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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The JPL 7.62-m Space Simulator Modification

Norman R. Morgan

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PREFACE

The work described in this report was performed by the Applied Mechanics Division of the Jet Propulsion Laboratory.

ACKNOWLEDGMENTS

The modification of the JPL 7.62-m space simulator described in this report was a result of the efforts of many people. The author wishes to express his particular gratitude to Robert Hahn, John Harrell, David Howe, Eugene Noller, Norman Riise, Frank Teeple, and Charles Youngberg for their dedicated efforts that were vital contributions to the success of this Project.

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ABSTRACT

The JPL 7.62-m space simulator was modified to simulate the solar intensities at the planet Mercury. The capability of the simulator was increased to support testing of both the Mariner spacecraft mission to Venus and Mercury (to be launched in 1973) and the Helios spacecraft. The design of the off-axis reflecting system of the JPL simulators allowed attaining increased solar intensity, at the expense of test area, by placing a smaller collimating mirror at a lower elevation in the space simulator. In addition to requiring a new collimating mirror 4.57 m in diameter, the optical integrating system required a new design and there were several other efforts necessary to support these primary alterations.

I. GENERAL DESCRIPTION OF MODIFICATION

The 1973 Mariner flyby mission to Venus and Mercury will encounter considerably higher solar intensity than that which was available in solar simulation facilities prior to modification of the JPL 7.62-m space simulator. The JPL simulator could have adequately provided intensities to simulate solar conditions at the orbit of Venus; this simulation capability extended through a test volume considerably larger than needed for the Mariner-size spacecraft to be used in the 1973 mission to Venus and Mercury. The purpose of the modification to the space simulator was to concentrate the available solar simulation capability into a smaller area of proportionally higher intensity.

The JPL 7.62-m space simulator is a large, diffusion-pumped vacuum chamber with liquid-nitrogen-cooled walls and floor. Its solar simulator consists of a system of compact arc lamps, beaming energy through a lens arrangement and window into the chamber where the energy is reflected by a 7.01-m-diam collimating mirror to the test article. The space simulator and the optical system design are described in detail in Refs. 1 through 3.

To provide the higher intensity/smaller test area requirements of the Mariner Venus/Mercury mission MVM'73, it was necessary to modify the existing optical design by installing a smaller mirror at a lower elevation and modifying the mixer lens optical design to provide uniformity of intensity with this lower elevation of the reflecting surface (Fig. 1).

In addition to the MVM'73 mission test requirements, consideration was given to testing the Helios spacecraft (Fig. 2), a West German mission involving NASA support. The Helios spacecraft is designed for exploratory

missions toward the Sun, inside the orbit of Mercury. It is a somewhat larger spacecraft than MVM'73, is spin stabilized, and shared with MVM'73 the problem of not having a test facility capable of providing adequate solar thermal-vacuum simulation for system tests. Therefore, test requirements for Helios were developed and incorporated into the modification requirements for the 7.62-m space simulator.

To satisfy the test requirements for the relatively larger Viking Mars Orbiter 1975, it was also necessary to provide the capability to revert to the original optical system. This requirement for solar simulator versatility engendered considerable effort in developing hardware and procedures to facilitate replacement of optical system elements.

The facility modifications, as carried out, included:

(1) Design and procurement of a 4.57-m-diam collimating mirror, fabricated of aluminum, electroplated with nickel, and optically polished. After attachment of the cooling manifolds by JPL, a final vacuum deposition of aluminum was applied by JPL personnel using the 7.62-m space simulator.

(2) Design and fabrication of two, new, optical "mixer" elements (lens arrays), which are placed at the focus of the xenon arc lamp collectors, and which integrate the light beams from the lamps into essentially one beam falling on the collimating mirror. The lens elements for these mixers were procured from an optical firm.

(3) Design and fabrication of three, water-cooled "cans" to hold the mixer elements during use and during installation and removal. The three cans were required so that existing mixers would also be compatible with the modified system of positioning these optical elements.

(4) Modification of the rail system used for installation and removal of mixers.

(5) Addition of an overhead hoist system for use in handling mixers.

(6) Addition of a support system, removable, attached to the vacuum chamber and from which the 4.57-m-diam collimating mirror is suspended.

(7) Modifications to existing cooling systems: water, air, and gaseous and liquid nitrogen, to allow connection to the mirror and mixers.

(8) Modifications to instrumentation systems to allow recording of various data, primarily temperature, of the optical system elements.

(9) Design and procurement of a wheeled cart for safely transporting the 4.57-m-diam collimating mirror.

(10) Design and fabrication of a system of removable tracks to control movement of the mirror cart into and within the 7.62-m space simulator during removal or installation operations.

(11) Design, procurement, and fabrication of a hoisting system to allow 4.57-m-diam collimating mirror installation and removal.

II. SUMMARY OF PERFORMANCE OBJECTIVES AND ACCOMPLISHMENTS

The purpose of the project was to provide the capability for simulating a 2.29-m-diam beam of solar radiation energy, in the existing 7.62-m space simulator, at intensity levels to be encountered by a spacecraft at the planet Mercury's distance from the Sun, and to retain the capability for testing at lower intensity levels. Further, the project would provide a large, 3.35-m-diam hexagonal (measured across the flats) solar beam for testing Helios, at the maximum intensity possible, using the existing thirty-seven 20-kW lamps operating up to 25% over rating. Helios testing capability was to be in excess of four solar constants. These stated objectives were all met, or surpassed.

In addition to these formal objectives, a more detailed set of design requirements was developed. These requirements have been met; however, the following comments are in order.

(1) MVM'73 test area: the defined test area of a 2.29-m-diam circular plane was later determined to be insufficient for the MVM'73 spacecraft as the design developed. Although the

existing penetration window (plano-convex) allowed a test area in excess of a 2.29-m-diam circle, this chamber penetration window was replaced by the alternate window that was used for initial checkout of the modification, and that had its convex side refinished to a flat surface. The plano-convex penetration window resulted in a hexagonal beam of 2.59 m across the flats; the flat window adds another 11.6 cm to this dimension at the test plane. Thus, the modification has considerably exceeded the original design requirement.

(2) MVM'73 spatial uniformity of intensity: the solar beam resulting from the modification initially did not attain the ±5% uniformity desired over its full width, particularly at low intensities. All intensity plots showed a beam with higher intensities on the periphery as compared to the center. Subsequently, certain mixer lenses were inverted and this flattened out the uniformity distribution. However, uniformity considerations were not deemed sufficiently significant to disassemble the mixer and invert lenses for the first tests which were run on MVM'73 and Helios test spacecraft.

(3) MVM'73 test reserve: the goal of 25% test reserve was significantly exceeded. Twenty-two lamps, at 20 kW, provided test plane intensities of 8071 W/m^2 (6 solar constants) leaving a reserve of 15 lamps, or 40%. When operating 28 lamps (75.7% of lamps available), test plane intensities of 10,329 W/m^2 (7.7 solar constants) were measured.

(4) Helios test area: the requirement of a hexagonal beam 3.35 m across flats was met and slightly exceeded.

(5) Helios solar beam characteristics: although the spatial uniformity of intensity was not specified for Helios, the measured performance using the Helios mixer showed the same peripheral peaking as that using the MVM'73 mixer. Inverted lenses improved this uniformity.

The Helios mixer system surpassed the minimum acceptable value of four solar constants (5595 W/m^2) when operating 28 lamps, and thus maintained the approximately 25% reserve

capability. The measured output with 28 lamps was 5894 to 6022 W/m^2, or 5917/1399 = 4.2 solar constants.

(6) General operating constraints - ability to install and remove mirror: the procedures developed in hanging the mirror for aluminizing and in suspending the mirror in final position proved very satisfactory; but the design goal of one week for installation or removal was not proven. Based on the experience to date, the two-week figure noted as maximum acceptable was confirmed. Because of the effort required to align the mirror, to leak-check the welded cooling lines, and to install thermocouple connections, installation has proven to be a more time consuming task than removal, and consumes the better part of two weeks. Removal is a simpler process and one week is a reasonable estimate of time necessary. Working multiple shifts and/or working more than five-day weeks would shorten the time necessary for installation or removal.

(7) Ability to install and remove mixer: the design goal was to allow interchange of mixers "without opening the chamber and within two shifts (preferably one shift)." This design goal was surpassed in that mixers were interchanged with the chamber under vacuum, and the actual time consumed was about one hour.

III. DETAILS OF MODIFICATION

A. Collimating Mirror

The 4.57-m-diam collimating mirror design borrowed heavily from the design and fabrication experience of the existing 7.01-m-diam mirror (Refs. 4 and 5), but there were numerous variations in areas such as fabrication technique, plating technique, sizing of cooling tubes, and relative size of the stiffening web to the faceplate.

The mirror was constructed of a dished aluminum plate with a rib structure, also aluminum, welded to the back of the mirror for stiffness (Fig. 3). The face of the mirror was nickel plated to acquire a sufficiently hard finish for optical polishing. Subsequent to polishing, the mirror was

delivered to JPL for the final operations of welding on the cooling tubes and manifolds, attaching the support hardware, and vacuum depositing of aluminum on the surface to increase reflectivity.

The mirror faceplate was fabricated of 5086-H112 aluminum, selected primarily for its long-term stability, annealed strength, and weldability (Ref. 4). The rib structure provided stiffness to the assembly during the handling, machining, and grinding operations. The primary factor in determining plate thickness and rib configuration was the optimization of the thermal design characteristics to minimize distortion and thermal stresses during mirror usage. The mirror structure resulting from these thermal design requirements is exceedingly stiff. Maximum dead-weight deflection of the center of the mirror while hanging in its operating position is only 0.13 mm. Specially fabricated cooling tubes were welded to the back of the mirror in an arrangement calculated to minimize thermal gradients. These tubes were bent to shape prior to welding in place, and were subsequently protected by plastic end caps during final machining operations, electroplating, and final polishing. The large manifolds that connected these cooling tubes were not welded in place until after the mirror had been delivered to JPL (Fig. 4).

The mirror cooling system was designed to limit temperature differences within the mirror structure to no greater than 24.5°C at the worst case thermal condition, e.g., full lamp power with the smallest impinging beam diameter. The maximum resulting thermal stress is approximately one-fourth the yield strength of fully annealed (5086-0) aluminum.

The mirror faceplate was fabricated by welding two sheets edge-to-edge, machining this to a circular configuration some 4.57 m in diameter, and then machining out a central circular plate 1 m in diameter. These two pieces were then "bumped" separately to shape; the reach of the pneumatic bumping machine being inadequate to handle the full 4.57-m-diam configuration. The two pieces, separately formed, were later welded back into one piece. This forming operation was different than that used on our 7.01-m mirror (Ref. 4), which was formed by welding together rolled strips of 5086 aluminum. The expected benefits of schedule associated with the bumping operation were not fully realized due to several problems. One of

these schedule problems included the decision to stress relieve (in a heat-treatment oven) the plate after bumping; as the plate required more bumping in the seam area after the center section had been reattached, both an additional bumping operation and an additional stress relief were performed.

There were additional difficulties in that the welding, bumping, and stress relief occurred at three different locations that required transportation of an outsized cargo; the heat treatment oven (Fig. 5) support system sagged due to the mirror weight, requiring redesign and construction of a new mirror support system; and the boilermakers went out on strike, resulting in delays in bumping. In addition, there were some welding difficulties that necessitated rewelding of some weld gaps during the rough machining operation. None of the above problems were insurmountable, and it appears that this method of fabrication is competitive with other methods, each of which has its own set of problems.

The rib structure was fabricated by saw cutting the individual pieces to shape, and then welding into an assembly (Fig. 6). This assembly was machined to the correct contour and later used to check the faceplate conformity (which resulted in the second bumping and stress relieving operations). Once the faceplate conformed adequately, the rib structure was welded in place, the final machining was performed on the faceplate, and the machining operations on the rim took place, i.e., trunnion supports and attachment points.

The nickel plating of the mirror was the subject of an extensive study into the alternatives of electroless nickel plating (Kanigen process or equivalent) and the electroplating method. Based on our experience with an electroless plated 3.05-m mirror and an electroplated 7.01-m mirror, the electroless plating offers advantages, particularly in corrosion resistance. However, it was not felt that the corrosion evidence uncovered in our 7.01-m mirror could be taken as condemning all electroplating, but could have resulted from the particular process employed; additional experience and attention to details could, hopefully, reduce the susceptibility of the electroplating to corrosion. In addition, cleaning procedures were developed and proven on the 7.01-m mirror; these procedures were effective in returning the mirror surface to a condition approximating an "as-new" condition.

The costs of electroless nickel plating were 50 to 100% higher than electroplating due to the necessity of building special plating tanks, which strongly influenced the decision to use electroplated nickel.

The mirror itself formed the base of the plating tank with an attached ring serving as the walls of the tank (Fig. 7). The mirror was mounted such that it could be rotated during plating, and tilted between the various plating operations to allow drainage of the numerous preplating steps, including cleaning, rinses, acid soaks, and zincate solutions. A thickness of over 0.50 mm of nickel plate was deposited during the final plating operation. Prior to the final plating of the mirror, the mirror was plated with a strippable coating of 0.10 to 0.20 mm nickel; the preplating steps were modified such that adhesion was precluded and this nickel could be mechanically stripped off. The purpose of this strippable coating was to determine the physical characteristics of the plating, such as density, purity, and variation in thickness. As a result of this operation, there was some adjustment of the plating electrodes to improve the uniformity of deposition.

The nickel plating deposited greater than 0.50 mm of nickel (measured by test coupon), Rockwell hardness between R_c48 and R_c52, with a purity of over 99.3% nickel, on the face of the mirror.

The grinding and polishing of the mirror was carried out on the same machine as previously used on the JPL 7.01-m mirror (Ref. 4).

Aluminizing of the 4.57-m mirror was based on the technique previously developed for coating the 7.01-m mirror (Ref. 6). As part of the modification work, a 30-kW electron-beam power supply was permanently installed for aluminizing mirrors in the simulator.

For aluminizing, the 4.57-m mirror was suspended 9.14 m above the chamber floor on cables. The walls of the chamber were protected by a Mylar shroud to collect aluminum deposition. The electron-beam-gun vapor source was centered on the floor (Fig. 8) with a source to mirror distance of 8.53 m. The aluminizing process is described in Ref. 6.

B. Optical Design

The optical design method for the mixer assembly was identical to past methods at JPL (Refs. 1, 2, and 7). However, the hexagonal lens elements were held in place by a nut and washer on a cooled shaft that attached only to three corners minimizing the obstruction of the light path. As shown in Figs. 9 through 12, the two lens sets are positioned in place by hollow tubes containing a splitter plate brazed inside the tube, and dividing the tube into two compartments. Small diameter cooling tubes not only support the vertical tubes, but carry the cooling water into one compartment of the support tube. After the water passes down one side and up the other side of the splitter plate, the water continues through the small diameter cooling tubes to the next vertical support tube. This forced cooling is not for the benefit of the quartz lens elements, but rather to maintain reasonable temperatures in the support tubes and retaining nuts. As stainless steel acorn nuts showed evidence of flaking during preliminary testing, indicating operating temperatures of 870°C or higher, the lower brazed studs and nuts were redesigned to increase the heat flow to the cooling fluid within the tubes.

The small diameter cooling tubes are bent to conform to the shadow caused by the seams where the hexagonal lenses meet. This configuration minimizes incident light impinging on the cooling tubes and also minimizes beam shadowing caused by the cooling tubes.

C. Mixer Cans

The mixer cans support the mixer lens system and provide for vertical and lateral adjustment of the lens assembly relative to a base flange on the cans (Fig. 13). Locating holes to match pins in the mixer cart are provided in each mixer base flange so, once aligned, each mixer returns to the same position on the cart (Fig. 13).

D. Mixer Can Installation

The cart rail system permits installation and removal of mixers in a few hours time, eliminating not only tedious hand-carrying, but also the necessity for realignment of mixers with other elements of the optical system. The track is accurately aligned with the optical axis of the solar simulation system. One side of the cart has grooved wheels that run on a

ground track, maintaining mixer/optical system alignment each time a mixer is installed (Figs. 14 and 15).

E. Hoist for Handling Mixers

The hoist is a 907-kg, two-speed hoist with a powered trolley, and handles the mixer between the storage area and the mixer cart, or between storage on the second floor and the first floor. The system expedites mixer handling and greatly diminishes the possibility of accidental damage to the mixers during handling.

F. Mirror Support System

The mirror support system, shown in Figs. 16, 17, and 18, was designed to allow suspension of the 4.57-m mirror in both its normal position and in a much lower, chamber-centered position, for aluminizing. The mirror and support system are both removable to allow reconfiguration of the chamber when large spacecraft necessitate use of the 7.01-m mirror. The support beams are bolted to hard points welded to the chamber wall; these hard points were installed as part of the modification effort.

The mirror structure, the mirror handling cart, the cart track, and the lifting cables were proof tested at loads in excess of 150% of the mirror weight (Figs. 19 and 20).

G. Modifications to Existing Systems

The capacity of the existing cooling systems was checked for adequacy to handle the increased heat loads from the higher solar intensities.

A new manifold was installed outside the east wall of the lens house to provide individual control of water flow to the dowser, mixer cans, and new cooling cone. The dowser is a water-cooled implosion plate designed to cover the penetrating window during emergencies, or during simulation of rapid solar occultations. Figures 14 and 15 show the dowser in its retracted position on rails, above the mixer can. Distilled water flow controls to the mixers were also moved outside of the lens house.

The new cooling cone, noted above, was added below the mixers to absorb stray energy from the lamps not striking the mixer inlet lenses, thus reducing heating of the surrounding structure and removing some of the heat load from the air cooling system.

The chamber LN_2 cooling system was modified to allow separate control of the wall shroud back pressure and floor shroud back pressure, thereby controlling the split of total flow to each system. The floor shroud circuits were modified to allow series or parallel flow. With parallel flow, the flow can be proportioned between the inner and outer floor, depending on heat load. A booster pump was added to the floor circuit to insure sufficient flow volume at high simulated solar intensities.

Connections were added to the existing 7.01-m mirror gas system to cool and warm up the 4.57-m mirror.

An air system, using a 2.24 kW blower, was added to cool the penetration window. Air was taken from the return of the lamp air cooling system.

H. Instrumentation Modification

The instrumentation system modifications consisted of installing thermocouples on the mixer support structure and the edges of the penetration window. In addition, a scanning radiometer was developed for vacuum use and was mounted in the chamber to survey the temperature of the surface of the penetration window. The temperatures indicated by this infrared (IR) radiometer have been somewhat higher than predicted, and have not yet been completely explained. The presence of a reflective test article has a significant effect on the output of this IR radiometer. The only logical argument postulated thus far for this effect presumes that infrared radiation from the test article is reflected back to the window where it is absorbed at the surface of the window, raising the surface temperature considerably. Analysis indicates there is insufficient reflected energy to raise the bulk temperature of the window. The properties of quartz (fused silica) in large sizes, such as used in this window, are neither well established, nor necessarily consistent from piece to piece. At this time, the indicated high window temperatures are limits to the simulator operation. Work is continuing to both understand the physics of this problem and then, hopefully, to overcome this problem. If, for example, the problem proves to be the IR absorption at the window surface, then a different type of quartz window, more transparent to IR, should result in lower window temperatures, with

resultant lower thermal stresses. At present, this window condition limits solar simulation to approximately 75% of that attainable with all 37 lamps operating at 20 kW each. If the penetration window presented no problem, it would be theoretically possible to double the solar simulation intensity available by operating all 37 lamps at 30 kW. Of course, other system limits may preclude this, such as lamp stability, lamp life, or mixer cooling limitations. This higher intensity is not necessary for the Mariner Venus/Mercury mission, but would be quite valuable to Helios.

The infrared radiometer uses an indium antimonide detector with a rotating mirror. Sensing in the 4- to 6-μm range, the instrument is mounted to view the vacuum side of the penetration window. Due to the previously noted apparent anomalies in the measurements, the radiometer has undergone numerous calibrations, has been moved to different locations relative to the window, and various modifications have been made to thermally isolate the IR radiometer from its surroundings.

I. Mirror Cart

A cart was designed and fabricated for transporting the 4.57-m mirror in and out of the chamber. The cart has four pneumatic tires, castered to allow positioning of the cart in the chamber for installation and removal (Figs. 3, 4, and 19). The cart is also used for mirror storage when the chamber is configured without the 4.57-m mirror.

J. Mirror Cart Tracks

A removable track system was designed and fabricated to support and guide the cart and mirror into and within the 7.62-m simulator during installation, or removal of the mirror. The tracks are supported from the chamber hard points (Fig. 19).

K. Mirror Hoisting System

The hoist system for the mirror was a relatively straightforward design. The two main lifting lines are attached to the trunnions of the mirror, pass upward in a four-part block and tackle to the mirror support structure; and then the two lines are carried back down to the floor of the chamber and out to two air motors (Fig. 21) securely mounted in the high bay area.

Figure 17, which shows the mirror in its suspended position, shows the trunnion attachment in the right foreground. This lifting point is also used for safety cable installation as shown in this photo. Figure 18 shows one of the two, four-part lifting lines under test. Figure 20 shows the lifting lines during proof test. Figure 22 shows the mirror in a suspended position for aluminizing. It has a Mylar cover for protection.

During the lifting operation, tag lines are used to control the mirror tilt angle, which must approach 90 deg as the mirror is lifted close to the north wall of the chamber; this wall has the large intrusion caused by the solar simulation system (Fig. 18). The mirror installation operation also requires the use of a truck-mounted extendable boom (Fig. 22) to make and break lifting point and tagline connections. Once lifted to the proper position, the adjustable supports connected to the mirror whiffle trees are secured to the support beams, the safety cables are installed at the mirror trunnions, and the mirror lifting cables are removed. Connection of the cooling system to the mirror manifolds requires a cutting operation during removal of the mirror, and a welding and leak check operation during installation. This leak check operation is the primary reason for the greater time required for installation, as opposed to removal.

The air motors shown in Fig. 21 are also used through appropriate cable systems to position the mirror cart as necessary.

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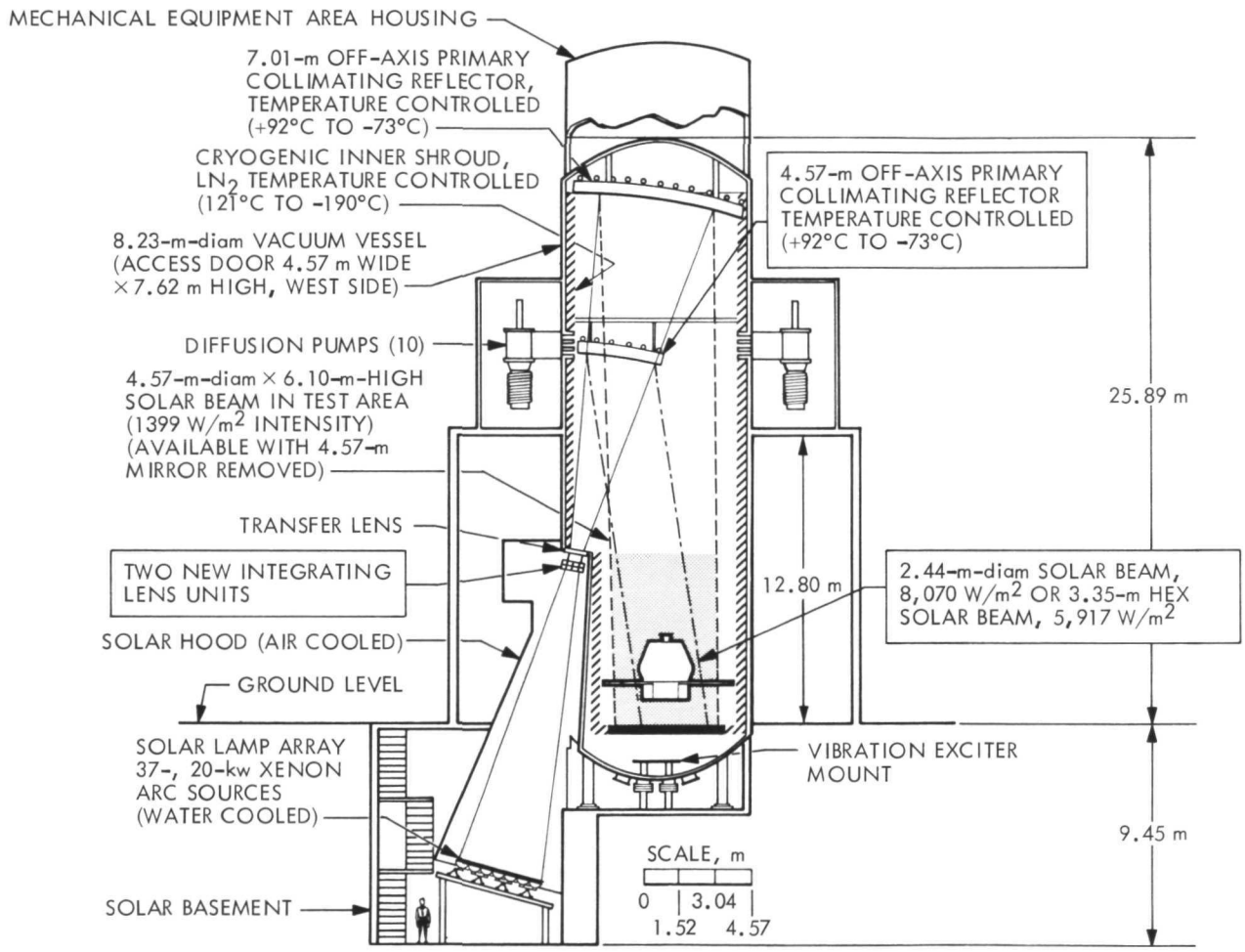

Fig. 1. JPL 7.62-m space simulator cross section (looking east) (the modifications performed are indicated by boxed-in callouts)

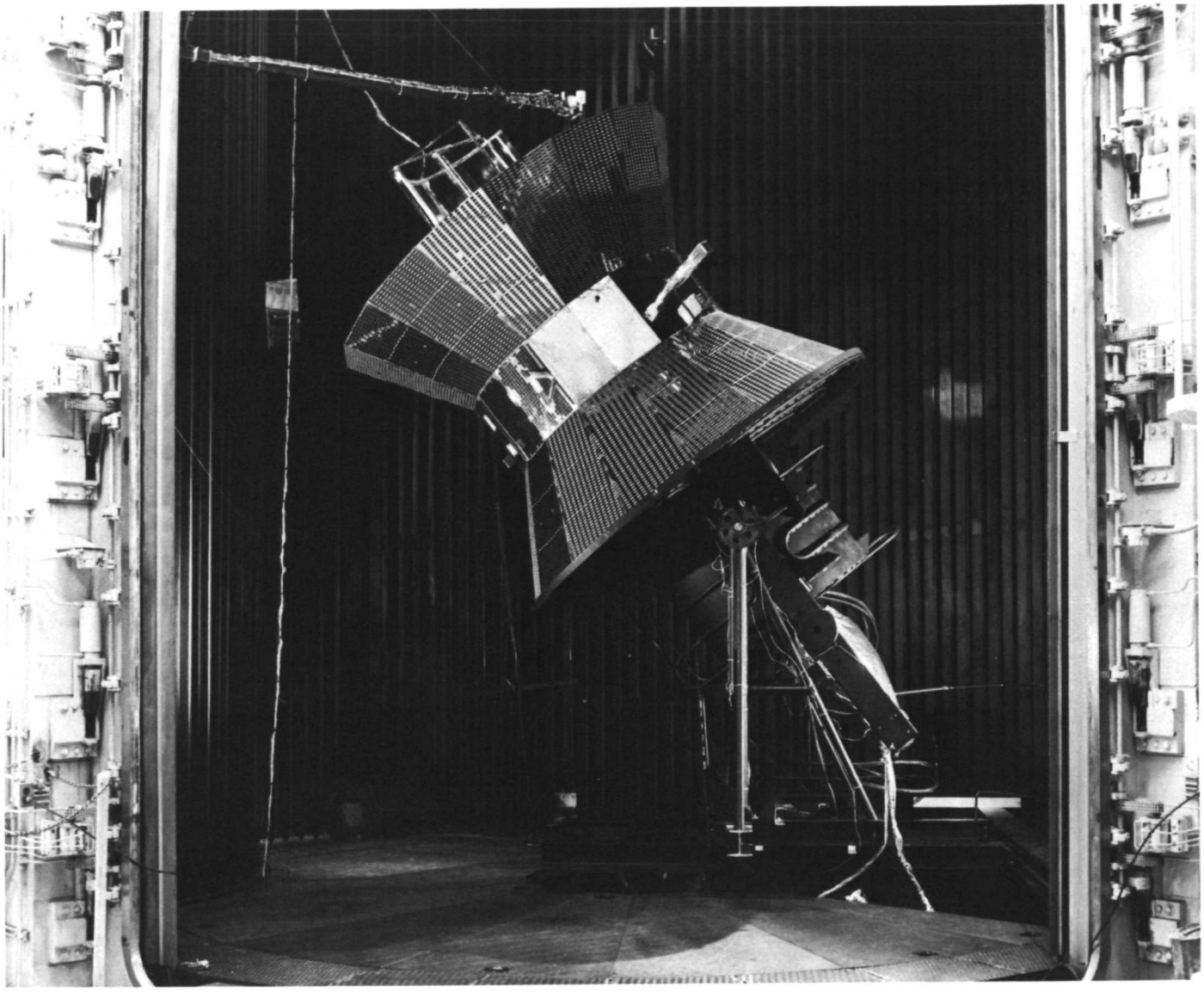

Fig. 2. Helios spacecraft thermal model installed in JPL 7.62-m space simulator. The Helios test model is mounted on a spin fixture that allows tilting and spinning the spacecraft during testing

Fig. 3. The 4.57-m collimating mirror on the mirror cart. Cooling tubes and grid support structure are apparent; the cooling tube manifolds were still to be installed

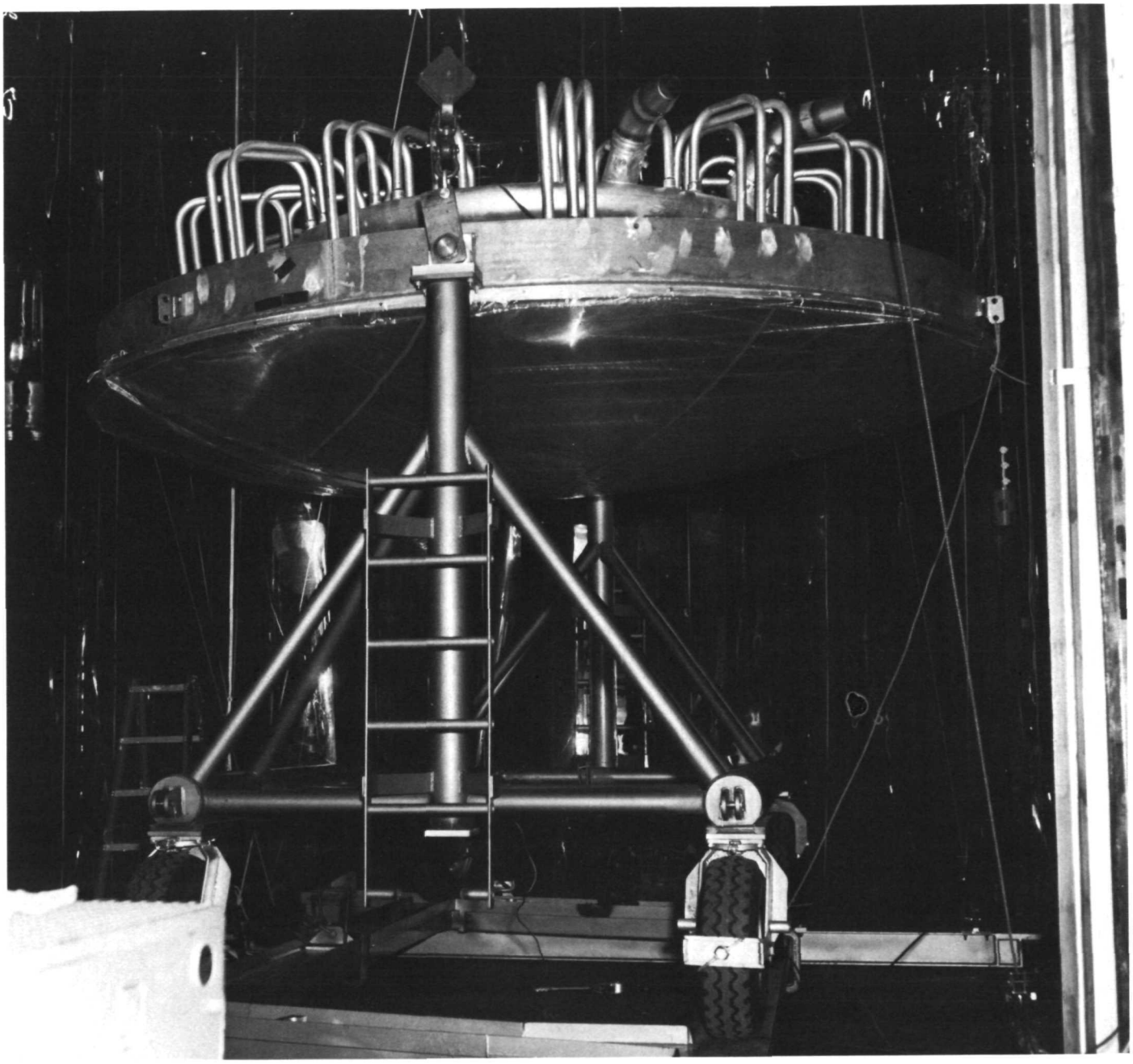

Fig. 4. The 4.57-m collimating mirror in position to be lifted off its cart and hoisted for aluminizing in the JPL 7.62-m space simulator. The mirror face is protected by a Mylar shroud

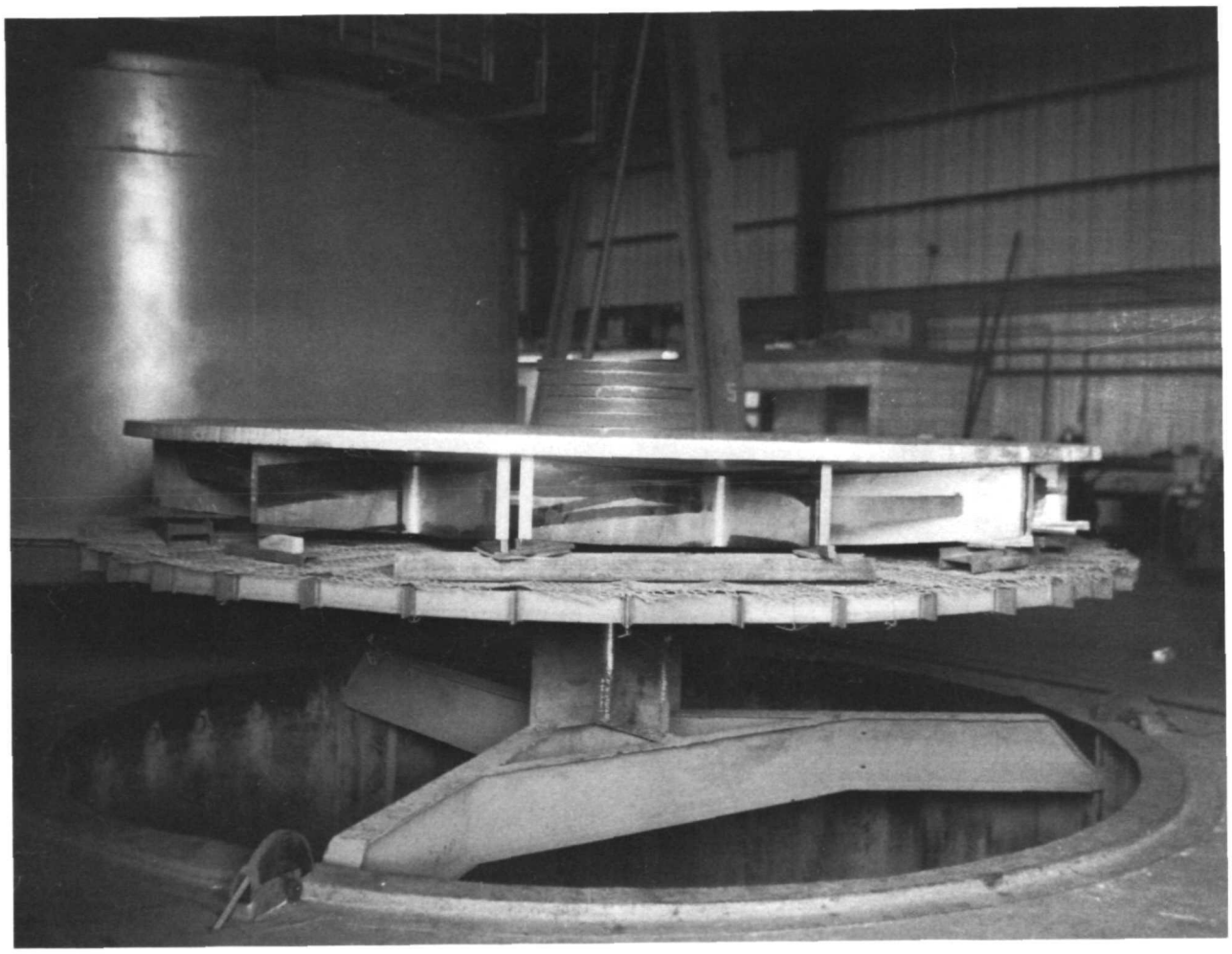

Fig. 5. The mirror faceplate preparatory to heat treatment. The cylindrical cover is in the background. The cylinder in the background forms the oven walls and top when put into position. The support fixture for the mirror faceplate required modifications to prevent the peripheral sagging evidenced in the first heat treatment

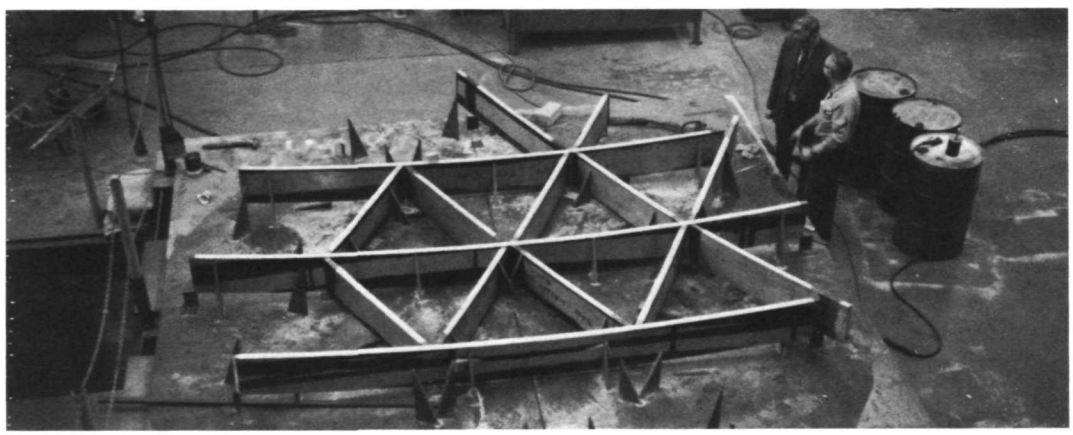

Fig. 6. The collimating mirror rib support structure being assembled and welded

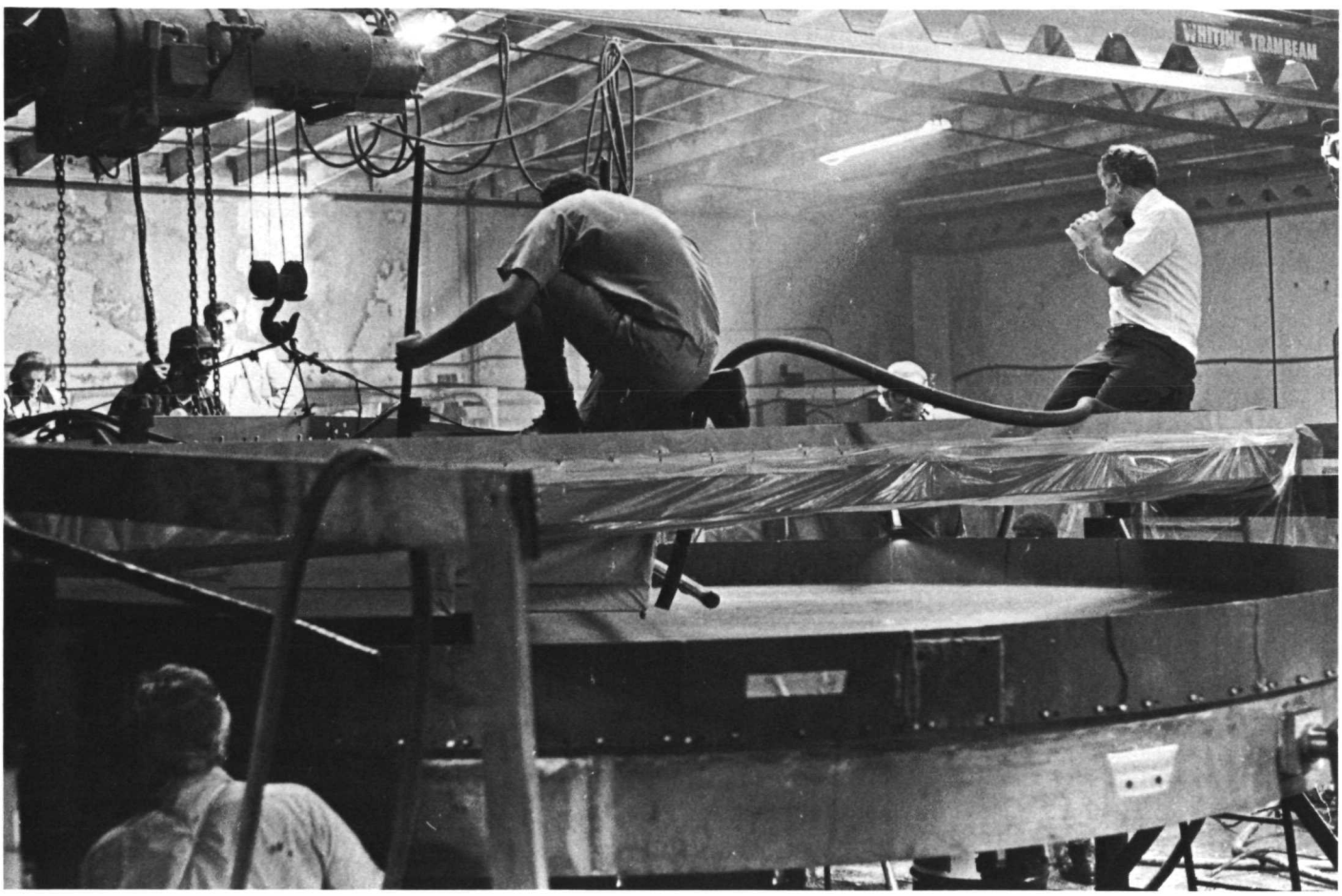

Fig. 7. The collimating mirror being prepared for plating

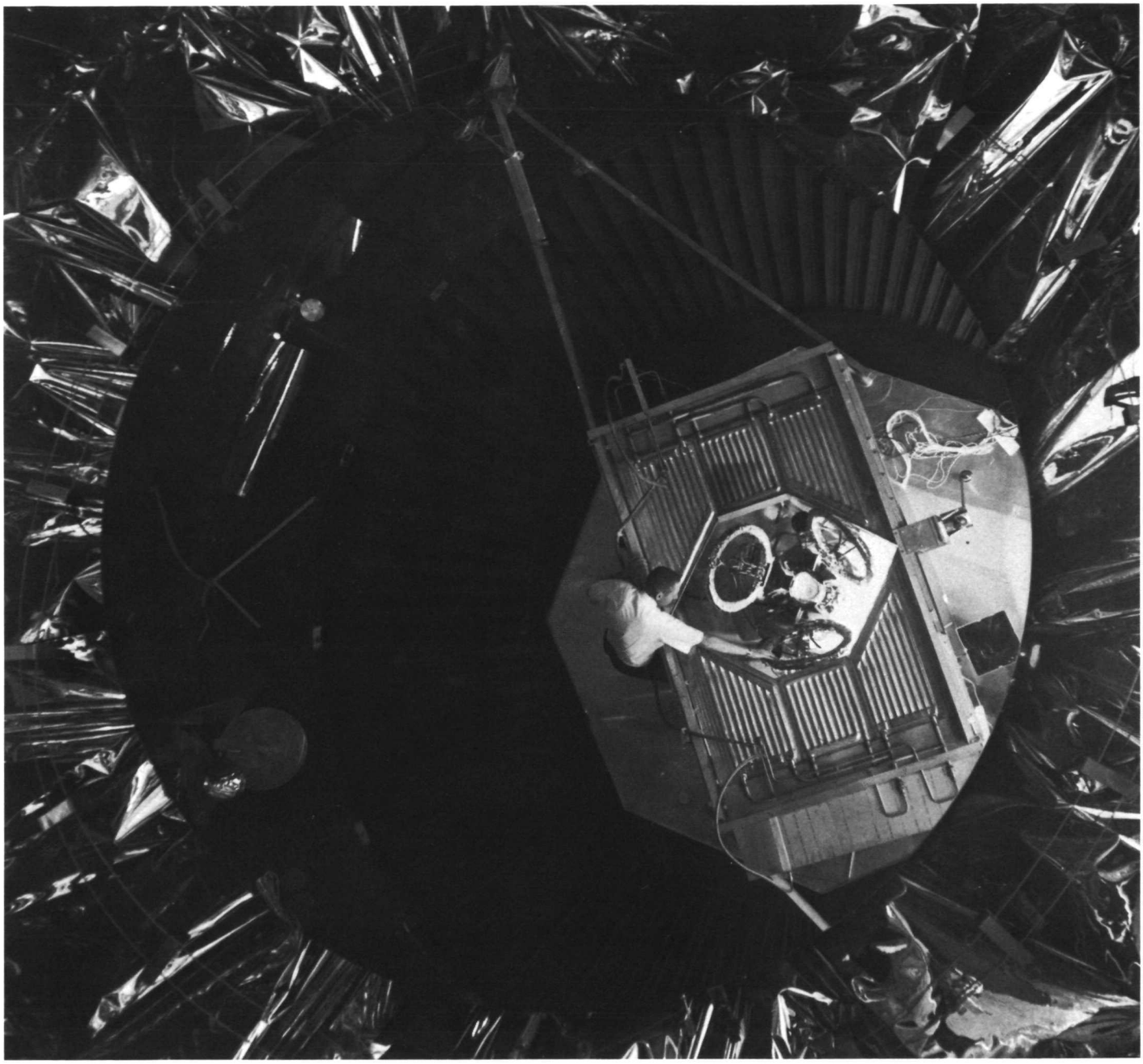

Fig. 8. The aluminizing set-up as reflected in the 4.57-m collimating mirror. The Mylar shrouds protecting the simulator walls have been aluminized during the mirror aluminizing process. The aluminum source, directional coils, and shutter mechanism are clearly visible

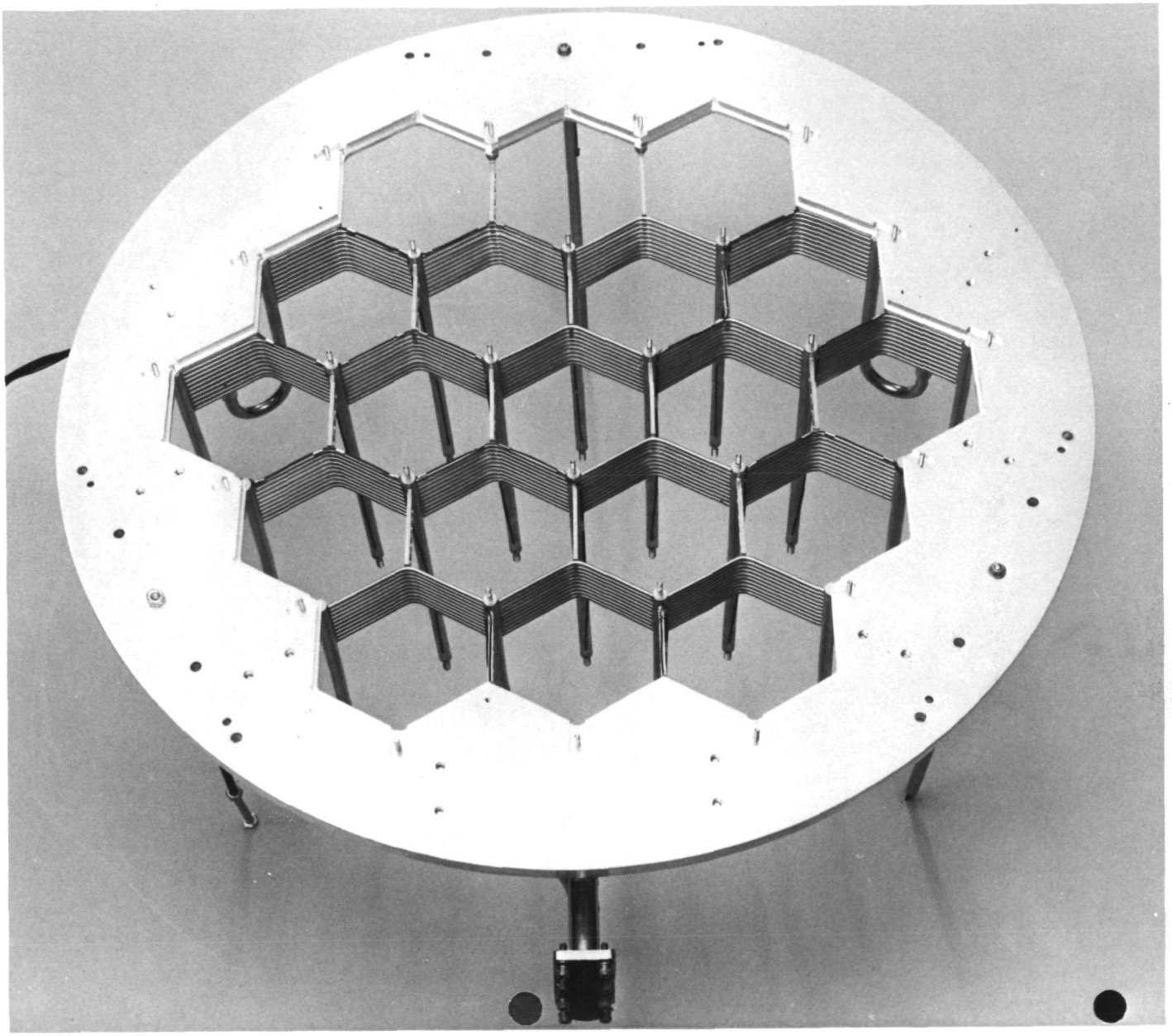

Fig. 9. The upper plate of the mixer assembly showing the arrangement of the support tubes

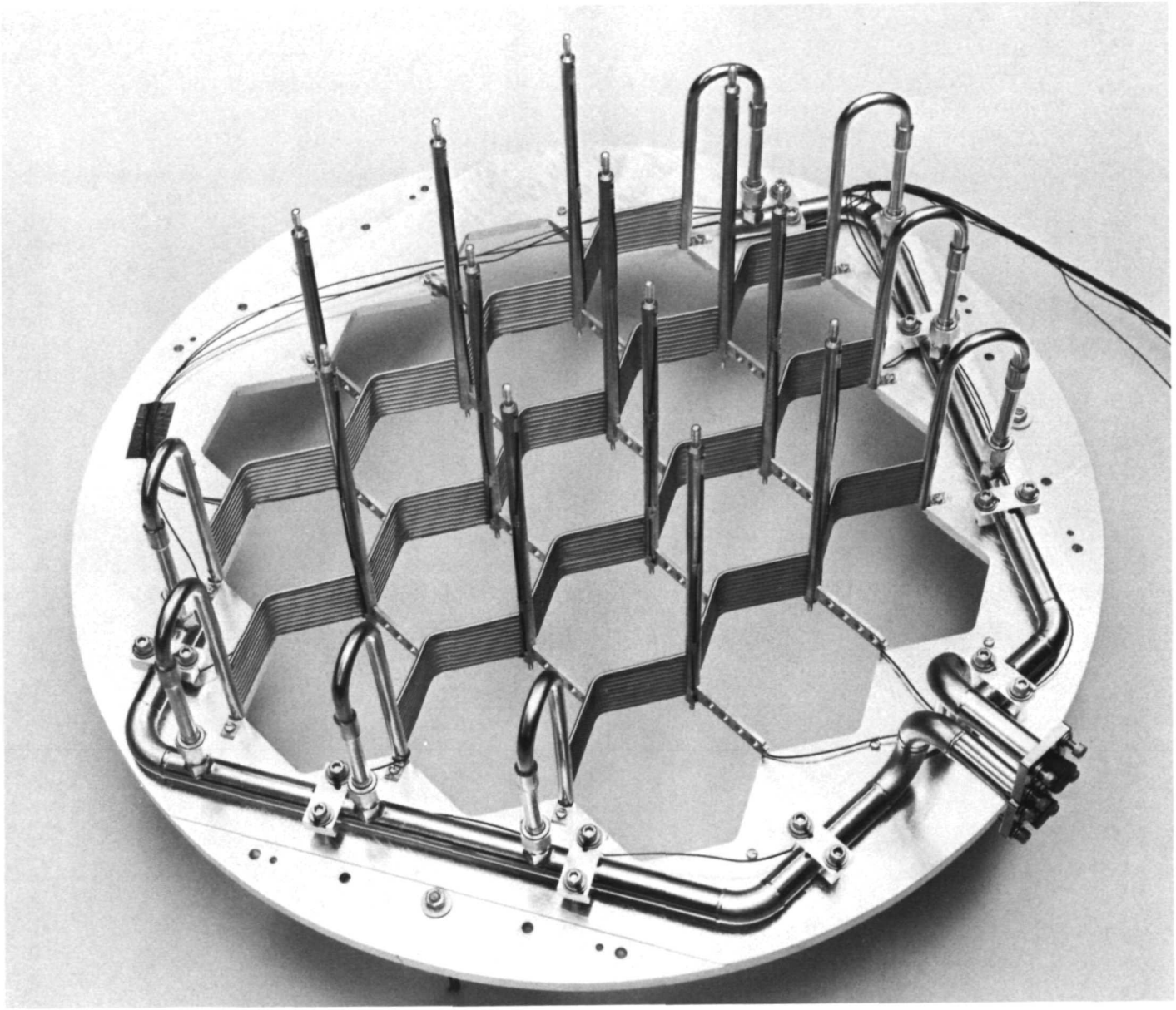

Fig. 10. The lower side of the upper plate of the mixer assembly showing the cooling water manifolding. Thermocouple wiring is evident

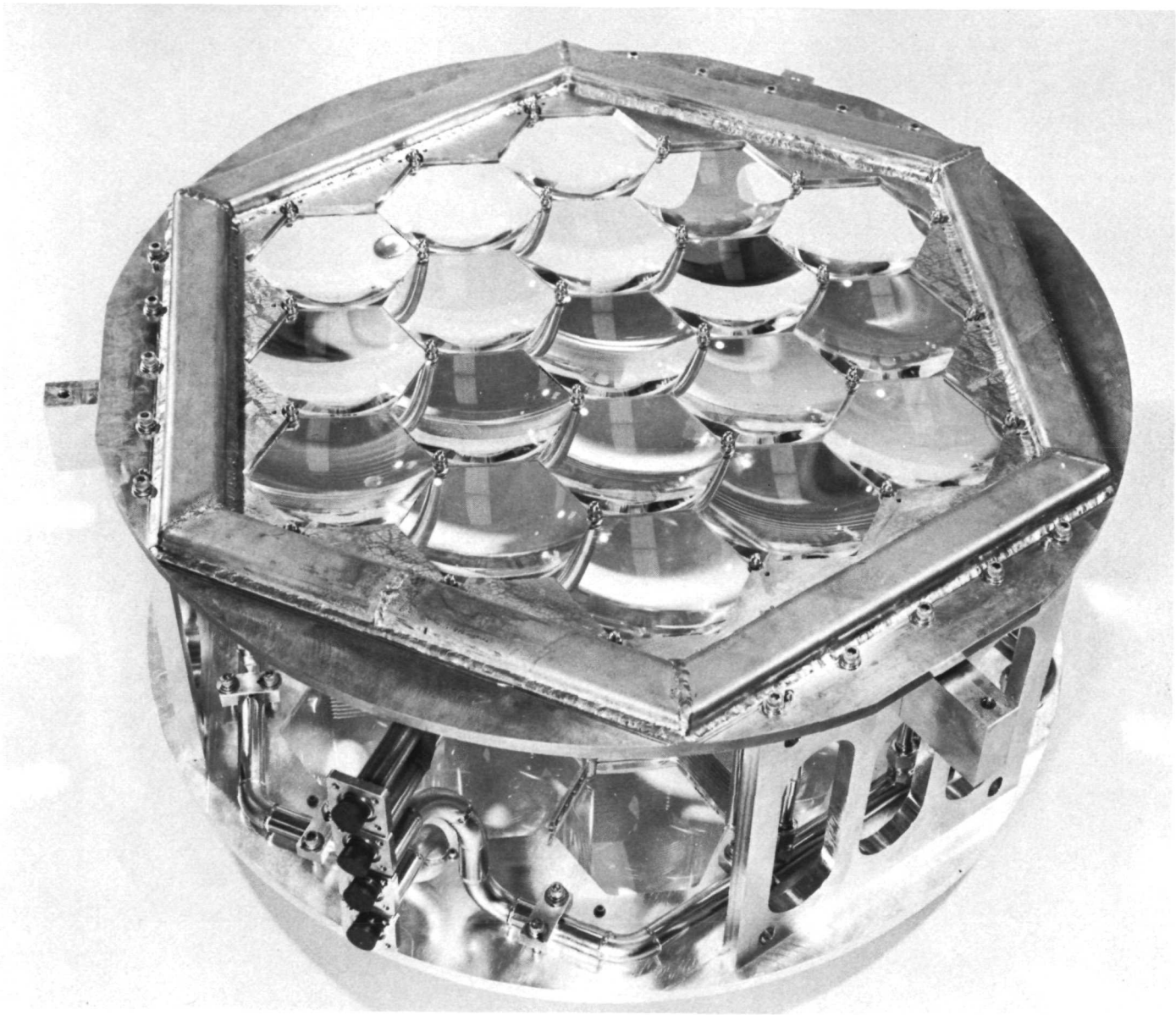

Fig. 11. Assembled mixer viewed from below

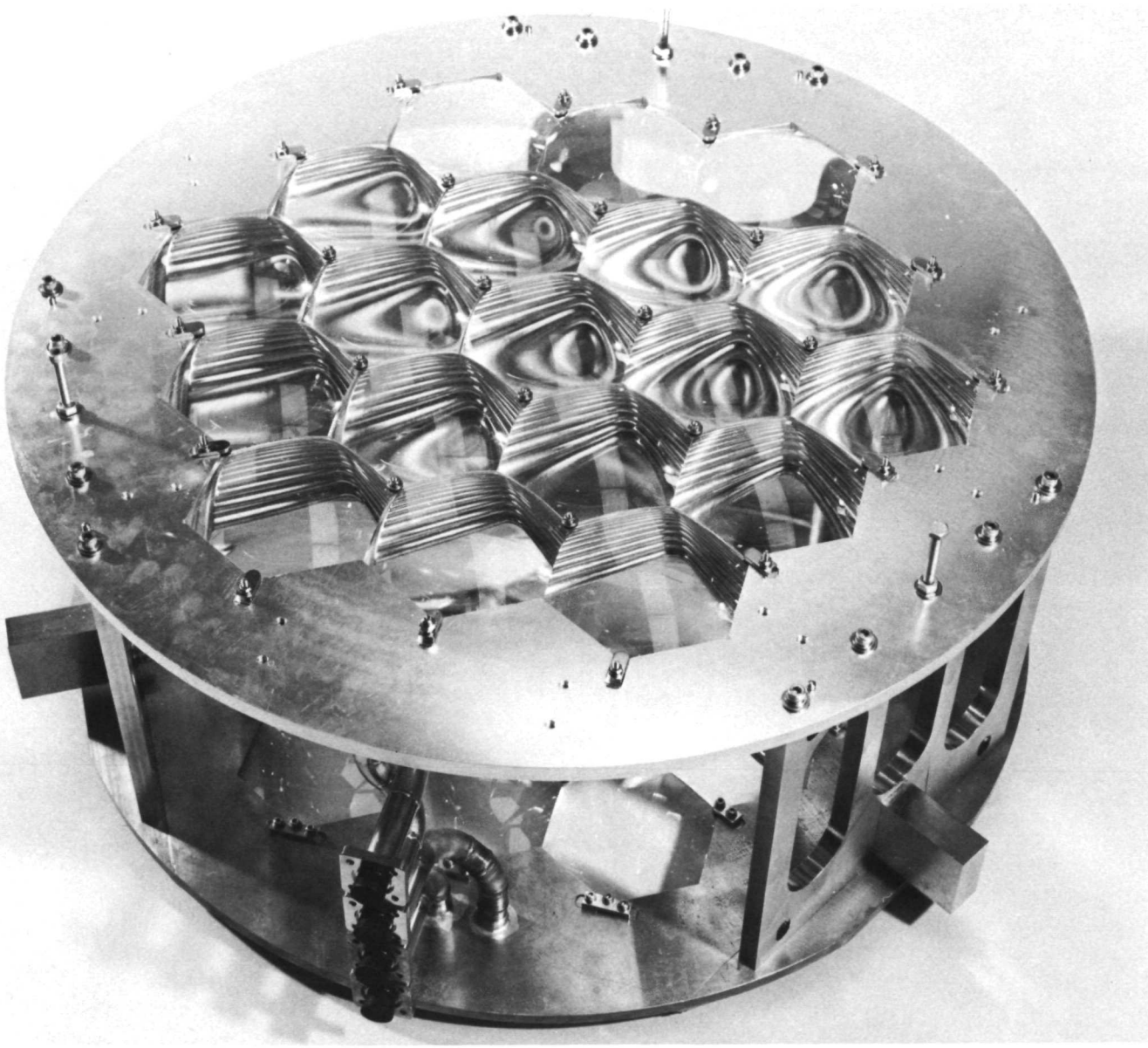

Fig. 12. Assembled mixer viewed from above

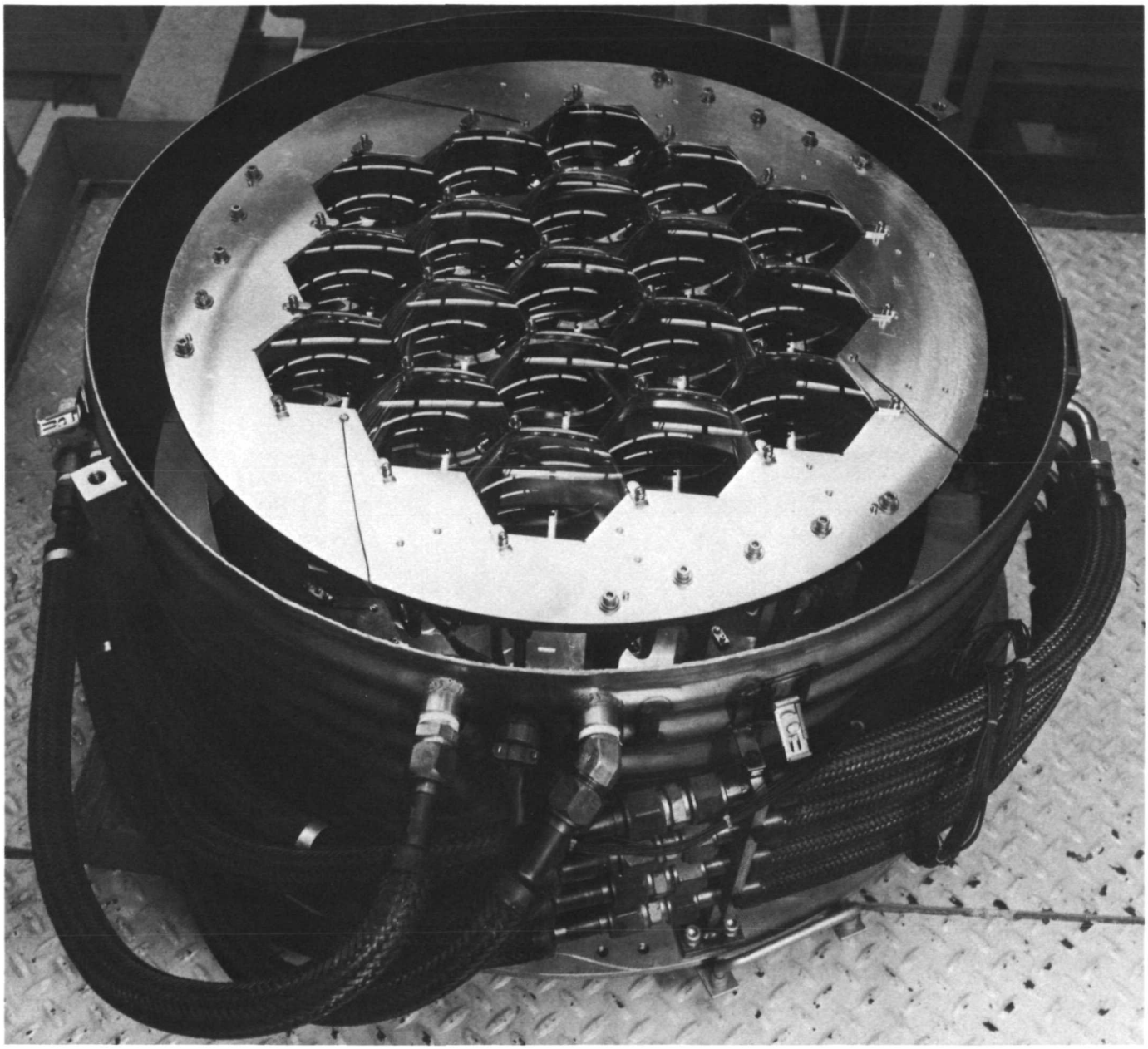

Fig. 13. Mixer installed in mixer can

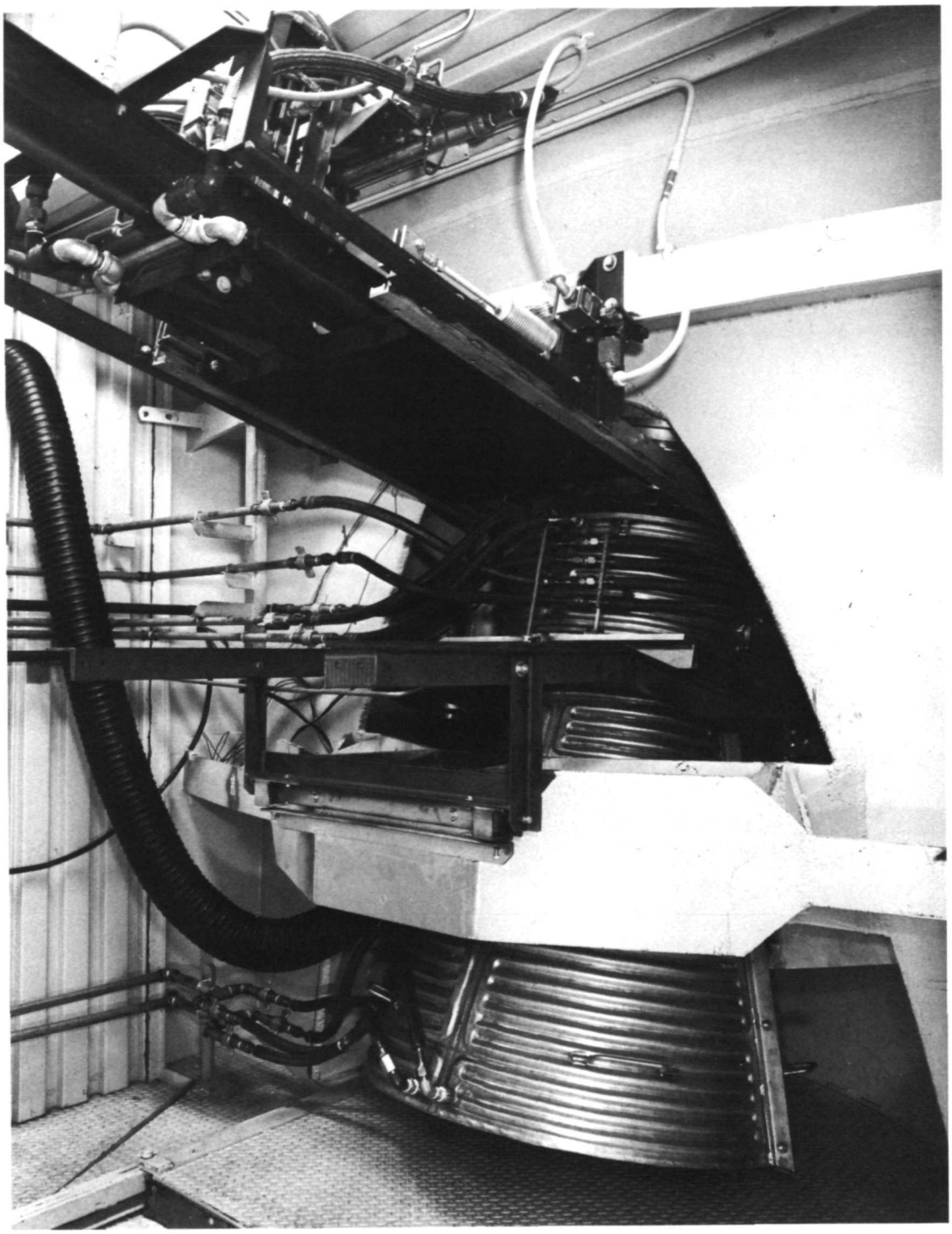

Fig. 14. Lens room of the JPL 7.62-m space simulator showing mixer can in position in center of photo. The cooling cone is evident under the mixer can. A sliding floor is in place, covering the opening from the lamp room. The powered implosion plate is in a retracted position on rails above the mixer can

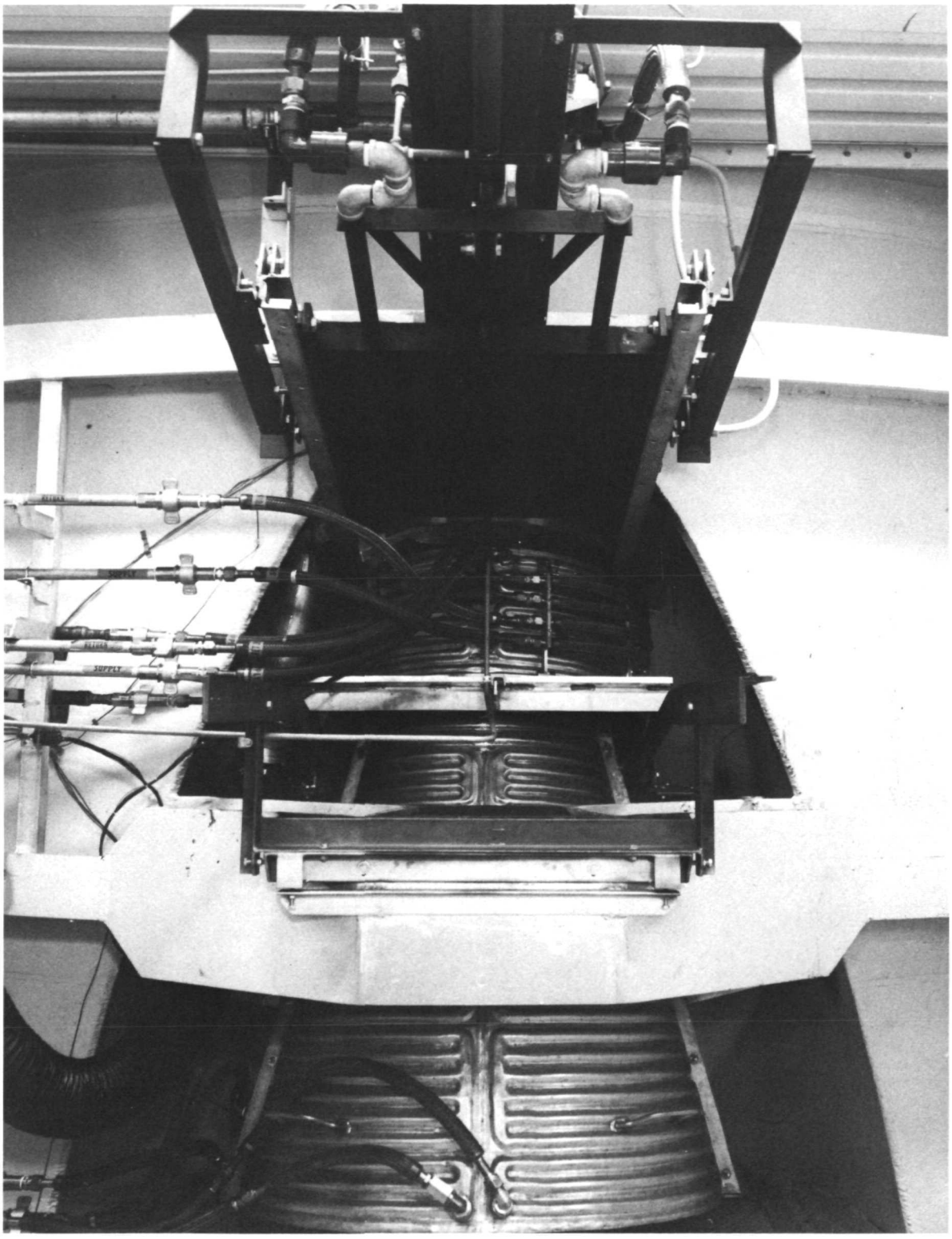

Fig. 15. Another view of the lens room. The penetration window and frame are just visible above the mixer can

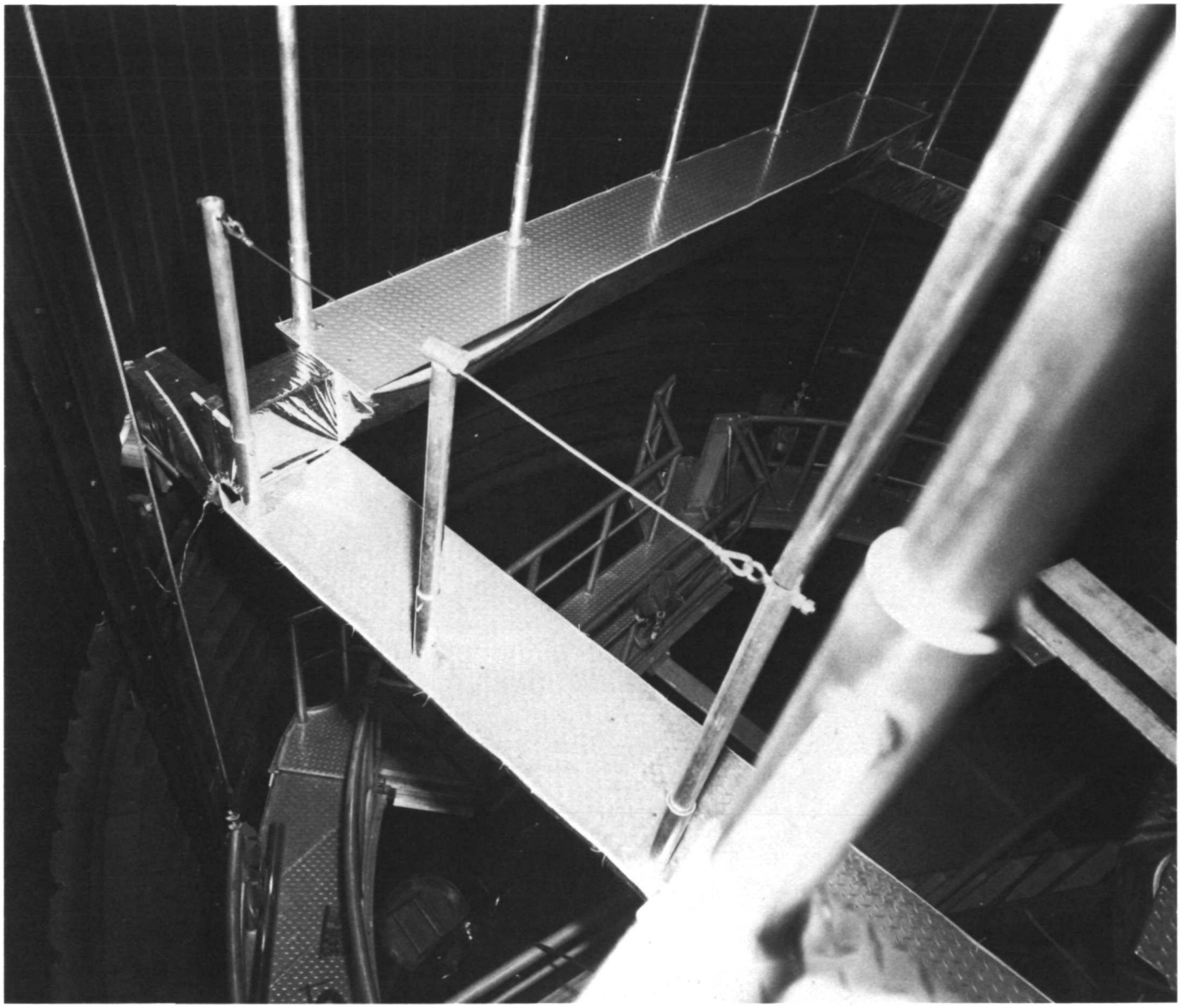

Fig. 16. The 4.57-m collimating mirror support structure mounted in the JPL 7.62-m space simulator. The support beams are thermally blanketed to assist in rapid chamber warmup. Nonslip plates, stanchions, and safety cables are used during mirror installation and removal. The structure beneath the cables is movable, on cables, and is used for working within the space simulator. It is dismantled and removed during simulator operation

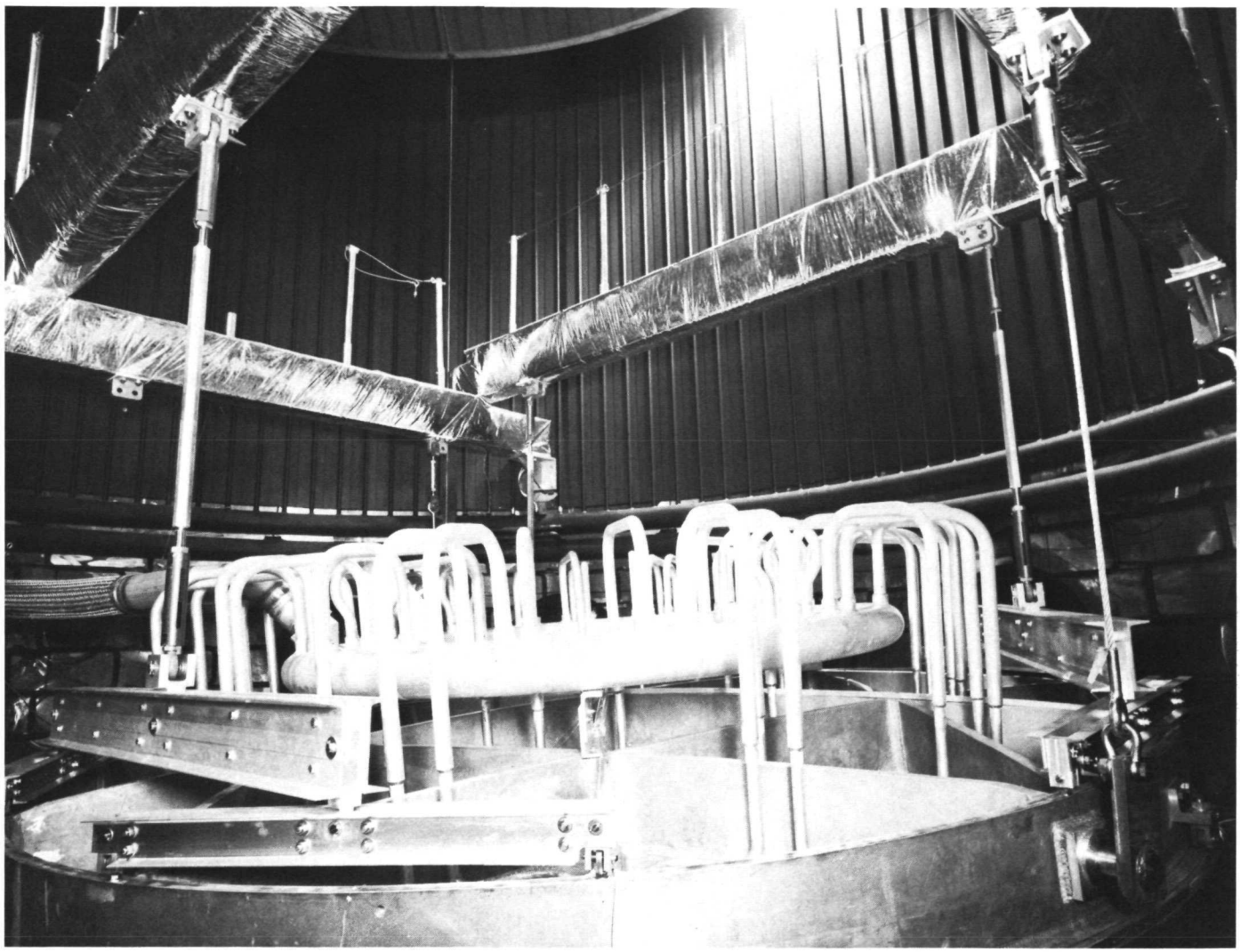

Fig. 17. The mirror support structure with mirror installed. The three whiffle-tree supports and the two safety cable supports can be seen

Fig. 18. Testing of the 4.57-m collimating mirror support system and rigging. The 7.01-m collimating mirror, covered by Mylar, can be seen at the top of the space simulator. The movable work platform is immediately beneath the support beams

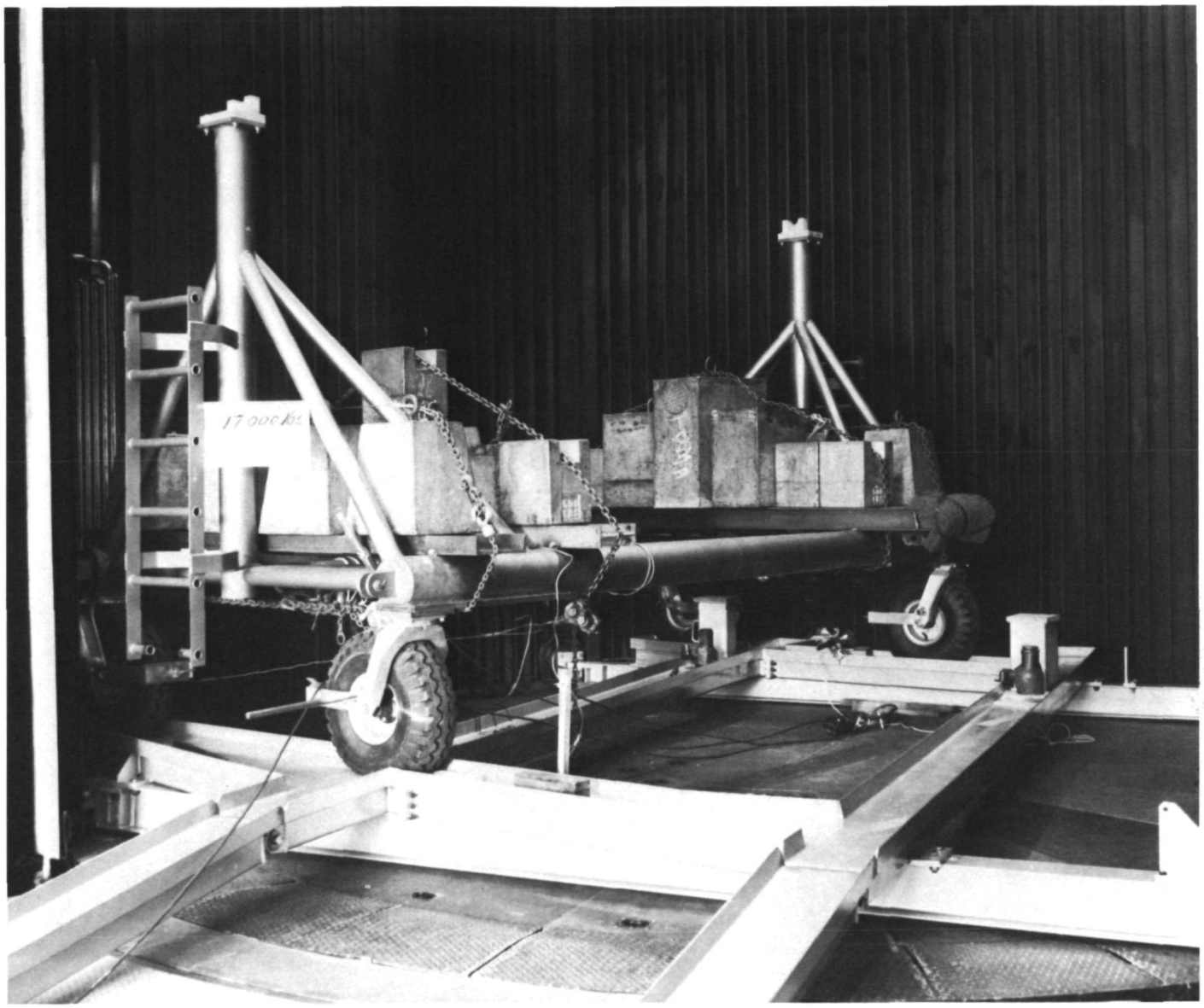

Fig. 19. Testing of the mirror cart and track

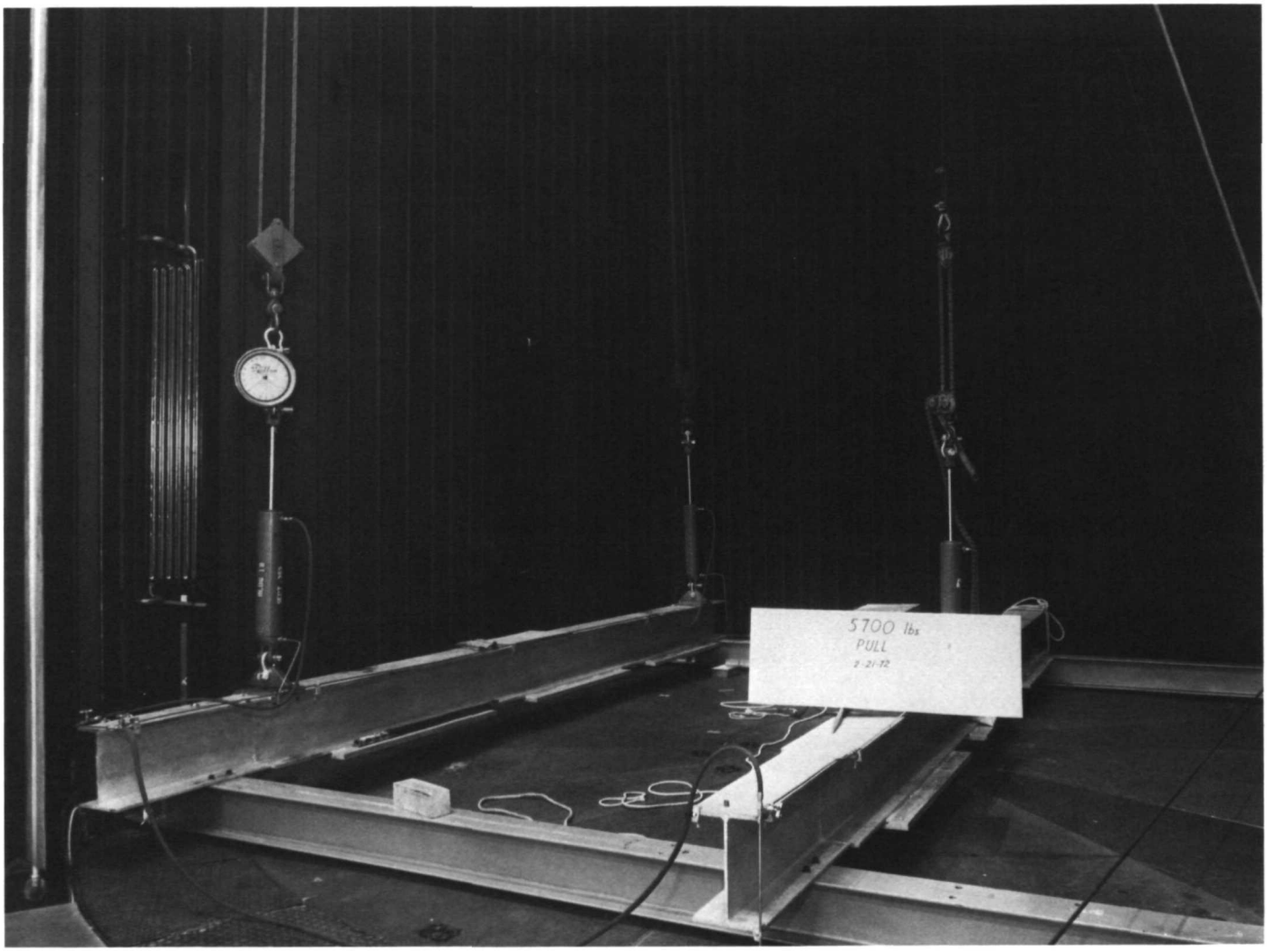

Fig. 20. Testing of the mirror lifting cables

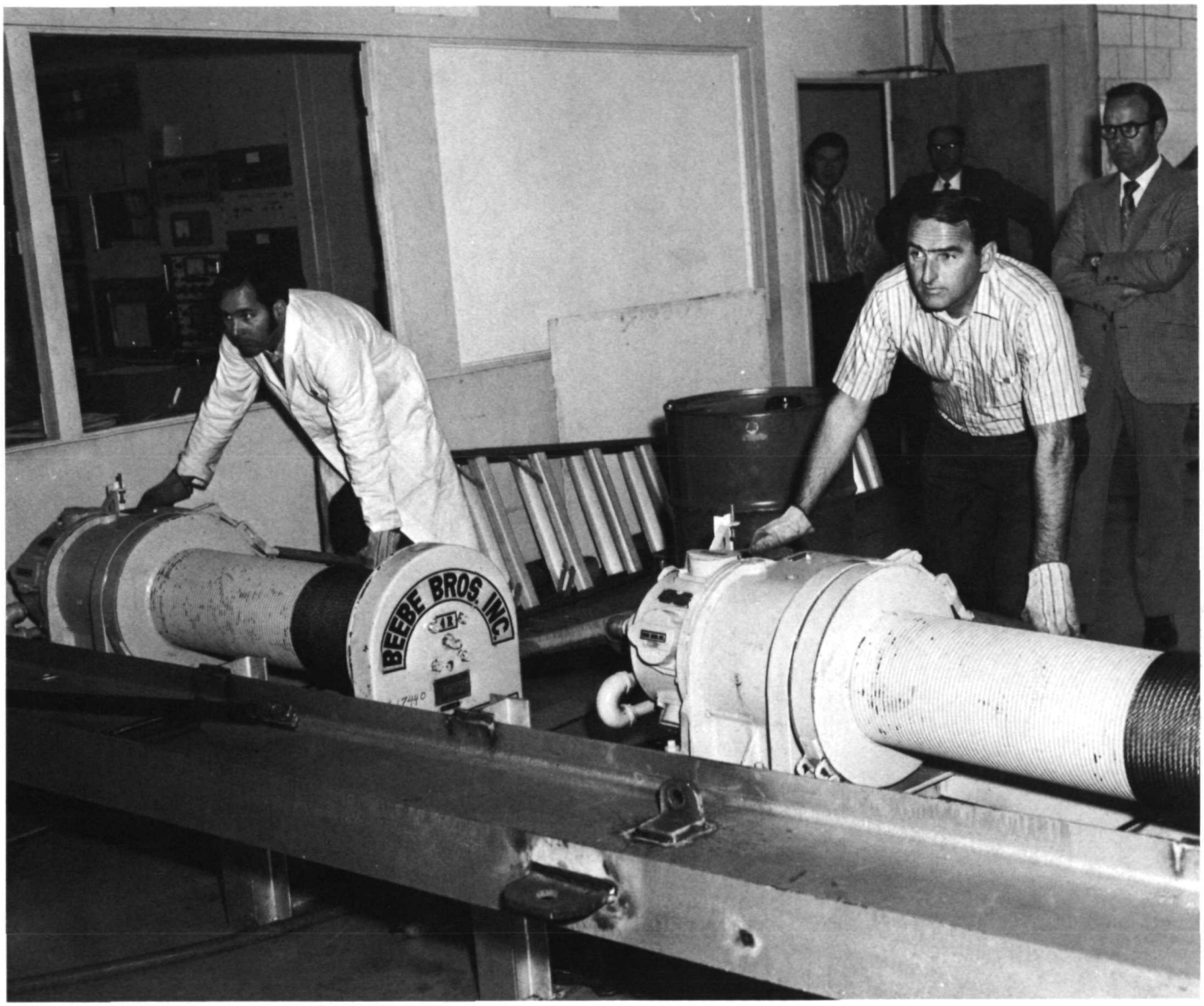

Fig. 21. The two air motors used to position the 4.57-m mirror cart and to lift (or lower) the mirror within the space simulator

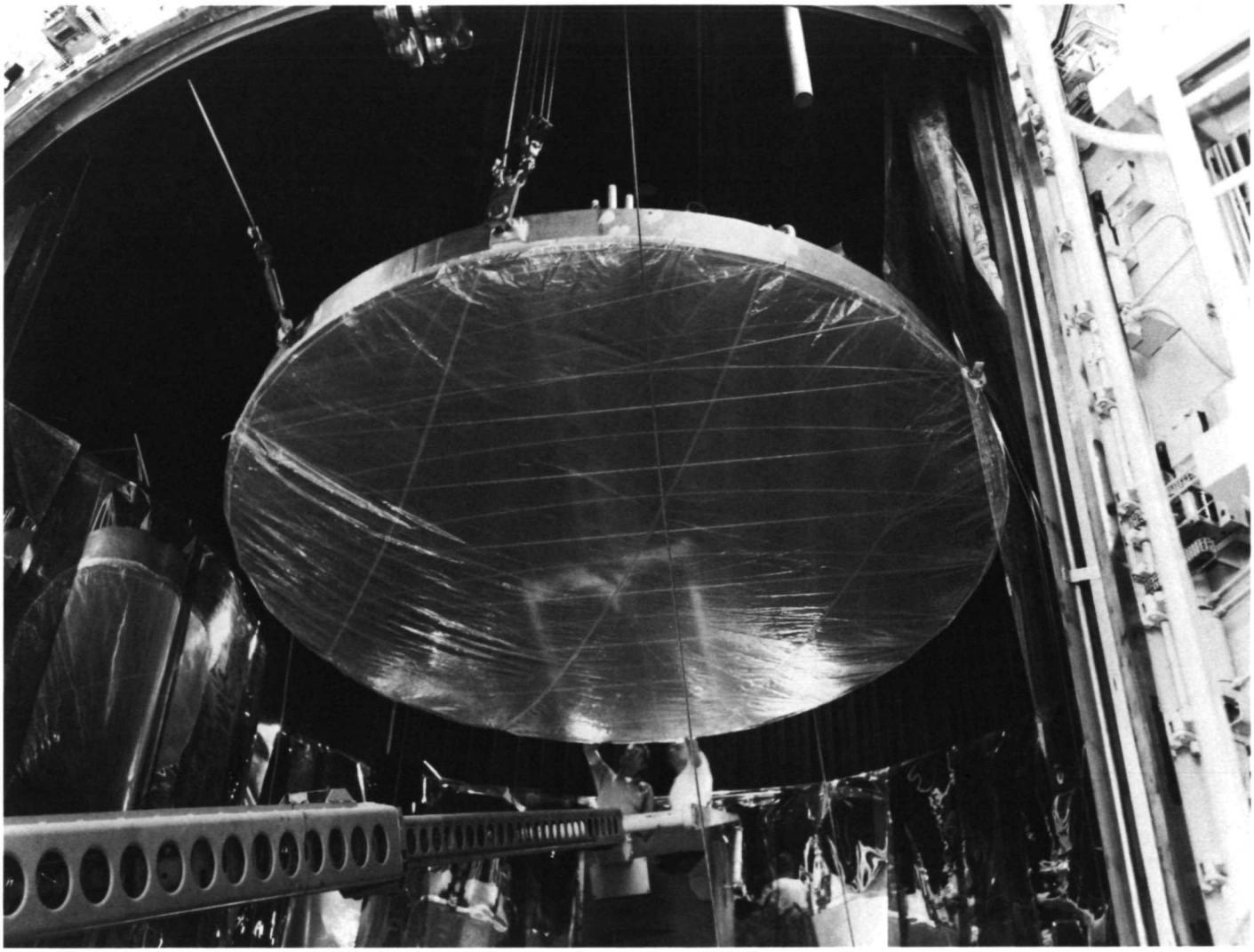

Fig. 22. The 4.57-m collimating mirror being lifted into position for aluminizing. The mirror is protected by a Mylar cover. The extensible boom with two-man cage in the lower foreground is being used here to connect the support cables

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16. Abstract

The JPL 7.62-m space simulator was modified to simulate the solar intensities at the planet Mercury. The capability of the simulator was increased to support testing of both the Mariner spacecraft mission to Venus and Mercury (to be launched in 1973) and the Helios spacecraft. The design of the off-axis reflecting system of the JPL simulators allowed attaining increased solar intensity, at the expense of test area, by placing a smaller collimating mirror at a lower elevation in the space simulator. In addition to requiring a new collimating mirror 4.57 m in diameter, the optical integrating system required a new design and there were several other efforts necessary to support these primary alterations.

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