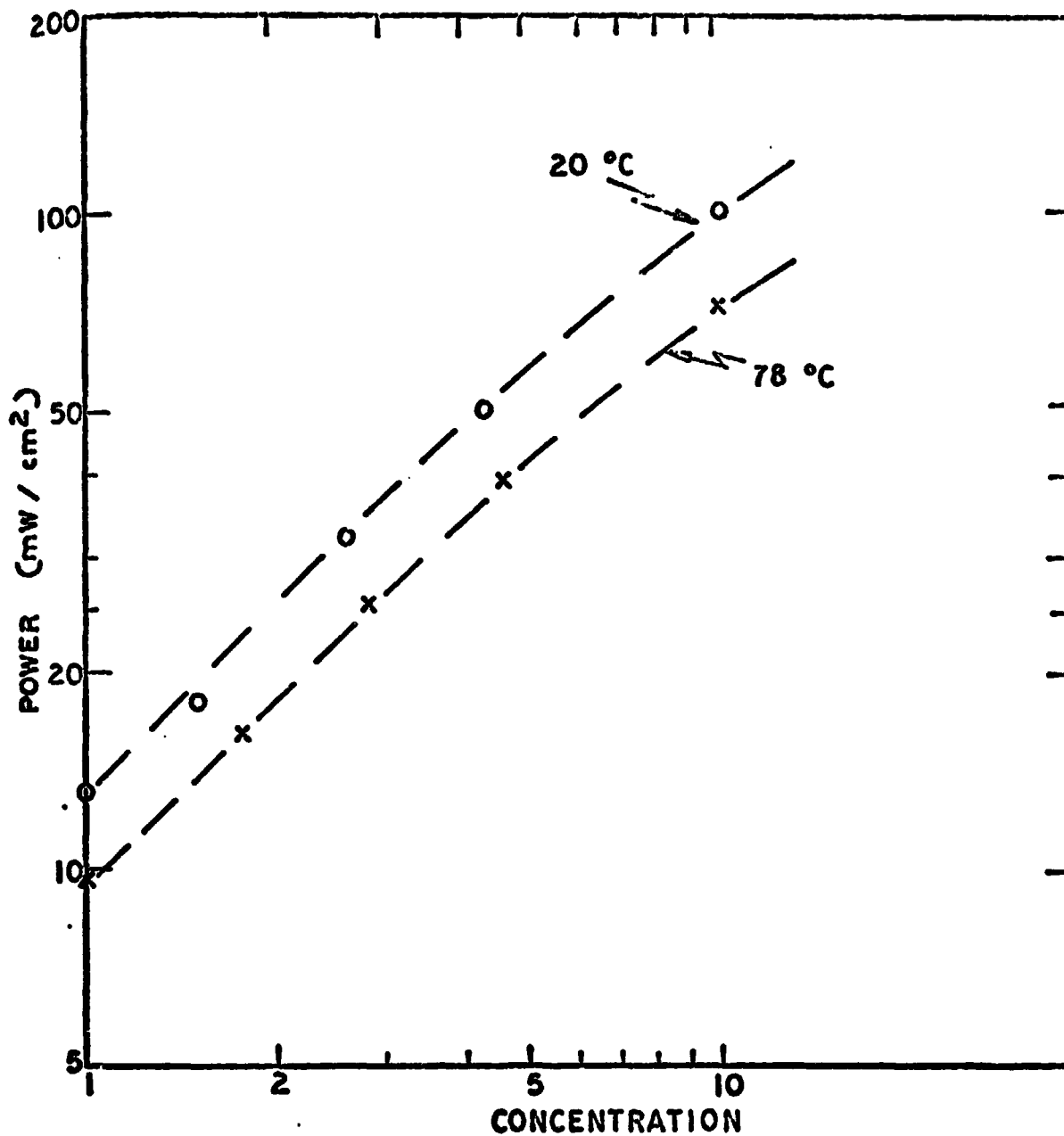
**INVESTIGATE TECHNICAL PROBLEMS
(COOLING, GRID SPACING, ETC.)**

OPTIMIZE CONCENTRATOR DESIGN,

CALCULATE SYSTEM COST.

TASKS PERFORMED BY MOBIL TYCO

1. DETERMINATION OF THE PERFORMANCE CHARACTERISTICS OF STATE-OF-THE-ART (I.E., CZOCHRALSKI N ON P) SILICON SOLAR CELLS AS A FUNCTION OF CONCENTRATION RATIO (UP TO 10 TIMES) AND TEMPERATURE (20 - 100°C).
2. MAXIMIZATION OF SOLAR CELL PERFORMANCE UNDER CONCENTRATION AND AT ELEVATED TEMPERATURES, INCLUDING ELECTRODE GRID DESIGN, JUNCTION DEPTH, AND ANTIREFLECTION COATING.
3. ANALYSIS OF CPC/SOLAR CELL PERFORMANCE AS A FUNCTION OF CONCENTRATION RATIO AND DEGREE OF TRUNCATION (AND HENCE OF ACCEPTANCE ANGLE), INCLUDING DETERMINATION OF THE ENERGY DISTRIBUTION ON THE CELL TO PROVIDE DESIGN GUIDANCE FOR THE LOCATION OF THE GRID STRUCTURE.
4. ANALYSIS OF THE COST EFFECTIVENESS OF THE CPC/SILICON SOLAR CELL SYSTEM.



Power output versus concentration for 20° and 78°C. The average decrease in efficiency was 0.4%/°C. The AR coating was 1200 Å and the junction depth was 0.25 μm.

(MEASURED WITH 20 MIRROR HELIOSTAT)

EFFICIENCY OF 8 X CPC AND SI PHOTOCELL COMBINATION

WAS MEASURED.

(ALUMINUM WITH REFLECTIVITY 85%, ACTUAL CONCENTRATION

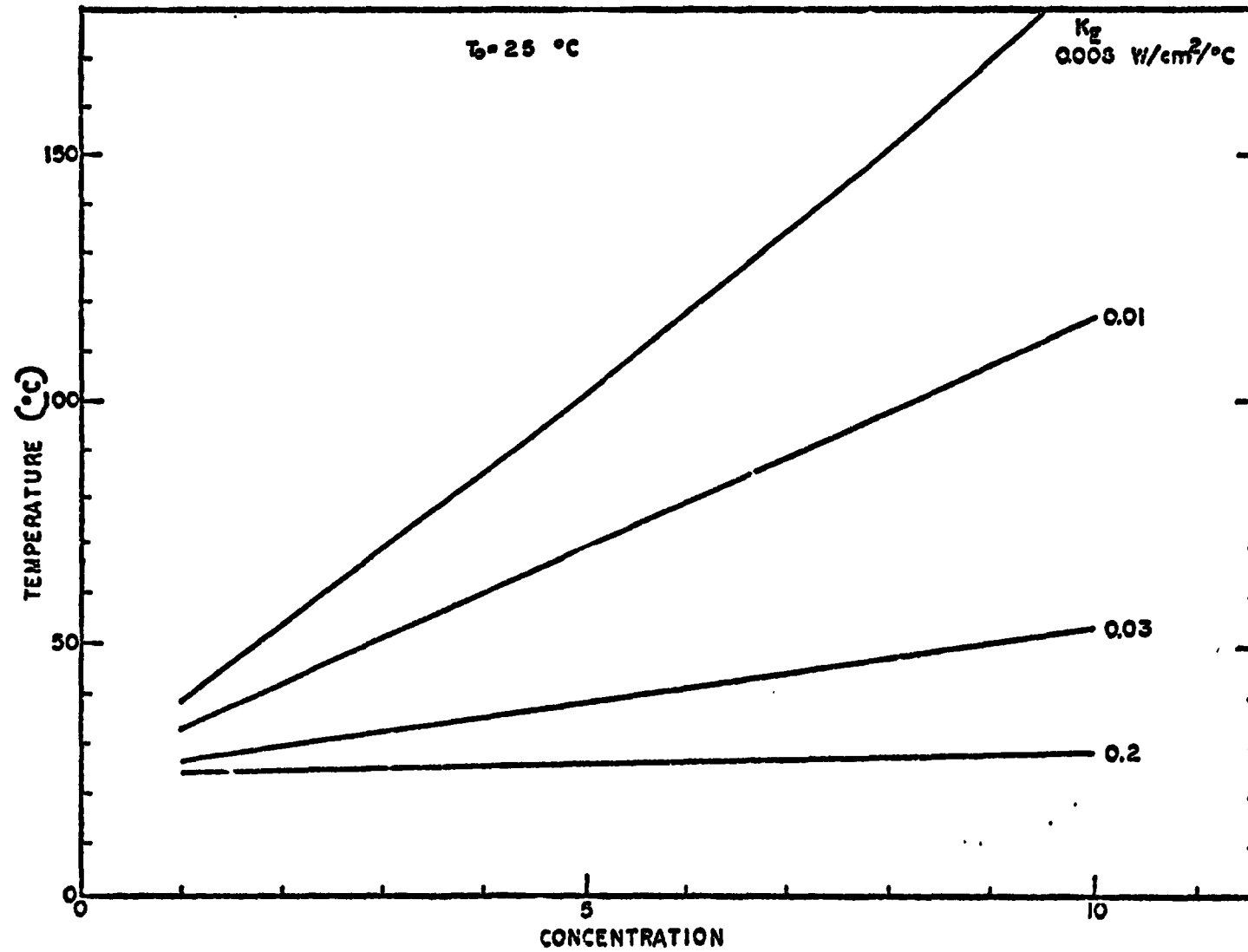
= 6, FOR MECHANICAL REASONS)

MEASURED OUTPUT: 5 X

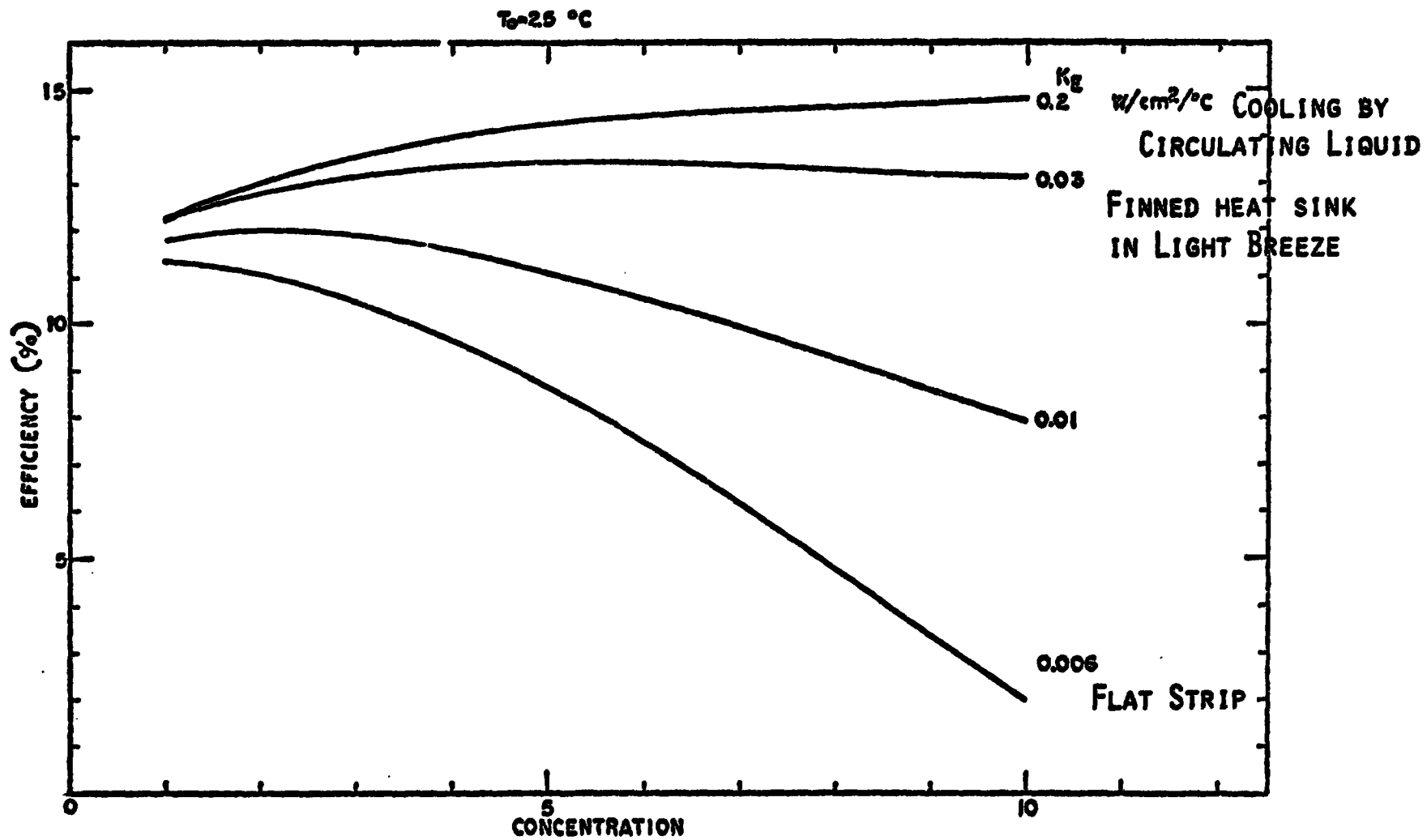
TEMPERATURE DEPENDENCE OF EFFICIENCY

- 0.5% PER °C (THEOR.)

- 0.4% PER °C (EXP.)



Temperature of a silicon solar cell as a function of concentration for different types of cooling. $K_c = 0.005 \text{ W/cm}^2/^\circ\text{C}$ corresponds to a flat strip, 0.03 a finned heat sink in a slight breeze, 0.2 cooling by a circulating liquid, and 0.01 to some intermediate cooling. The ambient temperature was 25°C .



Solar cell conversion efficiency as a function of concentration. For the types of cooling schemes corresponding to various values at K_g , see the preceding figure or text.

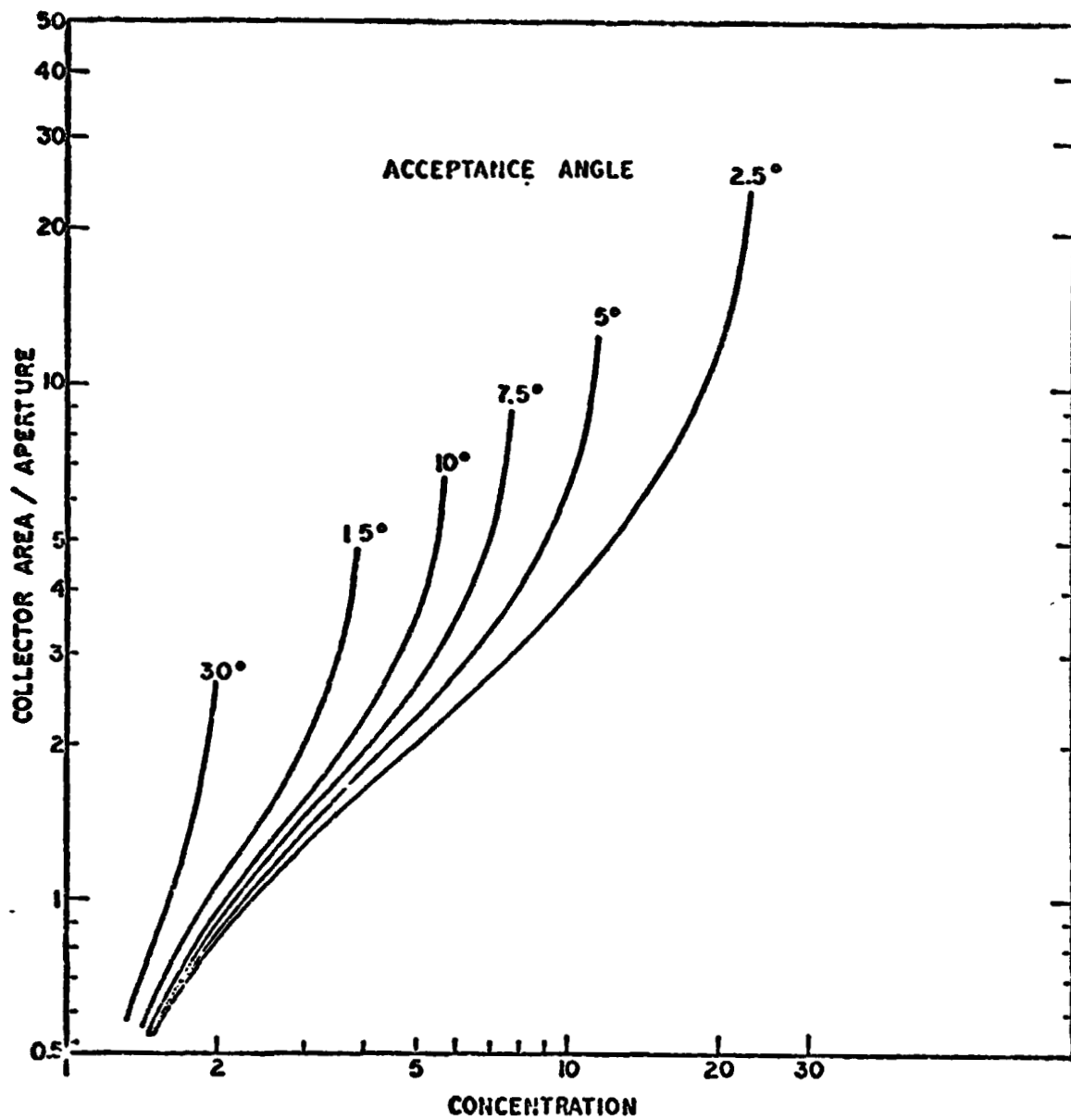
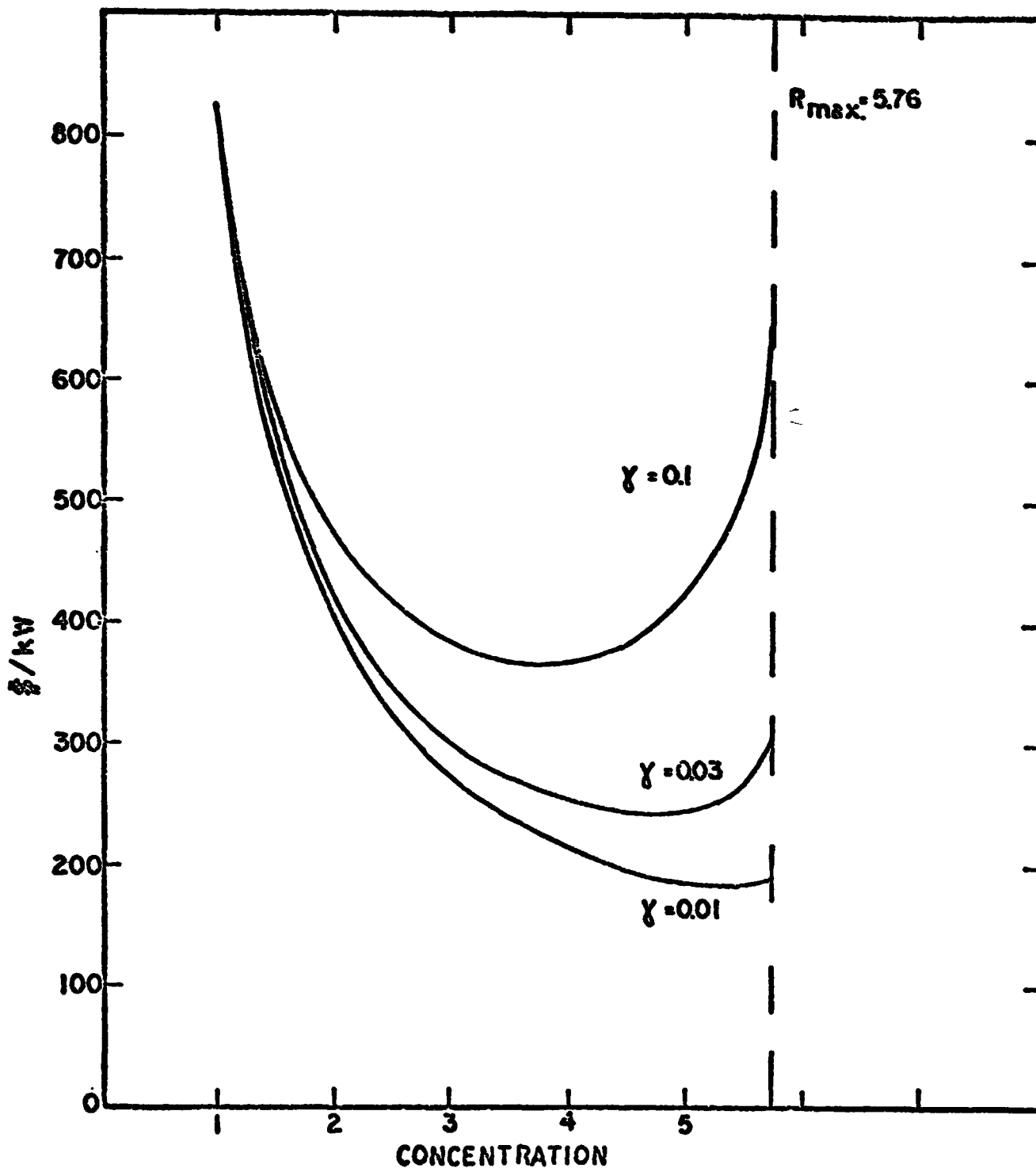
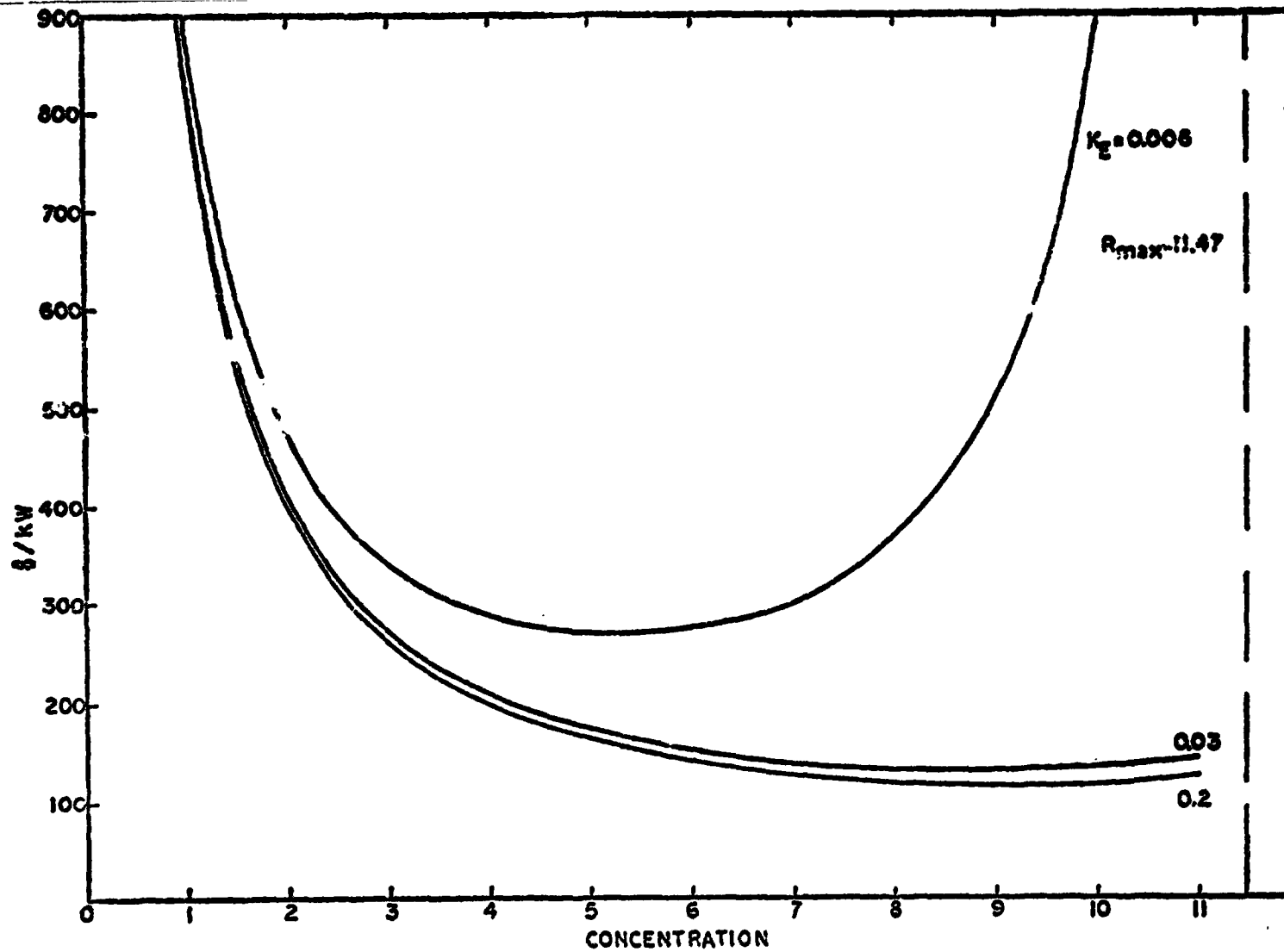


Fig. 39. The collector area per unit lengths divided by the aperture per unit length as a function of concentration for a CPC. Acceptance angles between 2.5 and 30° were used.



The cost in \$/kW of a CPC system versus concentration. γ is the ratio of reflector costs per unit area to Si solar cell costs. An acceptance angle of 10° and $K_e = 0.003 \text{ W/cm}^2 \cdot ^\circ \text{C}$ were used.



The cost in \$/kW of a CPC system versus concentration for different types of cooling. See the text for types of cooling corresponding to different values of K_e . The acceptance angle is 5° .

KEY RESULTS OF MOBIL TYCO

1. SILICON SOLAR CELLS CAN READILY BE DESIGNED TO INCREASE IN EFFICIENCY WITH CONCENTRATION UP TO 10 SUNS. SIMPLE IMPROVEMENTS IN GRID STRUCTURE PERMIT THE ATTAINMENT OF THE REQUISITE VALUE OF SERIES RESISTANCE.
2. THE SPECIFIC CELL PARAMETERS REQUIRED TO ACHIEVE ENHANCED EFFICIENCY WITH INCREASING CONCENTRATION HAVE BEEN DEFINED, AND THESE ARE READILY ATTAINABLE WITH MINIMUM MODIFICATION OF STANDARD SOLAR CELL FABRICATION TECHNIQUES.
3. RAY TRACING COMPUTER PROGRAM HAS BEEN DEVELOPED TO DETERMINE ENERGY DISTRIBUTION AT EXIT OF CPC.
4. THE COST OF A CPC/SOLAR CELL SYSTEM WAS DETERMINED AS A FUNCTION OF CONCENTRATION RATIO. TOTAL COST OF A CPC/SOLAR CELL SYSTEM WILL BE BETWEEN 4 AND 5 TIMES LOWER THAN FOR FLAT PLATE SILICON CELL ARRAYS.

THE STATEMENT OF WORK FOR SPECTROLAB

EVALUATE FOR PHOTOVOLTAIC APPLICATIONS THE USE OF THE
CPC DESIGN AS A FIELD COLLECTOR -- IN CONJUNCTION WITH
A PRIMARY FOCUSING CONCENTRATOR. THE PRIMARY FOCUSING
CONCENTRATOR MAY BE A PARABOLIC REFLECTOR, AN ARRAY OF
FRESNEL MIRRORS, A FRESNEL LENS OR SOME OTHER TYPE.

SINGLE CPC vs. TWO COMPONENT SYSTEMS

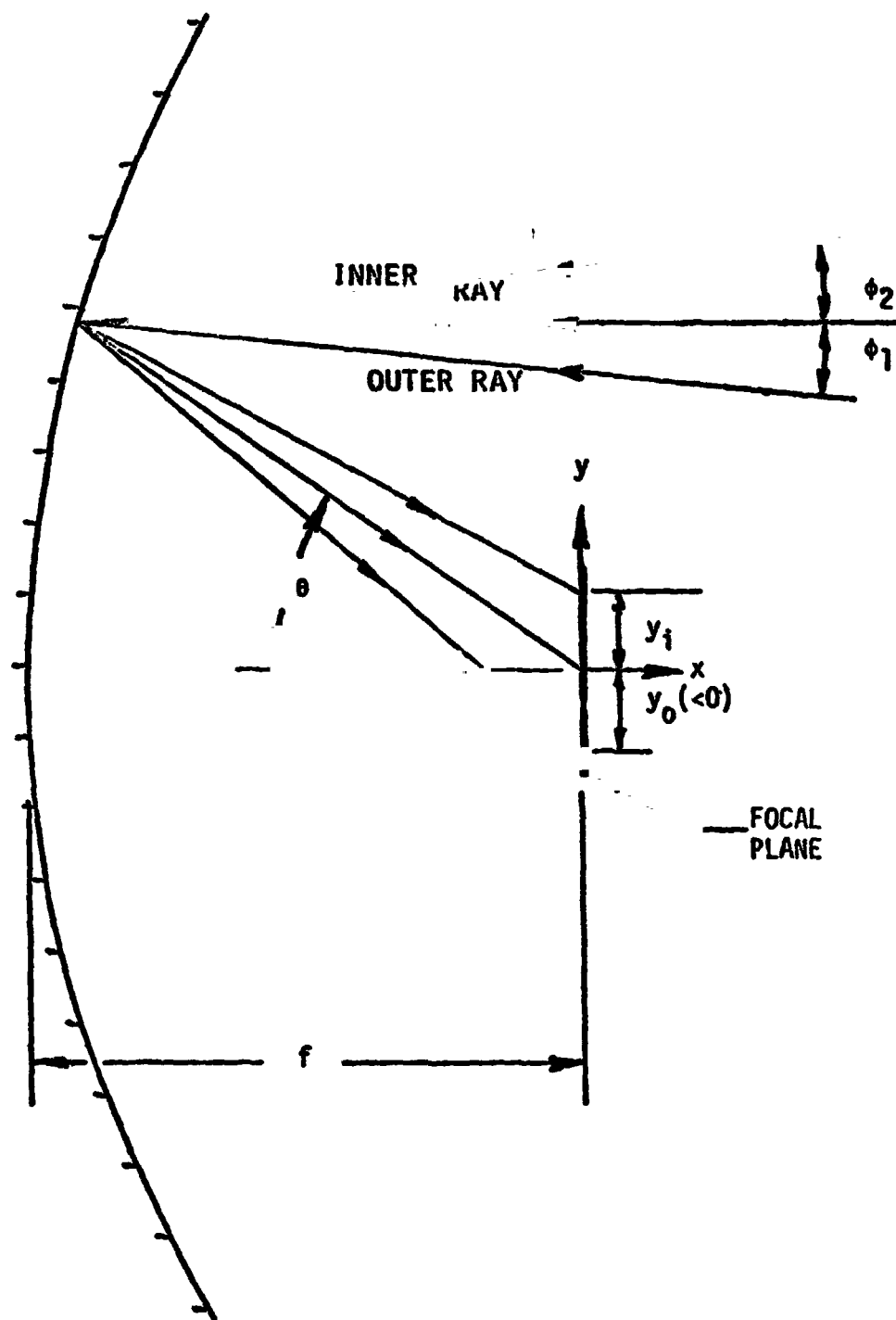


TWO COMPONENT SYSTEM ACHIEVES ABOUT 90% OF C_{IDEAL} .

VERY FAVORABLE REFLECTOR/APERTURE RATIO,

PREFERABLE FOR $C \approx 10$

(WITH OFF AXIS DESIGN MAY BE PREFERABLE FOR $C \approx 6$)



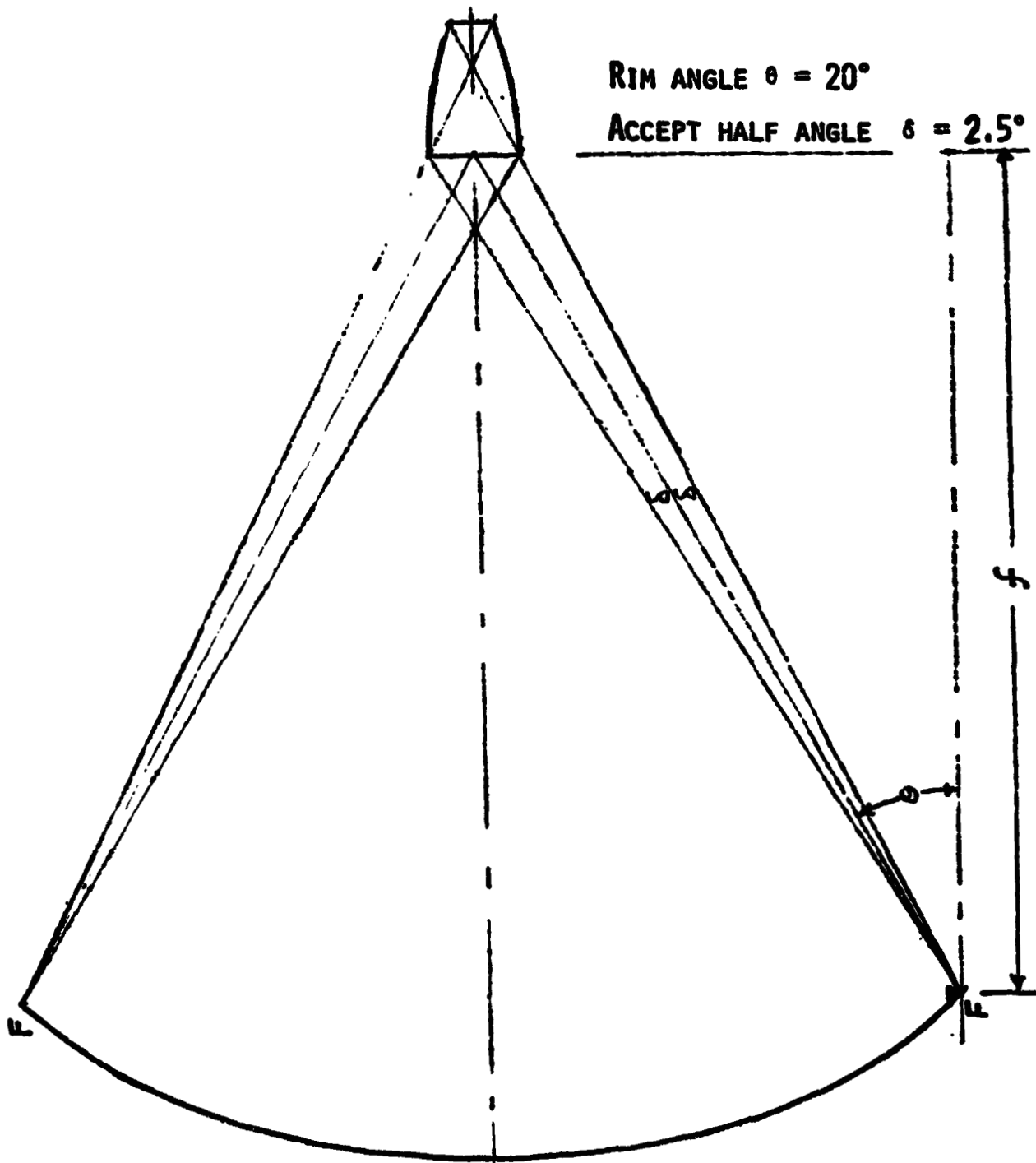
PARABOLIC TROUGH WITH RIM ANGLE $\theta = 65^\circ$, ACCEPTANCE HALF ANGLE $\delta = 2.5^\circ$.

HIGHLY NONUNIFORM FLUX DISTRIBUTION AT ABSORBER

$$P_{\text{MAX}}/P_{\text{AVERAGE}} = 15$$

(SIMILAR CONCLUSIONS FOR OTHER SINGLE STAGE CONCENTRATORS.)

PARABOLIC TROUGH WITH CPC SECOND STAGE



FLUX DISTRIBUTION AT ABSORBER NEARLY UNIFORM

$$P_{\text{MAX}}/P_{\text{AVERAGE}} = 1.2$$

CPC APPLICATION PROJECT
RESULTS OF PHOTOVOLTAIC APPLICATION STUDY

■ CPC AS FIELD COLLECTOR IN HYBRID SYSTEM
(SPECTROLAB / ASU)

CONCLUSION OF STUDY

TWO-ELEMENT DESIGN IS SUBSTANTIALLY BETTER THAN ANY SINGLE ELEMENT DESIGN STUDIED, FOR USE WITH PHOTOVOLTAIC CELLS BECAUSE :

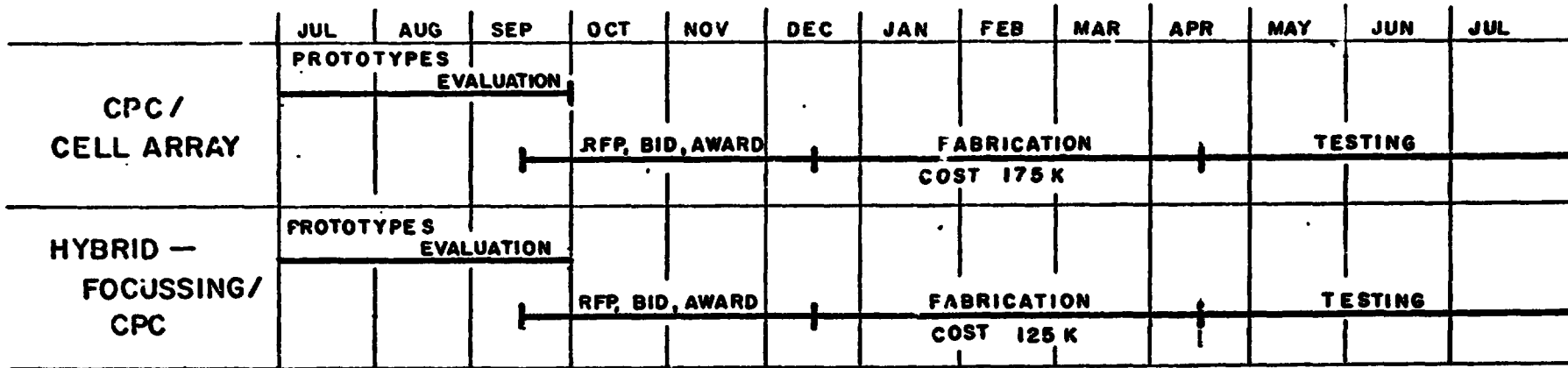
- a. ADDITIONAL CONCENTRATION OF ~ 2.5 POSSIBLE
- b. FLUX DISTRIBUTION IS SMOOTHED OUT
(PEAK / AVERAGE INTENSITY = $\times 15$ FOR PARABOLIC TROUGH, = 1.2 FOR HYBRID SYSTEM)
- c CPC CAN BE DESIGNED TO REJECT HEAT. HENCE DOES NOT ADD TO OVERALL COST OF SINGLE ELEMENT SYSTEM

RECOMMENDATION :

FURTHER STUDY LEADING TO DESIGN OF CONCENTRATOR SYSTEMS OPTIMIZED FOR SPECIFIC APPLICATIONS AND FABRICATION AND TEST OF PROTOTYPES

ORIGINAL PAGE IS
OF POOR QUALITY

CPC APPLICATION PROJECT PHOTOVOLTAIC SCHEDULE FY 1976



TOTAL COST — 300K