Research And Development Techniques For Fabrication Of Lightweight Solar Concentrators

Addendum to EOS Report 2100-Final Contract NAS 7-86
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E S ELECTRO-OPTICAL SYSTEMS, INC., Pasadena, California

Addendum Report

RESEARCH AND DEVELOPMENT TECHNIQUES FOR FABRICATION OF LIGHTWEIGHT SOLAR CONCENTRATORS

Prepared for

National Aeronautics and Space Administration
801 19th Street, N.W., Room 526
Washington 25, D.C.
Attn: Mr. Walter Scott, Code DA

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Prepared by the staff of
Engineering Development Department
M A. Pichel
Project Supervisor

Approved by

for
Lee M. Springer
Manager
Engineering Development Department

Approved by

J. Neustein
Manager
Advanced Power Systems Division

ELECTRO-OPTICAL SYSTEMS, INC. - PASADENA, CALIFORNIA

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FIGURES

1. INTRODUCTION

This report gives the results of final experimental work conducted during a six-week extension of the technical work on Contract NAS 7-86. During this period, fabrication of the 5-foot diameter copper concentrator was completed. This unit and the second 5-foot diameter nickel concentrator were coated and tested. The dimensions and configuration of these concentrators are shown in Fig. 1.

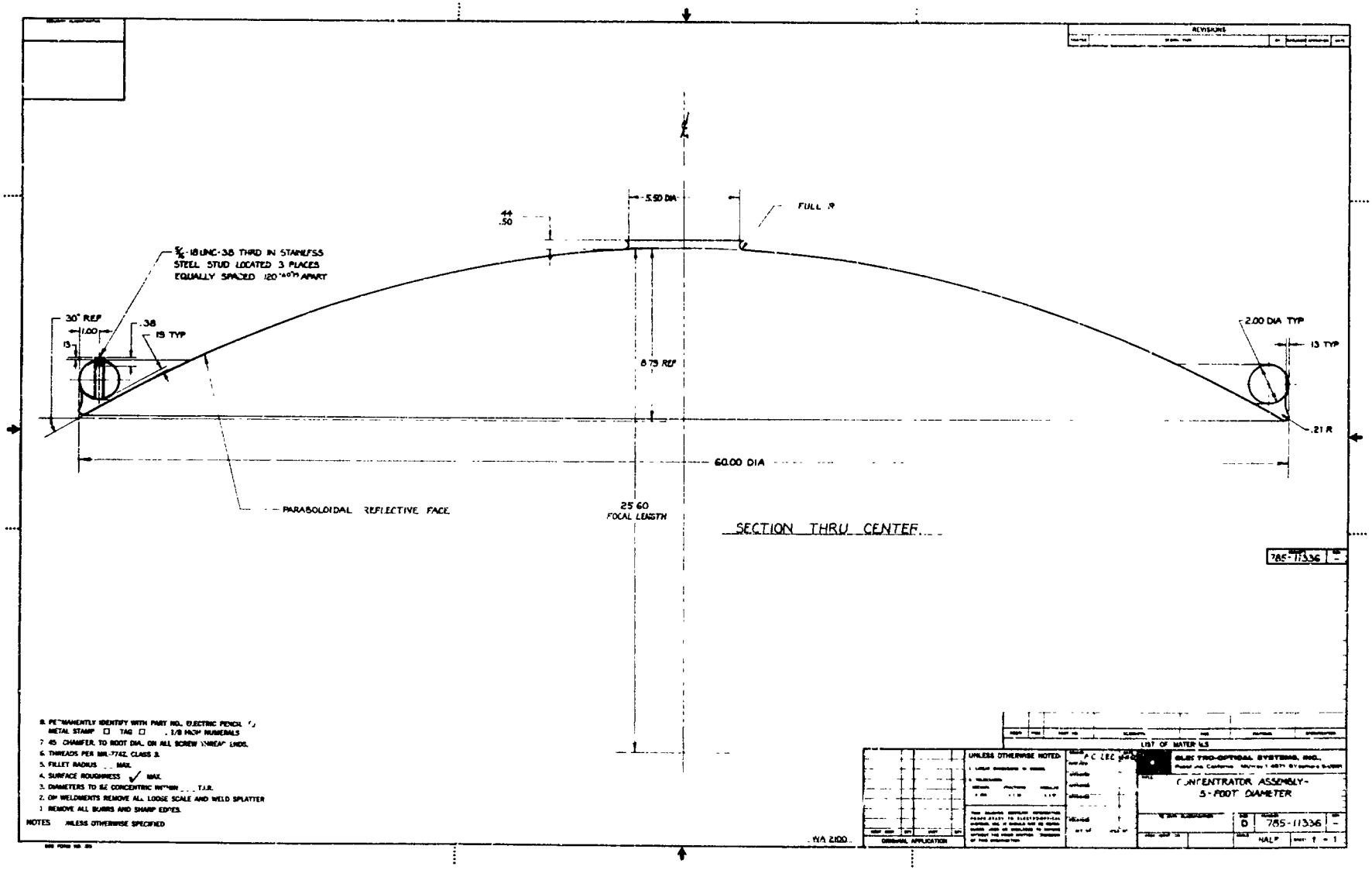

FIG. 1 CONCENTRATOR ASSEMBLY

2. FABRICATION COATING AND TESTING OF 5-FOOT DIAMETER CONCENTRATORS

2.1 Fabrication of the Copper Concentrator

The electroforming of a complete copper solar concentrator was accomplished using essentially the same master preparation procedure developed during the preceding work on nickel mirrors. The master used in the completion of the second nickel mirror (master No. 60-POM3) was employed. The procedures used to prepare the master for skin plating and silver sensitizing were identical to the steps outlined on pages 124-127 of EOS Report 2100-Final.

2.1.1 Copper Anode Array

The anode array used in making the copper concentrator conformed to the geometry of the master and was basically similar to that used in earlier copper plating work conducted under Contract NAS 7-10. Modifications for current use included an auxiliary anode assembly holding a copper bar anode that was 16 x 1½ x 1/16 inches in size, and certain special support arrangements. A lower view of the array is shown in Fig. 2. The purpose of the auxiliary unit was to augment the electrodeposition of sufficient material into the groove area on the rim of the skin. The auxiliary anode shape and the arrangement of the attendant gusher were similar to the auxiliary anode array used in the previous nickel work.

The entire anode array was suspended from the master holding fixture shown in Fig. 3.

2.1.2 Fabrication Procedure

As stated above, all steps in preparing the master for plating were the same as in previous work on nickel concentrators. However, in the actual plating, attention was given to several plating requirements peculiar to the electroforming of copper. Experiments on

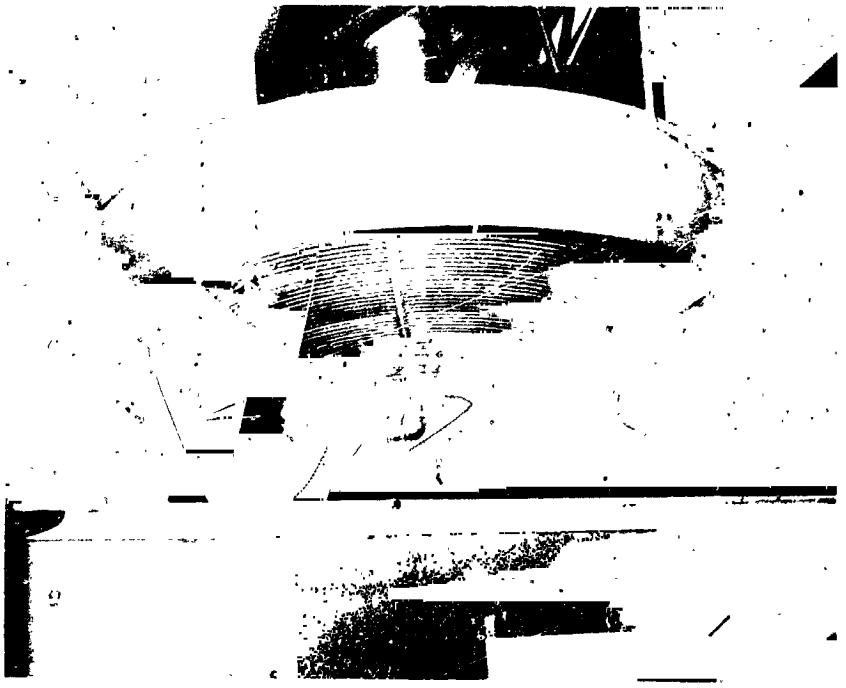

FIG. 2 ANODE ARRAY - COPPER

FIG. 3 MASTER AND ANODE ASSEMBLY

the effect of plating parameters on physical properties of electrodeposited copper (Ref. 2100-Final, pages 79-81) had indicated that the current density must be relatively high. Therefore, in the plating of the copper concentrator, a current density of 65 amps/ft^2 at 96^{o}F was selected. Extra rectifier capacity and connecting bus bars and cables were provided. During the plating of the concentrator face skin, a careful watch of the various electrical connections was maintained; especially those onto the rim and center plate of the master. A moderate heat rise occurred in the two connections to the center plate. However, no burnout on the edge of the plating appeared. A copper sulphate plating solution was used, similar to that employed in the physical properties test program, with Dayton-Bright hardening additive (Ref. 2100-Final, page 81, Sample F-71). The plating arrangement is shown in Fig. 4.

The master used in plating the copper concentrator was 60-POM3, the same master as was used in the latter portion of the work in nickel. Before using, the cracks in the glass underwent further repair. Bridge blocks, which had worked loose, were refastened using epoxy resin. The epoxy was also used in repairing holes along the cracks in the surface of the glass.

The first copper plated skin was scheduled to be a test skin. However, when it was completed, the quality of appearance suggested that it should be considered for incorporation into a complete concentrator. The technique of estimating material distribution of a skin resulting from a given anode-cathode relationship had been checked favorably in the work on nickel concentrators. A decision was then made to proceed directly to the completion of a copper concentrator. The torus flange mandrel preparation was similar to the procedures used with nickel concentrators, with the same flange design as on the second nickel concentrator (60-POM3: R12). The prepared mandrel flange is shown in Fig. 5. During the plating of the torus flange, 8 bar anodes were used. The bath temperature (96^{o}F) and current density (65 amp/ft^2) used on the

FIG. 4 ELECTROFORMING IN PROGRESS - SKIN, COPPER CONCENTRATOR

FIG. 5 MANDREL PREPARATION FOR PLATING TORUS TO SKIN

skin plating were held, and the rotation was periodically reversed to avoid excessive buildup on the sides of the numerous small holes in the torus used for lock-plating the flange. Parting of the completed electroform was uneventful, and the concentrator was put into the process of cleaning the mandrel wax out of the torus area preparatory to coating.

2.2 Coating the Second Nickel Concentrator

The second nickel concentrator (60-POM3: R12) was coated in the same manner as the first concentrator, at a rented 6-foot diameter vacuum coating facility. Coatings of chromium, silicon monoxide, and aluminum were applied, as with the first concentrator. The coating apparatus, including EOS-supplied electrodes, glow discharge ring, and vapor sources performed as expected, and the coating process was successful. Pressure-sensitive tape tests indicated that the coatings were firmly adherent.

2.3 Coating the Copper Concentrator

The copper concentrator (60-POM3: R13) was to be given the same type vacuum deposited coatings as were applied to the two nickel concentrators. The same 6-foot diameter facility was rented and the mirror was placed in the chamber, which was then pumped down to a vacuum of approximately 1.5×10^{-5} mm of Hg. The chromium and silicon monoxide were deposited in the same manner used with the nickel units. However, during deposition of the aluminum reflective layer an electrical failure occurred in the rectifier used to supply power for evaporation. There was no interruption in the vacuum during a temporary repair period of 35 minutes, after which time the aluminum was promptly deposited. Upon removal from the chamber, however, the pressure-sensitive tape test revealed low adherence of the coating, even though it presented a good appearance. Two days later the coating had started to flake off, and appearance steadily deteriorated. Apparently the time lapse between the silicon monoxide and aluminum coatings allowed contamination of the surface. The mirror was allowed to proceed to testing because the

possibility existed that stripping the partially adherent coating might degrade the quality of the mirror, and the area affected by the flaking was only an estimated one-tenth to one-fifth of the surface.

2.4 Calorimetric Testing

The concentrators produced during this final technical phase were tested for efficiency, employing the calorimetric technique detailed in EOS Report 2100-Final (pages 128-129).

2.4.1 Calorimetric Test Results

Concentrator 60-POM3: R12, the second nickel concentrator, represents a moderate improvement in efficiency over the first all-nickel concentrator, 60-POM5: R7. An average efficiency of 64.2 percent with the 1/2-inch orifice is still somewhat below the level desired on this program. Peak performance at the 2-inch diameter orifice was approximately 84 percent. An overall edge roll, effecting a band 1 to 1½ inches in width at the periphery, reduced performance somewhat and prevented "peaking" of performance at smaller orifice sizes. Much of the loss, however, may be attributed to several deformities in the skin, resulting from the degraded master and related parting difficulties. Test results for this unit are given in Fig. 6.

The copper concentrator, 60-POM3: R13, yielded a higher efficiency than either of the two nickel units, with an average of 68 percent efficiency at the 1/2-inch orifice. As in the case of the nickel units, it had some distortions due to poor master quality and parting, and the test results indicate the effect of the poor adherence of the aluminum coating. Test results are presented in Fig. 7. The overall geometry was better than either of the two nickel concentrators, as evidenced by the flatter performance curve in the larger orifice region. Extrapolation of the measured performance to the higher reflectivity value, which would be experienced with a better reflective coating, indicates a performance capability of 75 to 80 percent with the 1/2-inch orifice diameter.

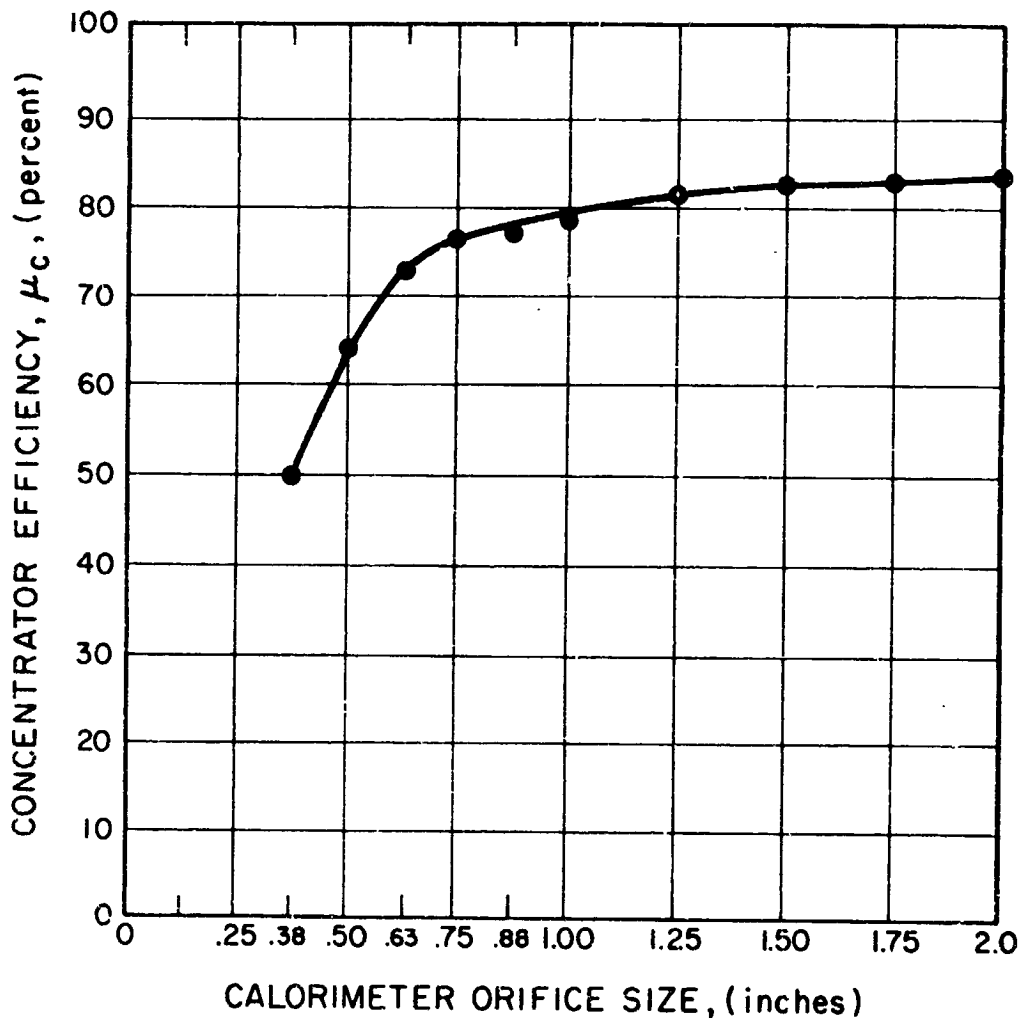

FIG. 6 TEST RESULTS, 60-POM3: R12 (SECOND NICKEL CONCENTRATOR)

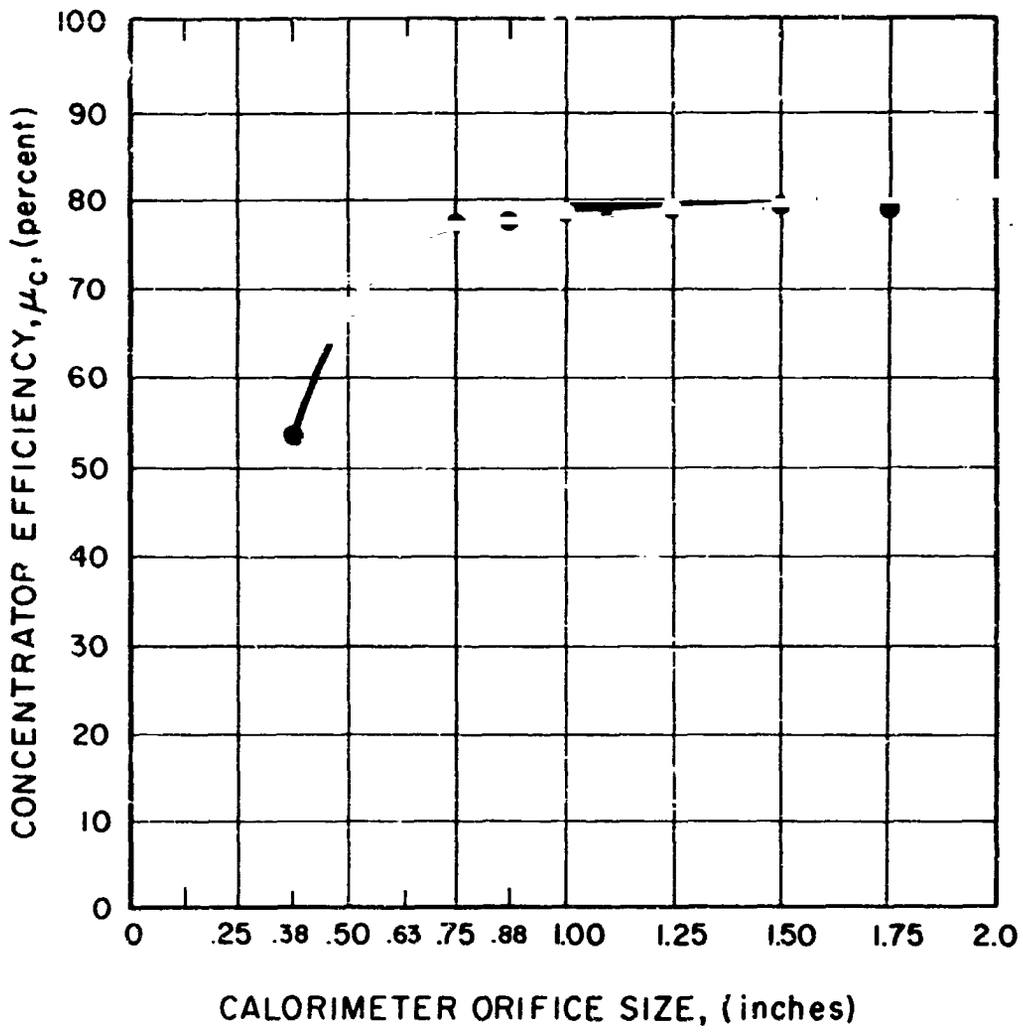

FIG. 7 TEST RESULTS, 60-POM3: R13 (COPPER CONCENTRATOR)

3. SUMMARY

The completion of several representative concentrators during the course of this program further confirms the feasibility of producing high-efficiency solar concentrators entirely by the electroforming process.

The basic design approach was directed toward development of an improved concentrator configuration having a maximum diameter of 60 inches and employing a rear-mounted torus to provide necessary rigidization and points of attachment without sacrificing the high performance and lightweight characteristics of previous all-electroformed units. These concentrators illustrate the practicality of the design that requires a secondary plating operation for effective locking together of the torus and reflective skin into an efficient, thin-shelled structure. Although the final edge configuration (Fig. 1) does not give a full 60-inch diameter reflective area due to the edge radius required and associated edge effect, the design does represent a considerable improvement over the front-mounted torus used earlier.

Tests of the three representative concentrators resulted in performance levels which were somewhat lower than desired. However, the progressive, step-by-step increase in performance, which was evident with each successive concentrator produced, indicates that a continued production effort involving further development of the techniques associated with this modified design concept, especially those related to the control of the edge effect and parting procedures, plus the use of better masters, will substantially improve concentrator efficiency.