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DEVELOPMENT, TESTING, AND CERTIFICATION OF THE
NORTHROP, INC., ML SERIES CONCENTRATING
SOLAR COLLECTOR MODEL NSC-01-0732 -
FINAL REPORT

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March 1979

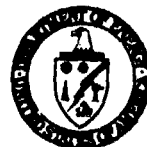
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Solar Energy

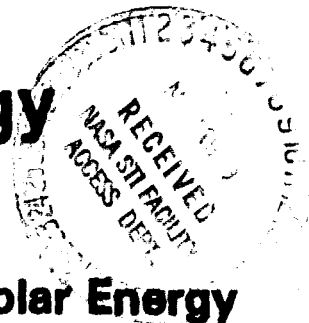


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TECHNICAL MEMORANDUM

DEVELOPMENT, TESTING, AND CERTIFICATION OF THE NORTHROP, INC., ML SERIES CONCENTRATING SOLAR COLLECTOR MODEL NSC-01-0732 - FINAL REPORT

SUMMARY

This report is intended to provide product development information as an aid to the solar systems manufacturing industry in their effort to determine the products adaptability for use in a specifically configured total solar heating and/or cooling system in residential and commercial applications.

This report will also serve as an aid to those who desire to remain abreast of the state-of-the-art of solar energy heating and cooling projects.

The collector is a concentrating collector with a fresnel lens mounted on top of a trough-like enclosure which focuses the Sun's rays on a target near the bottom of the enclosure. The collector is gimbaled about its long axis tilting east to west allowing the Sun's rays to be nearly normal to the fresnel lens surface in one plane. This focuses the solar energy on the absorber or target very close to the focal point of the fresnel lens.

The concentrating collector as developed under this contract had its beginning during the 1974 to 1975 time frame. Prior to this contract, Northrup, Inc., installed collector systems at various sites throughout the United States totaling approximately 14 000 ft² (Fig. 1). On October 4, 1976, Northrup entered into a contract with NASA/MSFC to upgrade their product so that it could be classified, by Government standards, as marketable. The main thrust was devoted to lowering production costs and increasing the efficiency of the existing collector system to enable it to operate continuously at high temperatures to drive solar air conditioning equipment.

At contract completion (over a 21-month period) Northrup, Inc., obtained certificates (Appendix A) from professional engineers in the plumbing, heating, cooling, electrical, building code, test laboratories, and structural disciplines stating that the product meets performance criteria and applicable standards and codes.

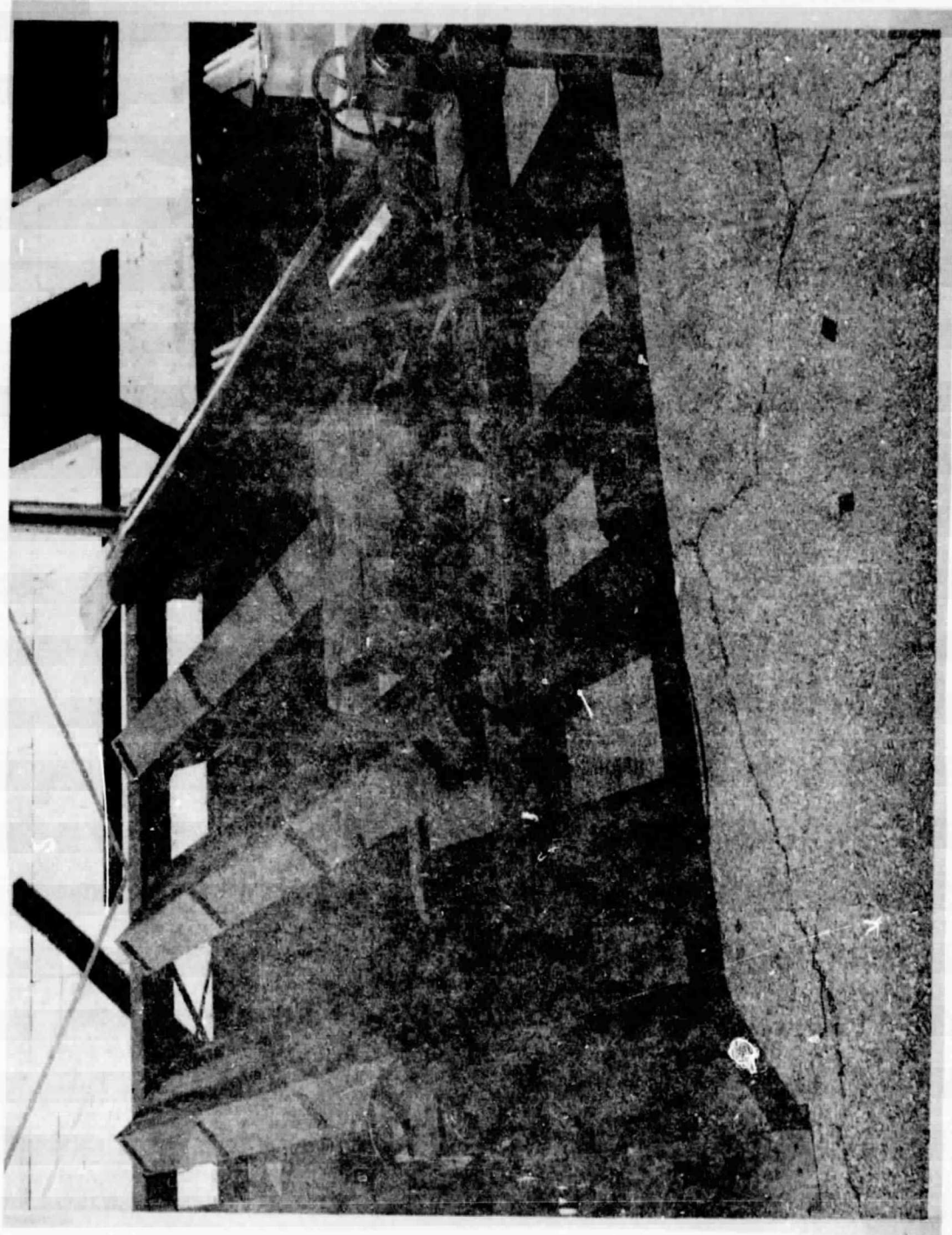


Figure 1. Northrup, Inc., collector array configuration prior to contract.

A total of 300 ft² of concentrating solar collectors complete with attitude control system was delivered to MSFC under this contract. The collectors are now installed and operating at the solar demonstration facility at MSFC, Huntsville, Alabama (Fig. 2).

INTRODUCTION

Program Background and Goals

Prior to dealing with the specific aspects of the Northrup, Inc., solar collector, a few background statements are pertinent. The problems of energy availability and increasing costs have led to a major national effort to develop alternate energy sources. One such source is the energy in solar radiation which can be used for heating and cooling buildings, domestic hot water, and other applications. The National Energy Policy, as established in the Solar Heating and Cooling Demonstration Act of 1974 (PL93-409), is to provide for the demonstration within a 3-year period of the practical use of solar heating technology, and demonstration within a 5-year period of the practical use of combined heating and cooling technology. Responsibility for implementing the Demonstration Act was given to the Energy Research Development Administration (now the Department of Energy). The National Aeronautics and Space Administration (NASA), George C. Marshall Space Flight Center (MSFC) manages a large part of this work.

Purpose of This Product Development Contract

The purpose of this contract was to provide funding to Northrup, Inc., to do additional design development, fabrication, and test work on their existing solar collector system so that it can be classified by Government standards as a marketable product and suitable for public use.

During the product improvement development effort, the contractor was required to:

- 1) Meet the applicable parts of the Interim Performance Criteria for Solar Heating and Cooling Systems as stated in the subsystems performance specifications [1].
- 2) Provide test data/analysis to verify that hardware meets the subsystem performance specification.

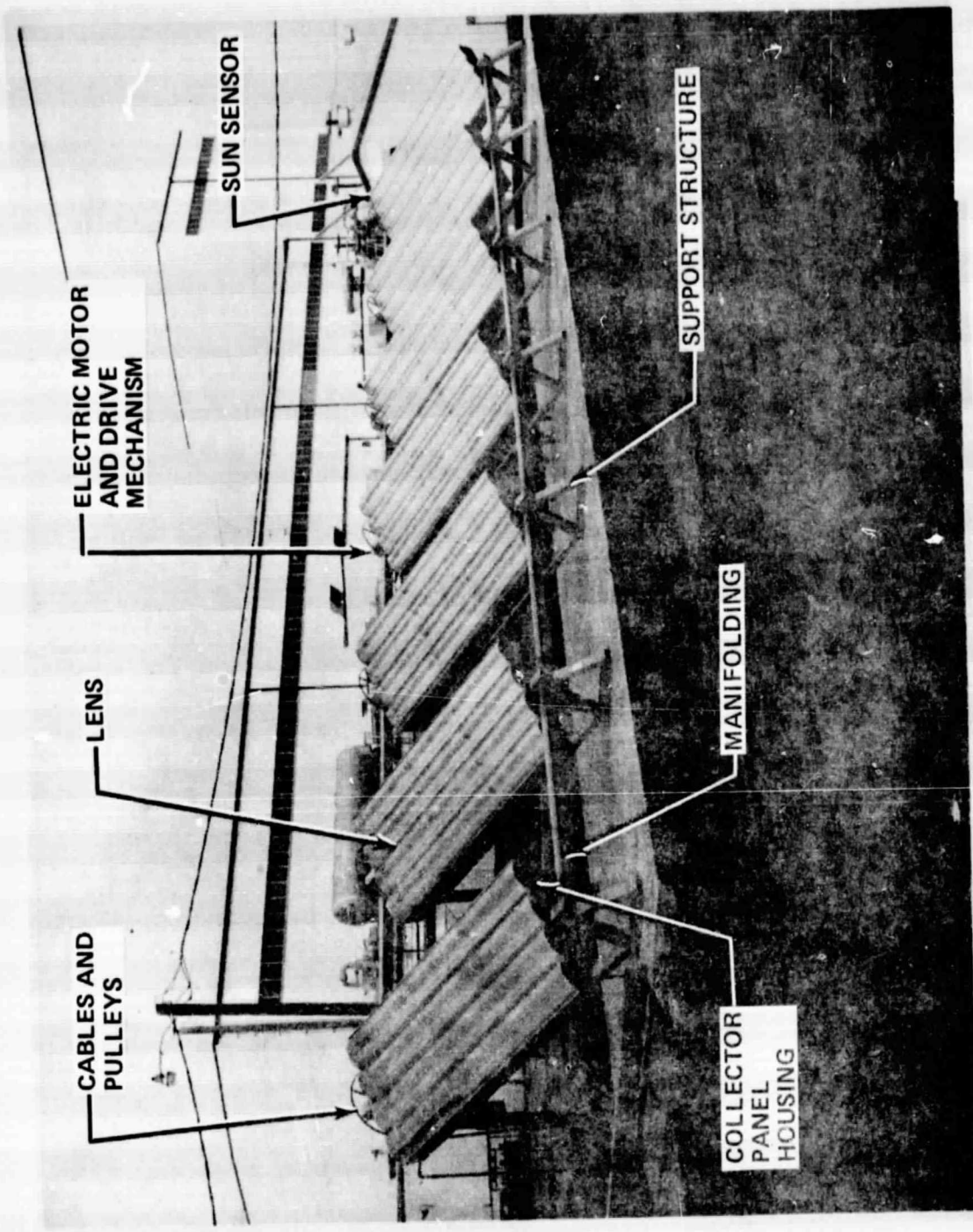


Figure 2. Northrup, Inc., ML series concentrating solar collector model NSC-01-0732, new configuration.

3) Provide drawings and specifications in sufficient detail to define the configurations and to assure manufacturing repeatability [2].

4) Provide installation, operation and maintenance manuals, and application information [3].

5) Provide program execution plans, design review data, periodic status reports and acceptance data packages [4].

6) Provide subsystem and/or component hardware certified by an independent test laboratory to meet nationally recognized standards and codes (such as American Society of Heating, Refrigeration and Air Conditioning Engineers; American Society for Mechanical Engineers; American Standards Institute and American Refrigeration Institute).

To meet these objectives the contractor was required to reevaluate the design of certain salient major subsystems, namely, the casing element, concentrating element, receiver tube element, attitude control elements, manifold element, and structural components. The contractor was also required to upgrade the hardware, to verify its performance through testing, and to certify that the total system is marketable [1].

The contract performance period was from October 1976 through July 1978.

DESCRIPTION

General

The collector is a concentrating collector with a fresnel lens mounted on top of a trough-like enclosure which focuses the Sun's rays on a target near the bottom of the enclosure. The collector is gimbaled about its long axis tilting east to west allowing the Sun's rays to be nearly normal to the fresnel lens surface in one plane. This focuses the solar energy on the absorber or target very close to the focal point of the fresnel lens.

The ML Series solar collector panels (Fig. 2) comprise a complete packaged array consisting of collector panels, supporting framework, insulated fluid manifolding, and tracking drive system shipped from the factory in unassembled components for field erection. Each collector panel has four lenses,

each having a net aperture of 10.75 ft² making a total of 43 ft² for each collector panel. Overall size of each collector panel is 58 3/8 × 133 5/8 in. Panels are spaced 10 ft on center.

Detailed

The various components are (Figs. 2 and 3):

1) Lens — Modified, fresnel, prismatic lens extruded from acrylic with a transmissivity of 0.95 and concentration ratio of 10:1.

2) Absorber Tube — Made of copper, formed to an elliptical shape from a 1 1/4 in. diameter tube flattened to a width of 1.78 in. for maximum collection for all seasons. The exterior surface of the absorber tube has selective black chrome over a nickel coating.

3) Collector Panel Housing — Constructed of galvanized steel.

4) Insulation — Fiberglass with a K factor of 0.28 at 200°F.

5) Framing Supports — Double A frame constructed of heavy gauge galvanized steel.

6) Manifolds — All fluid manifolds are constructed of copper and insulated with fiberglass having a K factor of 0.30 at 200°F.

7) Expansion Compensation — Flexible swivel connections between fluid manifolds and steel support structure.

8) Tracking System (Figs. 4 and 5) — The system essentially consists of a Sun sensor and related electronics and electric motor and drive train. The system is designed for east-west tracking with axis of collectors mounted parallel to polar axis. Collector panels are linked together with a system of heavy, galvanized aircraft cable and pulleys. This system is driven by a mechanism consisting of a two-directional motor, chain drive, stainless steel (acme) screw and a Delvin drive nut. The two-directional motor is controlled by photovoltaic cells through an integrated circuit to constantly maintain collector panels in focus on the Sun. This circuit has a low light level which directs the collector to track to the East during night time and stop at the proper position for morning start up. Tracking is set for 4 hr before and 4 hr after solar noon which is the optimum for nonshading between collector panels.

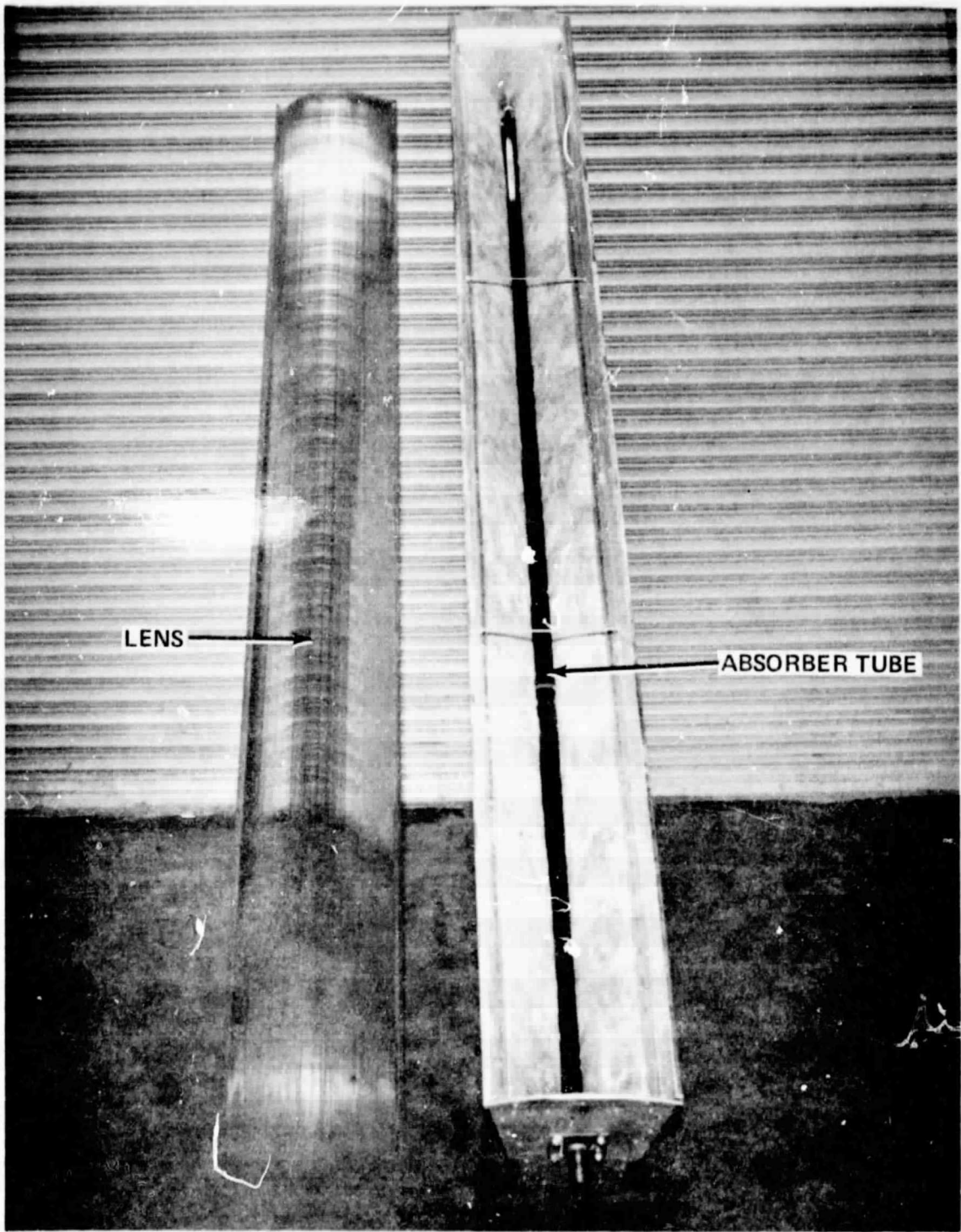


Figure 3. Lens, absorber tube, insulation.

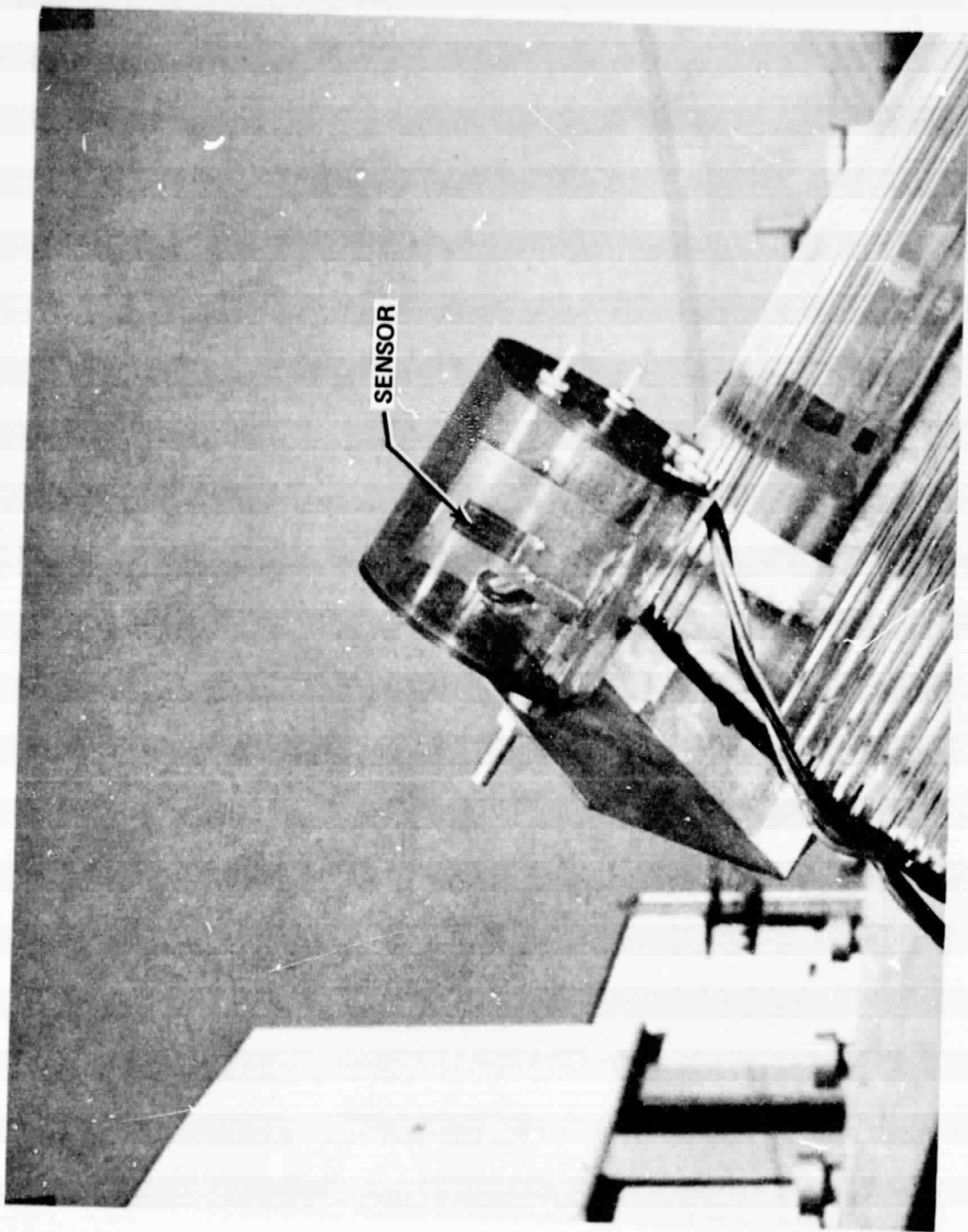


Figure 4. Sun sensor.

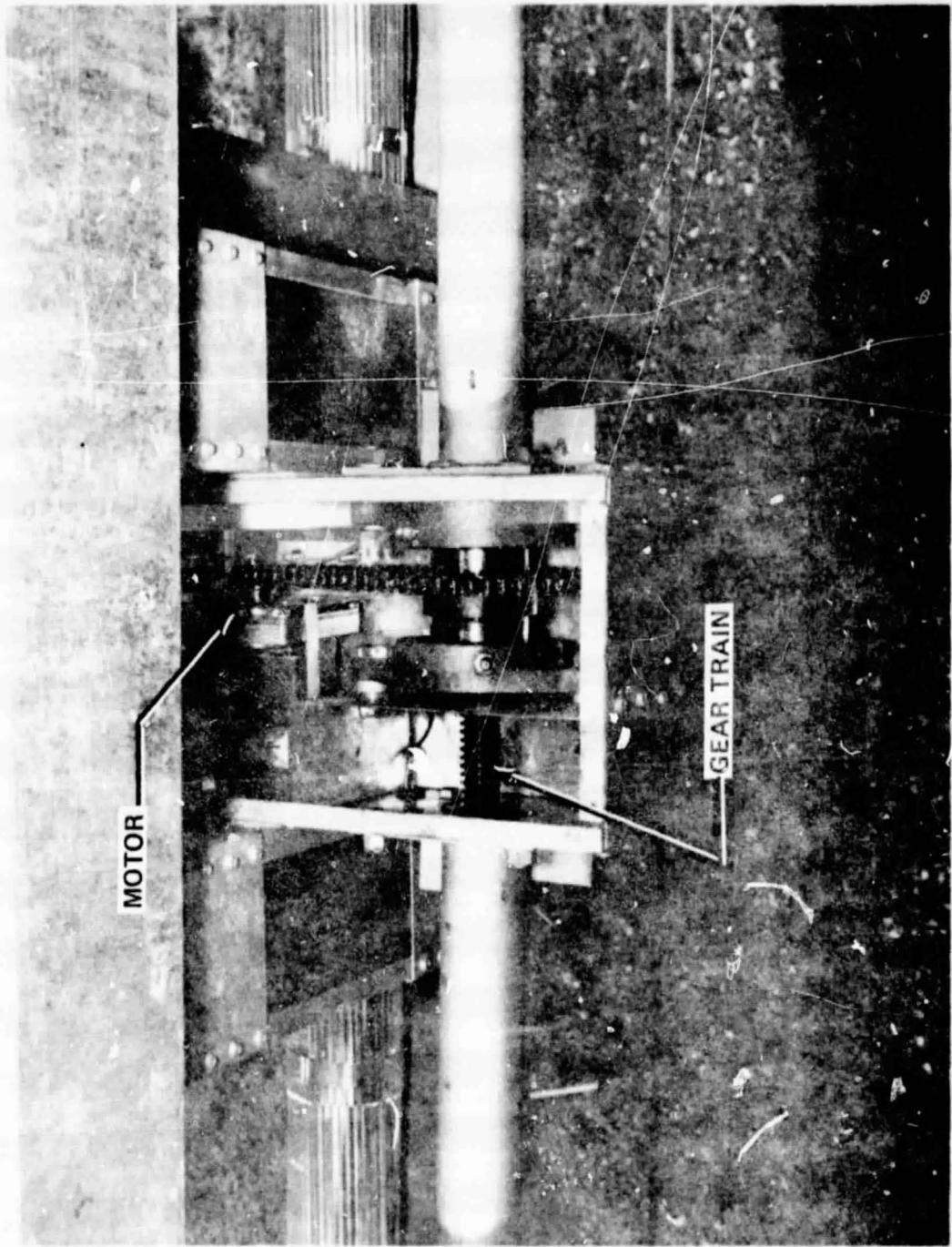


Figure 5. Electric motor and gear train.

The collectors are applicable to any system requiring fluid temperatures up to 240°F. Water or a combination of water and ethylene glycol is recommended as the heat transfer fluid. The arrays are available with a minimum of 2 and a maximum of 11 collector panels in one array.

Collector Sizing

Appendix B presents a copy of the "Northrup Collector Sizing Example."

Systems Performance Specification [1]

For Dallas, Texas, the MF Series concentrating solar collector Model NSC-01-0732 will collect a minimum of 1,144 Btu / ft² / day of energy at an inlet fluid temperature of 190°F (water) (Fig. 6). The tilt angle at this performance basis will be equal to the latitude angle, azimuth = 0 degree, average ambient dry bulb = 100°F, wind velocity = 0, date — August 21, direct normal noon solar flux = 283 Btu/hr/ft², longitude = 97 degrees, and latitude = 32 degrees.

When used primarily for heating, a single collector will provide 1242 Btu/ft²/day at an inlet fluid temperature of 150°F (water). The tilt angle at this performance basis is equal to the latitude angle, azimuth = 0 degree, average ambient = 50°F, wind velocity = 0, date — February 21, direct normal noon solar flux = 316 Btu/hr/ft², longitude = 97 degrees, and latitude = 36 degrees.

Manufacturer's Facilities

Their 84 000-ft² facility includes the equipment needed to accurately test the solar collectors it manufactures. Test procedures, data collection, calculation, and reporting essentially conform to the recommendations of the National Bureau of Standards. In addition, all the equipment necessary for Underwriters Laboratory (UL) approval and the American Refrigeration Institute (ARI) approval for HVAC units is also contained within the facility.

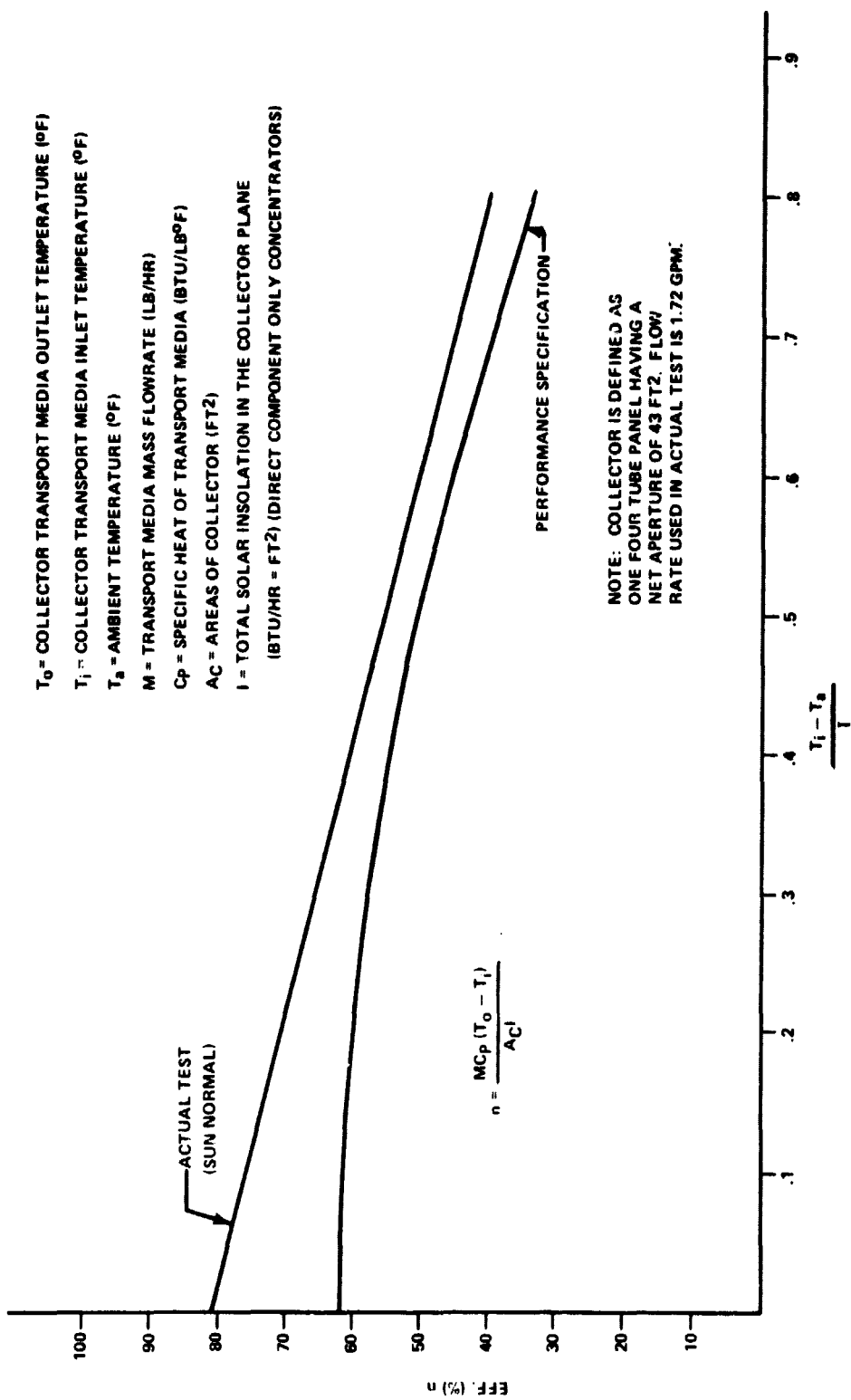


Figure 6. Performance curve — Northrup Model NSC-01-0732.

PROBLEMS ENCOUNTERED AND THEIR SOLUTIONS

Receiver Tube Element (Fig. 7)

Problem [5]:

Heat loss tests were performed comparing "cost effectiveness" [5] (% increase in energy collected/% increase in cost) of an atmospheric receiver versus a medium vacuum receiver versus a deep vacuum receiver. These tests [5] showed the atmospheric receiver tube to be most durable and the best performer per cost/efficiency.

Solution [6]:

As a result the tube element was modified, eliminating the evacuated receiver tube (which was the configuration prior to this contract) and replacing it with the atmospheric receiver tube.

Concentrating Element (Fig. 8)

Problem:

The fresnel lens is an extruded product. Precision in fabrication, as well as high quality control, is a requirement to assure maximum light concentration on the absorber tube (focusing accuracy).

Solution [6]:

To obtain the focusing accuracy desired, it was necessary to chrome plate and highly polish the extrusion die.

Attitude Controller Element (Figs. 4 and 5)

Problem:

The attitude controller (tracking element) could not handle the load requirements of large arrays (20 or more collectors per tracker).

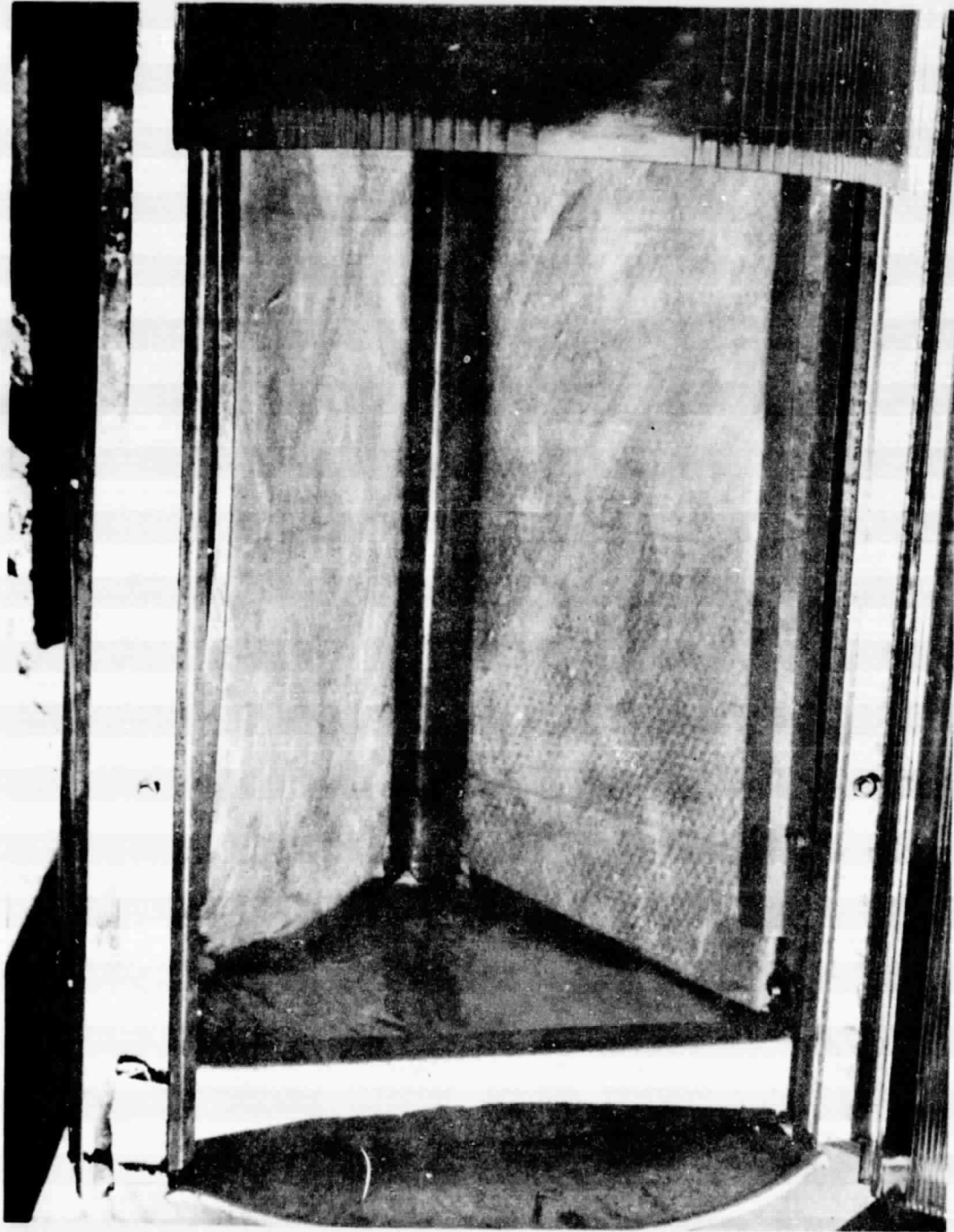


Figure 7. Receiver tube and casing element.

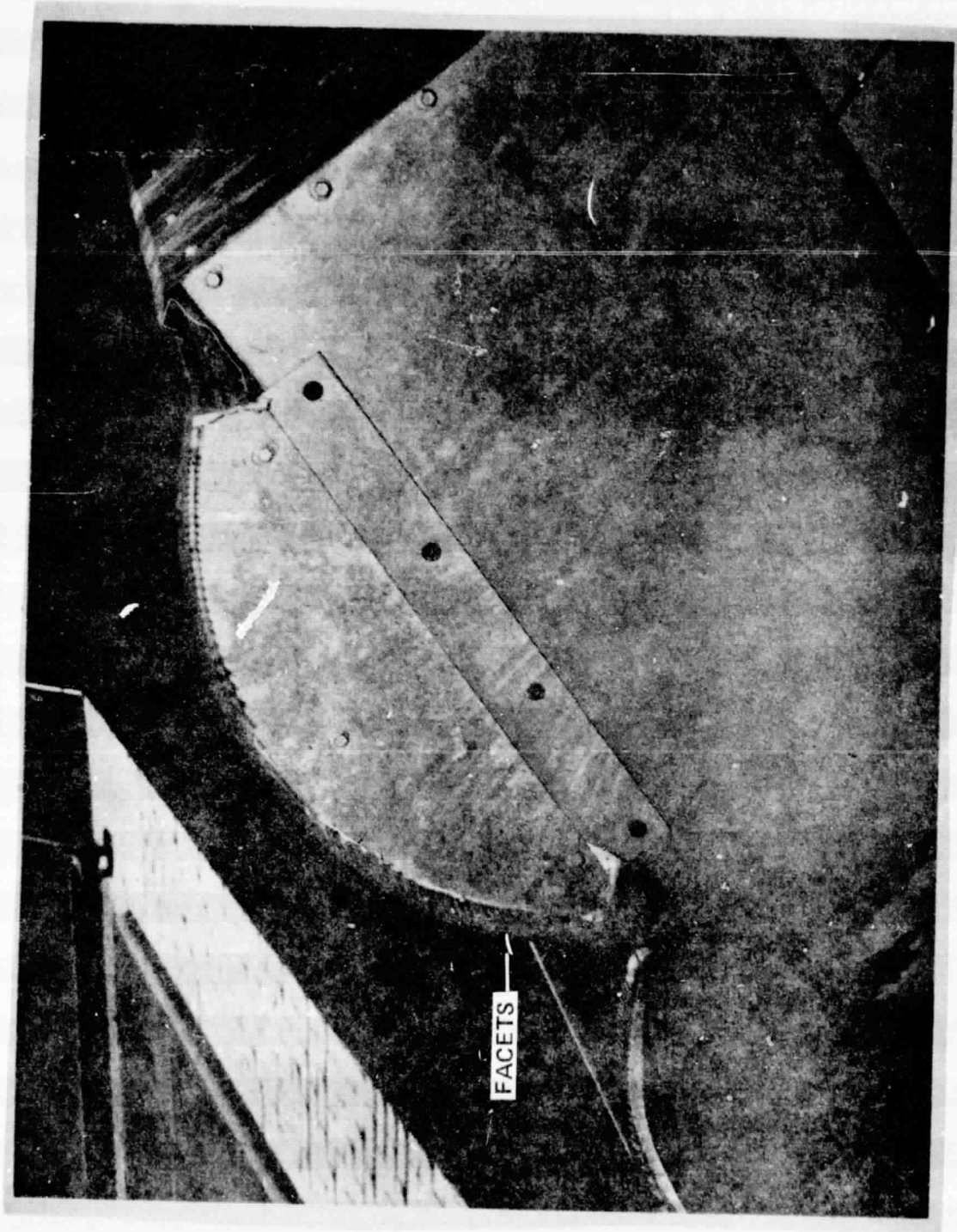


Figure 8. Fresnel lens facets.

Solution [7]:

The selection of a heavier duty motor rated at 30-in. -lb starting torque and 50-in. -lb breakdown torque and the incorporation of a chain-sprocket drive with a 1.5 gear ratio to reduce the torque required by the motor.

Problem:

The silicon cell Sun sensor which controls the tracking mechanisms east/west attitude, on those occasions where the beginning of the day is overcast then clears in the afternoon, allows the collectors to remain in the east facing position after the Sun appears. This is because the light rays enter the sensor housing past the acceptance angle of the sensor configuration.

Solution [6]:

This problem was solved by mounting the solar cells in a triangular configuration (Fig. 4) which increased the acceptance angle.

Problem:

On occasions, on partly cloudy days, the Sun sensor hunted light colored clouds rather than the Sun.

Solution [6]:

This problem was solved by placing an optical blue filter over the silicon cells.

Casing Element (Fig. 7)

Problem:

The inside surfaces of the casing element, which houses the receiver tube, is lined with insulation material to reduce thermal losses from the absorber tube. This insulation which initially was foamed glass and fiberglass with binders and adhesives out-gassed at temperatures above 400°F, resulting in contamination deposits on the receiver tube.

Solution [6]:

A pure fiberglass without adhesives or binders eliminated this problem. This material is a little heavier, less rigid and not quite as strong, but it was a necessary tradeoff due to the high temperatures associated with concentrating collectors.

TESTS CONDUCTED AND RESULTS

Upon completion of the reevaluation of the salient hardware items described in the introduction, one collector subsystem was assembled and tested. The results are documented in Reference 1. These tests were:

Thermal Performance

Stagnation-Defocusing Test

Collector Pressure Drop

Internal Vacuum Test

Thermal Changes

Pressure Test

Tracking Test

Fluttering Test

Accelerated Swivel and Flexible Joint Life Test

Evaluation of Structural Design.

Following these individual subsystem tests, an entire collector array consisting of four collector modules was constructed and tested [1].

CONCLUSIONS AND RECOMMENDATIONS

At the conclusion of the contract performance period, the system was certified by independent professional engineers [1] to comply with the following national codes:

- 1) National Standard Plumbing Code, National Association of Plumbing-Heating-Cooling Contractors 1971.
- 2) National Electrical Code 1975.
- 3) Building Code ANSI A58.1-1972. Applied to the Dallas/Fort Worth Region for installations less than 30 ft above the ground.

In addition, the thermal performance test was certified by a qualified independent professional engineer [1].

The silicon cell Sun sensor which controls the tracking mechanism's east/west attitude and which was improved during this contract performance period still dysfunctions to some degree on cloudy days (see Problems and Solutions); however, this is not classified as a major subsystem malfunction. MSFC personnel have developed a design which improves performance accuracy [8].

The 300 ft² of concentrating collectors delivered to the Government under this contract is one of several different types of solar collector systems installed and operating at the NASA/MSFC solar demonstration facility at Huntsville, Alabama. (This facility is open to the public.)

Northrup, Inc., was manufacturing and installing concentrating solar collectors prior to this contract, and is continuing to do so with the knowledge gained under this contract being reflected in its current production articles. The Northrup solar installations in operation are as follows:

| <u>Name</u> | <u>Location</u> | <u>Application</u> | <u>Collector Area (ft²)</u> |
|---------------------------|--------------------|--------------------|--|
| Trinity University | San Antonio, Texas | H/C/DHW | 16 080 |
| Mansfield School District | Mansfield, Texas | H/C/DHW | 1 410 |

| <u>Name</u> | <u>Location</u> | <u>Application</u> | <u>Collector Area (ft²)</u> |
|--|--------------------------|---|--|
| Institute of Gas Technology (Lone Star Gas Co.) | Dallas, Texas | Munters Heating and Cooling Systems (M.E.C.) | 500 |
| State of Florida Visitors Welcoming Station | Jacksonville, Florida | H/C/DHW | 2 700 |
| Williams Forestry Service | Williams, Arizona | H/C/DHW | 2 300 |
| Intermediate School District | Macomb Co. Michigan | H/C/DHW | 4 000 |
| College House Apartments | Austin, Texas | H/DHW | 2 228 |

Note: H — Heating
C — Cooling
DHW — Domestic Hot Water

GENERAL

The referenced documents indicated by [] throughout the text are extensions of this final report and are recommended reading to provide a more detailed understanding of each hardware item developed under this contract. They may be obtained through DOE, Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830 or purchased from National Technical Information Service, Springfield, Virginia 22151.

APPENDIX A

This document constitutes the certification of the Northrup ML Series Collector, Model NSC-01-0732.

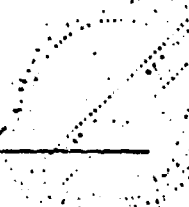
CERTIFICATION STATEMENT

The ML Series concentrating Collector complies with the following national codes where applicable:

National Standard Plumbing Code, National Association of Plumbing-Heating-Cooling Contractors 1971.


Frank A. [Signature]
Professional Engineer

National Electrical Code 1975


John A. Swage
Professional Engineer

Building Code ANSI A58.1-1972
Applied to the Dallas/Ft. Worth Region
For Installations less than 30 ft. above ground


Bijan [Signature]
Professional Engineer

I have reviewed the performance requirements, testing procedures, test facility, and data for the ML Series Concentrating Collector, Model NSC-01-732 under Contract No. NAS8-32251. I am able to certify that the collector satisfies those requirements.


J. J. [Signature]
Professional Engineer

APPENDIX B

----- AND EASY TO SIZE TO YOUR NEEDS

THE NUMBER OF SQUARE FEET OF NORTHRUP COLLECTOR REQUIRED FOR A SPECIFIC ENERGY OUTPUT WILL VARY WITH LOCAL CONDITIONS. BY SUBSTITUTING YOUR OWN DATA IN THE EXAMPLE BELOW, YOU WILL BE ABLE TO DETERMINE THE COLLECTOR AREA NEEDED IN YOUR PARTICULAR APPLICATIONS.*

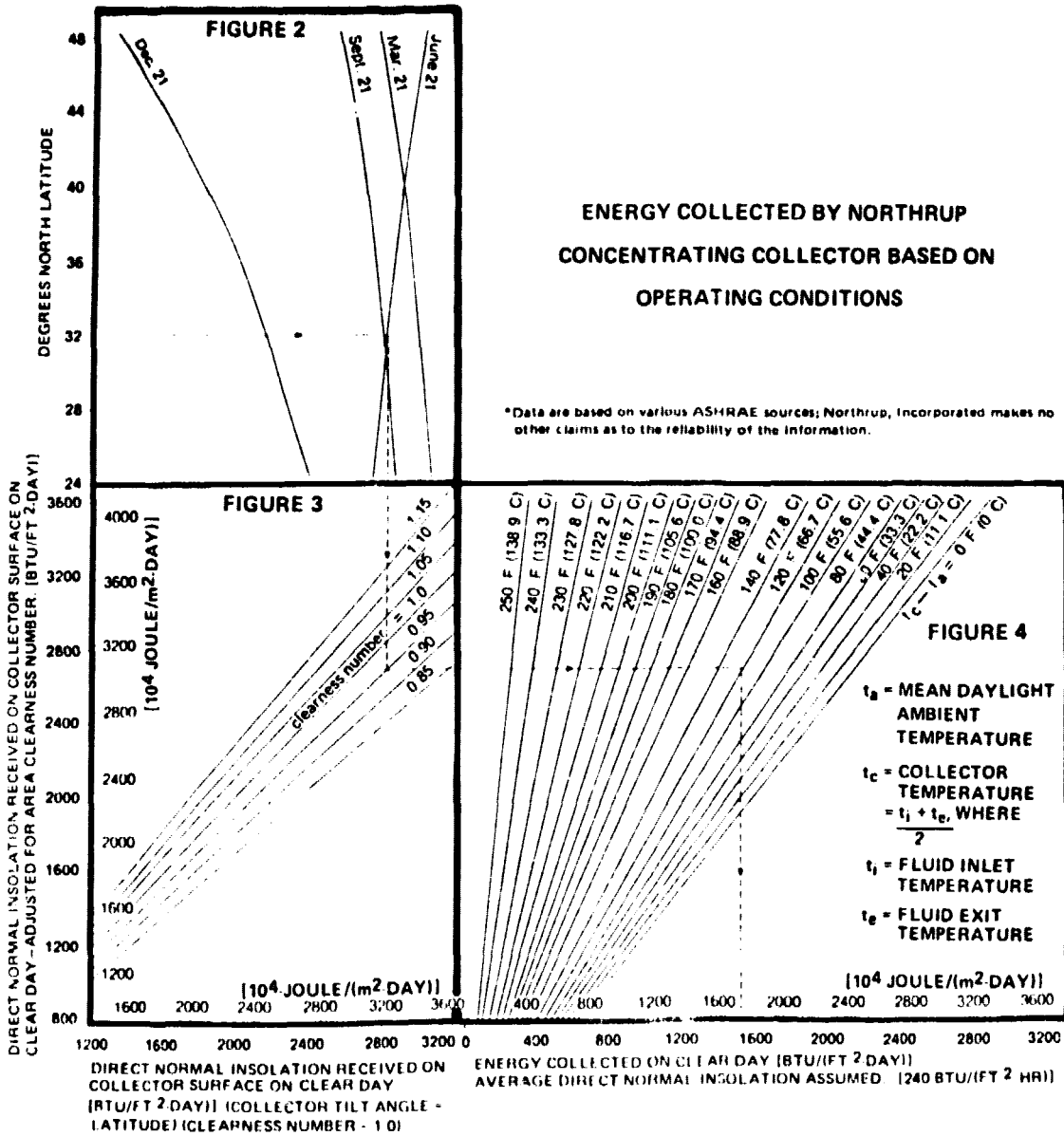
NORTHRUP COLLECTOR SIZING EXAMPLE

Required: 1,000,000 Btu/Day at 200 F

Given: 32° North Latitude (Dallas, Texas)

June 21, Day Daylight Mean Ambient: 80 F

(Absorber fluid: Water)



Procedure:

1. From Figure 1 estimate the atmospheric clearness number for Dallas as 0.95 for summer. For industrial locations, the clearness number should probably be reduced.
2. Enter Figure 2 at 32° north latitude and proceed horizontally across to the line for June 21. Interpolation is necessary for some periods of the year. From the intersection with the latitude and time of year, proceed vertically down onto Figure 3. As the example shows, the direct normal insolation received on the collector surface on a clear day is approximately 2825 Btu/ft² · day.
3. At Figure 3, from the intersection of the vertical line obtained in Figure 2 and the line for area clearness number as found in Step 1,

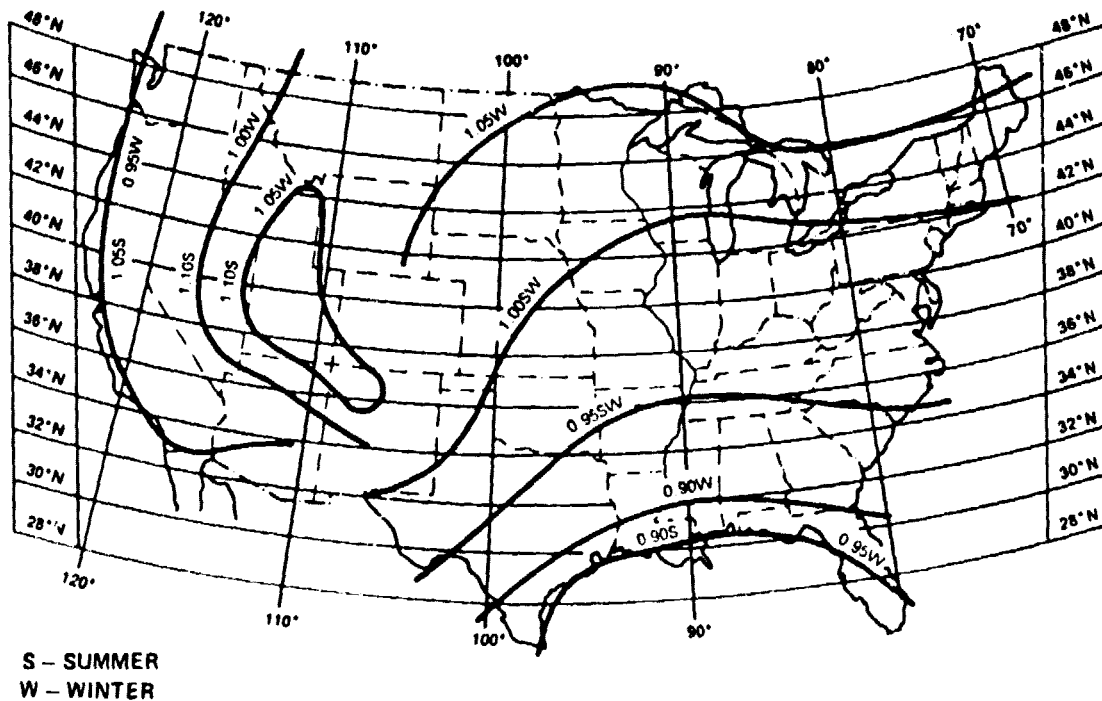
proceed horizontally to the right onto Figure 4. The example shows that the direct normal insolation received on the collector surface on a clear day adjusted for a clearness number of 0.95 is 2660 Btu/ft² · day.

4. Enter Figure 4 horizontally from the left, proceed across to the operating temperature line, then vertically downward to obtain the amount of energy collected on a clear day. As the example shows, at $t_c - t_a = 120$ F, read 1540 Btu/ft² · day energy collected. Thus, area required $\approx \frac{1,000,000 \text{ Btu/day}}{1540 \text{ Btu/ft}^2 \cdot \text{day}} \approx 650 \text{ ft}^2$

As indicated on Figure 4, $t_c - t_a = 120\text{F} = 200\text{F} - 80\text{F}$

FIGURE 1

Estimated atmospheric clearness numbers in the United States for non-industrial localities.



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REFERENCES

1. **Certification and Verification for Northrup Model NSC-01-0732 Fresnel Lens Concentrating Solar Collector.** DOE/NASA CR-161164, Northrup Inc., Hutchins, Texas, Contract NAS8-32251, March 1979.
2. **Design Package for Concentrating Solar Collector Panels.** DOE/NASA CR-150788, Northrup, Inc., Hutchins, Texas, Contract NAS8-32251, August 1978.
3. **Installation Package for Concentrating Solar Collector Panels.** DOE/NASA CR-150780, Northrup, Inc., Hutchins, Texas, Contract NAS8-32251, August 1978.
4. **Concentrating Solar Collectors Subsystem (Preliminary Design Package and First Quarterly Report).** DOE/NASA CR-150714, Northrup, Inc., Hutchins, Texas, Contract NAS8-32251, January 1977.
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7. **Development and Fabrication of a Concentrating Solar Collector Subsystem (Quarterly Reports).** DOE/NASA CR-150787, Northrup, Inc., Hutchins, Texas, Contract NAS8-32251, July 1978.
8. **Solar Tracking Control System "Sun Chaser",** DOE/NASA TM-78199, D. R. Scott and P. R. White, MSFC, August 1978.

APPROVAL

DEVELOPMENT, TESTING, AND CERTIFICATION OF THE NORTHROP, INC., ML SERIES CONCENTRATING SOLAR COLLECTOR MODEL NSC-01-0732 - FINAL REPORT

By John C. Parker

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.



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