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N69-35815
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65
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CR-101858
(NASA CR OR TMX OR AD NUMBER)
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(CODE)
11
(CATEGORY)
FACILITY FORM 602

MELPAR, INC. FALLS CHURCH, VIRGINIA 22046 / A SUBSIDIARY OF WESTINGHOUSE AIR BRAKE COMPANY

NASA CR 101858

APOLLO
RECOVERY QUARANTINE EQUIPMENT
FINAL REPORT

Contract NAS9-6874

Submitted to
National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas 77058

July 1969

MELPAR
An American-Standard Company
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ACKNOWLEDGEMENT

The contract effort documented in this report was performed for the Landing and Recovery Division of the Manned Spacecraft Center. Melpar wishes to acknowledge the assistance provided by members of the Recovery Systems Branch. Throughout the entire contract effort, personnel of this Branch, assigned as technical monitors, provided critical information concerning both equipment interface requirements and those aspects of operational procedure which were important to the final design.

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1. INTRODUCTION

This report describes the contract effort performed by Melpar during the fabrication of the Mobile Quarantine Facilities (MQF) for the National Aeronautics and Space Administration, Manned Spacecraft Center. This equipment resulted because of the scientific community's uncertainty of the existence or type of pathogenic life on the lunar surface. In July 1964, the Life Sciences Committee of the Space Science Board, National Academy of Sciences, convened a conference on the "Potential Hazards of Back Contamination from the Planets." The recommendations of this committee resulted in the NASA decision to impose the requirement of quarantine on the astronauts returning from the moon, and any persons coming into contact with them.

The Lunar Receiving Laboratory (LRL) was designed and constructed to allow the samples of lunar material to be opened and studied under conditions of isolation as soon as possible after the Command Module was recovered. The LRL provides living facilities, medical facilities, etc., for the astronauts during the quarantine period.

Transportation of the astronauts from the recovery zone to the LRL necessitated the design of equipment which could provide biological isolation immediately upon recovery, and continue this isolation until transfer to the LRL.

Melpar was selected as the contractor for the fabrication of the Mobile Quarantine Facilities based upon a design concept which utilized a commercially available travel trailer as the primary structure for these units. This approach was proposed in the interest of both minimum production time and cost. The time factor was significant, for the concept was developed prior to the tragic Apollo Launch Pad fire, which later delayed the entire program schedule. Since the modifications to the commercial travel trailers were intended to be rather minor in nature, a relatively short period of performance (seven months) was established. The items to be delivered under this contract included a total of four MQF units, 35 transfer tunnels, and 90 biological isolation containers. The contract effort was initiated in June 1967. Modifications of the equipment were developed after the program was started, which extended the period of performance. The final unit was delivered to NASA on 27 June 1969.

This report discusses the performance characteristics of the equipment as delivered, and reviews the total design and fabrication effort to document the basis for certain design changes which were introduced during the course of the contract effort.

2. OPERATIONAL PROCEDURES

This contract effort included the fabrication of isolation transfer tunnels and biological isolation containers in addition to the Mobile Quarantine Facilities. Performance specifications established for these items were derived from the operational procedure, at that time, for the lunar recovery mission. Detailed discussions of the performance characteristics of the equipment fabricated for NASA required familiarity with the overall operating procedure, at that time, which is described briefly in the following paragraphs:

The spacecraft (with the flight crew inside) will be retrieved and placed on the ship's deck. Two transfer options are afforded at this point, the choice dependent on the type of recovery ship and its configuration. On an aircraft carrier and any other recovery ship where the spacecraft is placed on the same deck level as, and in proximity to, the Mobile Quarantine Facility's entrance, a flexible plastic transfer tunnel will be placed to link the two. The outer spacecraft hatch will be unlocked and removed and a plastic transfer tunnel sealed over the hatch opening and to the inside of the Mobile Quarantine Facility. The crew will exit from the spacecraft and then help to transfer the lunar samples, flight tapes, film, crew equipment, etc., into the Mobile Quarantine Facility for additional packaging. The inner hatch will be replaced, decontaminated and locked, the end of the tunnel sealed, and the exposed ends decontaminated. The flight crew will fold the tunnel into the Mobile Quarantine Facility as they enter. The spacecraft outer hatch will be replaced in the opening and locked, the door on the Mobile Quarantine Facility closed, and all outside exposed areas decontaminated.

Aboard a recovery ship where the Mobile Quarantine Facility and the Apollo spacecraft are separated by extreme distance or deck levels, the inner and outer spacecraft hatches will be unlocked and opened and the crew will exit onto the deck of the ship. Outside the spacecraft they will don protective clothing, remove the lunar samples, flight tapes, film, etc., from the spacecraft, close, lock, and decontaminate the hatches. The crew and their attending personnel will then proceed to the Mobile Quarantine Facility carrying with them the samples, tape, film, etc., for additional packaging. Exposed areas of the spacecraft and all areas traversed by the flight crew will be properly decontaminated. All personnel in the immediate area will be required to wear respirators and protective clothing, as warranted for protection. Similar precautions will be taken if it is necessary to remove the crew from the Command Module while it is still in the water.

The packaged lunar samples, flight tapes, film, crew equipment, etc., will be "out locked" from the facility and transferred to another mode of transportation for accelerated return to the Lunar Receiving Laboratory at NASA Manned Spacecraft Center.

The Mobile Quarantine Facility will be transported to an appropriate port by the recovery ship, offloaded by a crane, and moved to an awaiting cargo aircraft at the closest airfield. It will then be loaded onto the aircraft and transported to Ellington Air Force Base, Texas. There the Mobile Quarantine Facility will be offloaded, and trucked to the Lunar Receiving Laboratory at NASA Manned Spacecraft Center.

A transfer tunnel will be attached between the door of the Lunar Receiving Laboratory and the Mobile Quarantine Facility. The flight crew and attending medical personnel will transfer to the Lunar Receiving Laboratory. The door on the Mobile Quarantine Facility will be closed and all joints and openings tape "sealed" for the decontamination period. The tunnel will be sealed and decontaminated and the sealed tunnel withdrawn into the Lunar Receiving Laboratory.

The Mobile Quarantine Facility will then be moved to an area set aside for purposes of decontamination, refurbishment, and storage.

During the course of this contract effort, there have been changes in the overall recovery procedure. These do not affect the design requirements for the Mobile Quarantine Facility, however, and no attempt is made in this report to document the final procedure as it was later modified.

3. PRELIMINARY DESIGN CONCEPT

This contract effort was based to a large extent upon the preliminary design which Melpar developed to meet the operational requirements of the Lunar Recovery Mission. Members of the Melpar technical staff believed that the greatest economy and minimum fabrication schedule could be realized through the modification of a commercially available product. A survey of the trailer manufacturers (mobile home, travel trailers, and truck body) established the fact that the travel trailer manufactured by Airstream, Inc., best provided the basic living facilities which were necessary to accommodate the three astronauts and their attendants during the trip to Houston. Additionally, the physical envelope of these trailers was well within the limitations imposed by the requirement that the facility be air transportable.

Through detailed study of the construction of the Airstream travel trailer, Melpar determined that it would be possible to seal the body in such a manner that it would be essentially airtight. Commercially available exhaust fans and filters would allow the establishment of the internal negative pressure which was required to provide the biological isolation. There was also ample room in the galley area to install a decontamination transfer lock to pass materials into and out of the trailer without violating the biological isolation. The length of the trailer (32 feet) was such that a motor generator unit and ac-to-dc converters could be positioned at the front end without exceeding the maximum length allowed by the aircraft restriction. The use of all aluminum construction was desirable as a consequence of anticipated exposure to the ocean environment.

Melpar proposed to fabricate the Mobile Quarantine Facilities in the configuration shown in figure 1. Although the overall complexity of the Mobile Quarantine Facilities gradually increased during the course of this effort, the basic design concept which was developed remained unchanged. Those modifications which were introduced were primarily items for operational convenience or improved crew safety.

Figure 2 shows a cutaway view of the Mobile Quarantine Facility, in the final configuration, attached to the Command Module by the shipboard transfer tunnel. Figure 3 shows a photograph of Serial Number 1. The two protective covers on the roof located at each end house the air conditioning units; the two protective covers in the center of the roof contain the filtered air inlets. The large structure located on the outrigger of the frame toward the front of the unit is an external storage box. The small door directly above the storage box is one of the two doors that cover the decompression blowout panels at all times except during aircraft transportation. The second decompression blowout panel is located on the other side of the unit.

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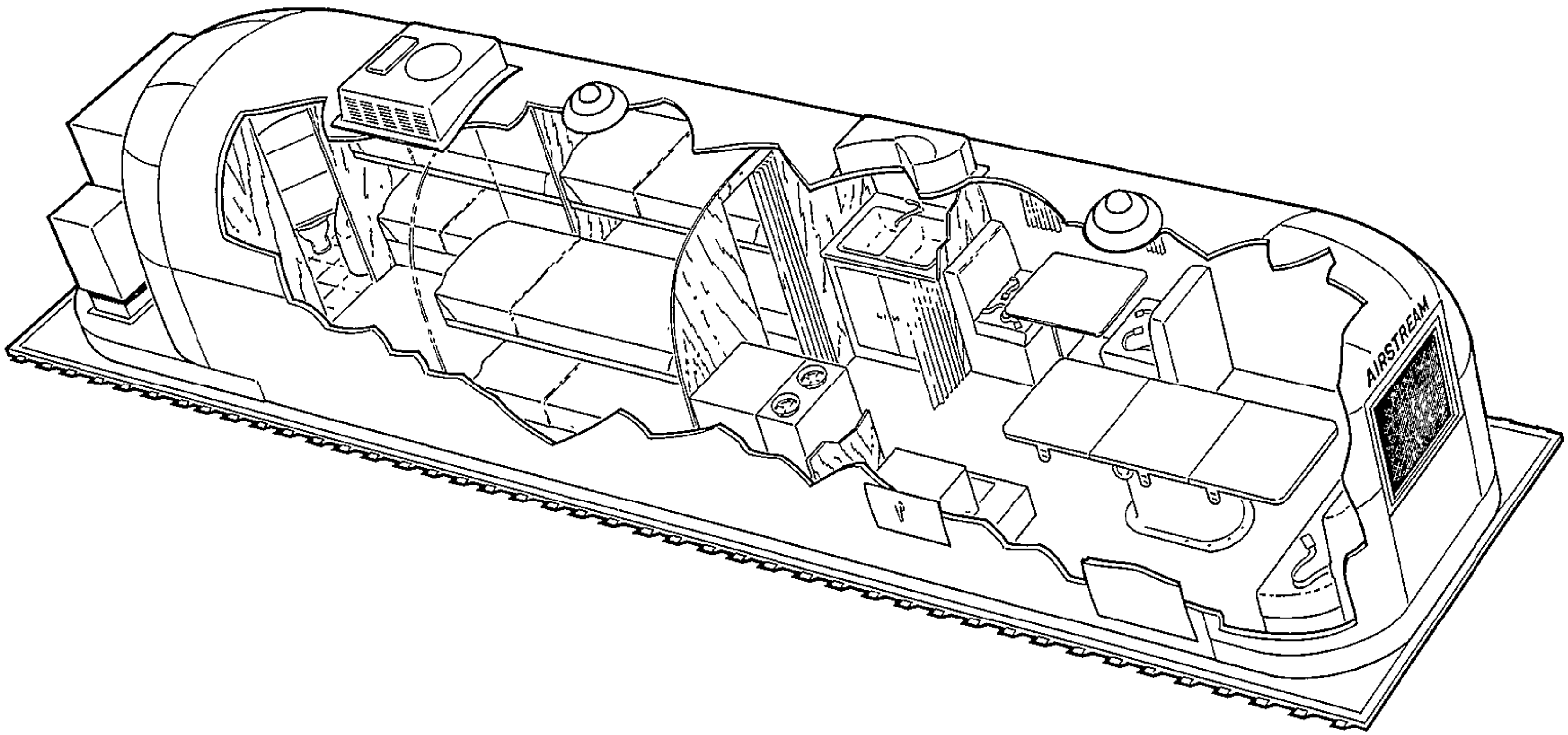

Figure 1. Original Concept of Mobile Quarantine Facility

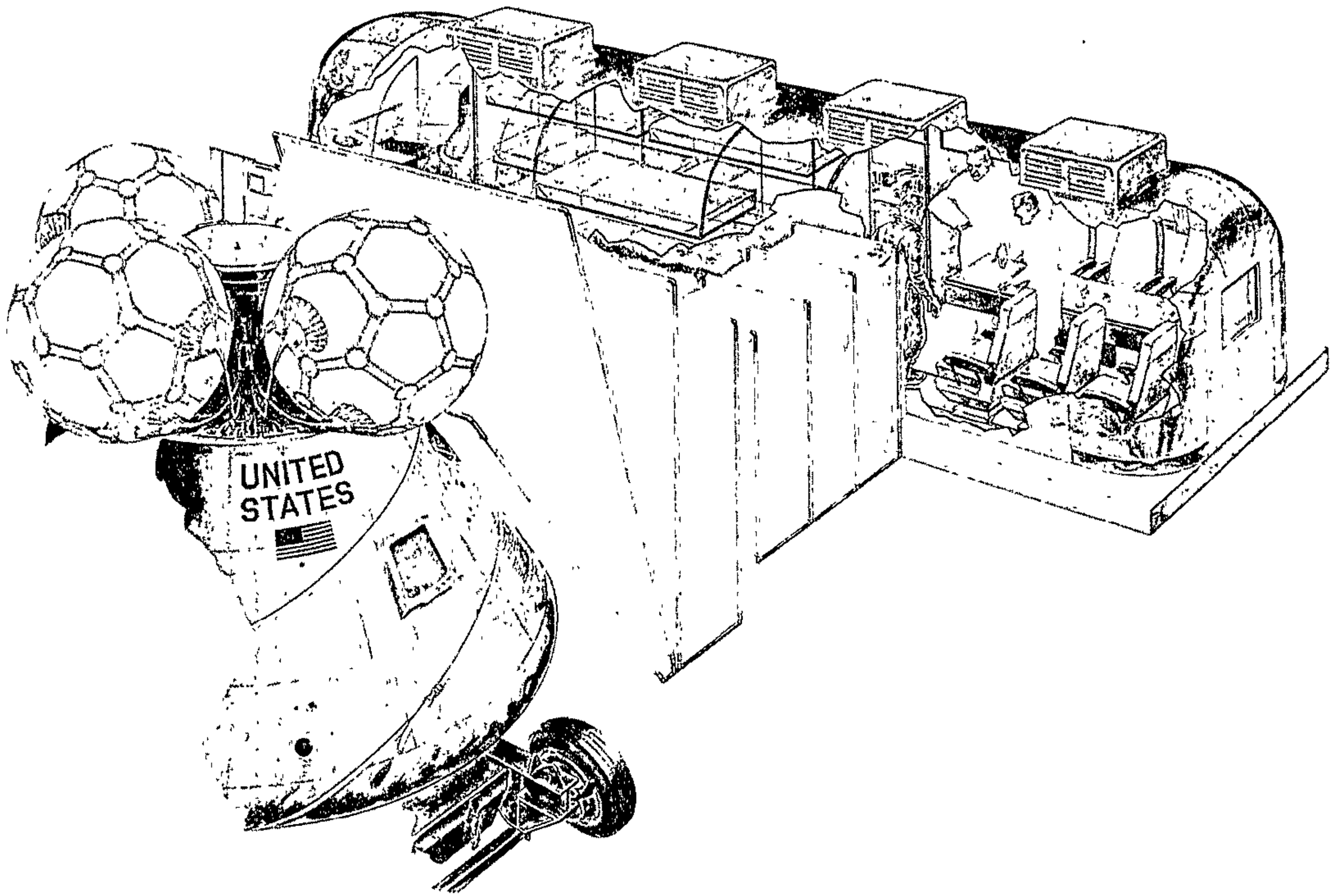

Figure 2. Sketch of Final Design Concept

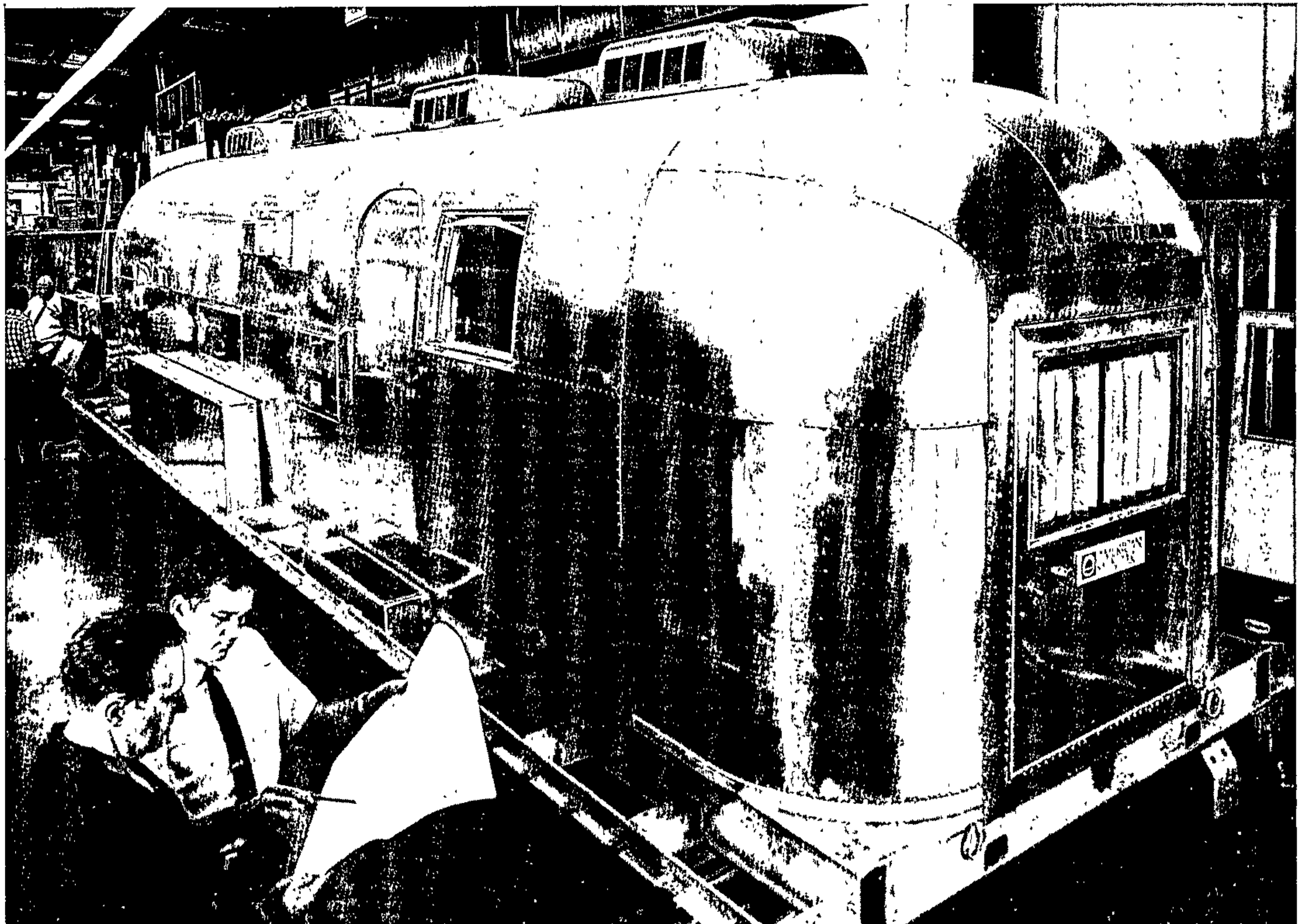

Figure 3. Mobile Quarantine Facility

Also clearly visible is one of the filtered exhaust fan housings and the door which protects the decontamination transfer lock when not in use (this is located immediately forward of the side door).

The interior of the Mobile Quarantine Facility is separated into four distinct areas: lounge, galley, bedroom, and bathroom.

4. FINAL DESIGN AND SUBSEQUENT MODIFICATIONS

Although the preliminary design concept and the performance specifications were adequate to form the basis for this contract effort, the details of design were not established at the time the work was initiated. This was desirable because the technical staff of the Manned Spacecraft Center Recovery Branch was in the process of establishing the detailed operational procedure at the same time, and the final design of the Mobile Quarantine Facility could be integrated directly into this procedure.

The Recovery Systems Branch designated a technical monitor to work directly with the Melpar technical staff to provide any information needed relative to interface requirements or operational parameters which might influence the detailed design.

A subcontract was negotiated with Airstream, Inc. The final design was based upon the modification of a standard Airstream trailer, with final assembly to be accomplished at their Jackson Center, Ohio, plant.

A final design review was held at Houston, Texas, on 7, 8 September 1967, at which time Melpar presented the details of construction for agency comment and approval. At this time, Melpar was requested to make changes in design, some of which were out of the scope of the contract work statement. These were incorporated into the design, and the contract work statement modified accordingly.

Subsequent to the final design review, the technical staff of both the Manned Spacecraft Center and Melpar recognized the advantage of delaying the fabrication of the final three units until such time as a simulated recovery mission could be conducted to fully evaluate the functional performance of both the Mobile Quarantine Facility and the recovery mission operational procedures. This resulted in an extended delivery schedule, which was later delayed even more as a consequence of agency direction to coat all interior surfaces and furnishings with a fire retardant material.

The extended contract performance period realized from these actions resulted in an effort which then coincided with other portions of the overall recovery mission operational readiness program, and a number of additional modifications to the final design were introduced late in the fabrication schedule.

Following the delivery of Mobile Quarantine Facility, Serial Number 1, 29 February 1968, the simulated mission was conducted, and a second design review was held at Houston, Texas, on 29, 30 April 1968. A total of 34 Requests for Changes was documented, the majority of which were either very minor in nature, or were clearly out of the scope of the contract. Melpar provided firm proposals and prices for all out-of-scope items, and made the other changes in design necessary to satisfy the in-scope requests for change.

Many of the items requested for inclusion in the equipment were changes suggested by other mission functions, such as the Public Information Office. Other changes represented noncritical modifications of an operational convenience nature.

The Manned Spacecraft Center selected those changes which were desired, and directed Melpar to resume construction on 9 September 1968. Since certain of the changes, primarily in the electrical system, were extensive, Mobile Quarantine Unit Serial Number 1 was retrofitted to incorporate these features prior to the fabrication of the remaining three units. The retrofitted unit was delivered to the Manned Spacecraft Center on 28 October 1968.

Melpar was notified on 13 December 1968, that the agency wished to replace the carpet in the remaining three units with floor tile, and was directed to stop assembly. On 19 December 1968, Melpar was directed to replace the carpet with floor tile, and to coat all interior surfaces and furnishings with Preserv-O-Paint SS1001/clear, a fire retardant coating. Attempts to apply this material proved unsuccessful, and the painting procedure was modified. Still unable to obtain satisfactory appearance and adherance, Melpar requested a meeting with NASA Representatives at the Subcontractor's plant in Jackson Center, Ohio, on 17, 18 March 1969. It was determined that the Preserv-O-Paint was not suitable for this application, and the Manned Spacecraft Center assumed the responsibility of selecting an alternate material to coat the inside of the units. The only material available was Refset, manufactured by Raybestos-Manhattan, Inc. Since this material is experimental, the Manned Spacecraft Center furnished both the material and the personnel to apply the coating to the interior and furnishings of the Mobile Quarantine Facilities.

Mobile Quarantine Facility units number 2, 3, and 4 were delivered on 7, 27 May and 27 June.

In the sections of this report that follow the design and performance characteristics of each functional requirement will be discussed. The basis for later modifications to the design and resulting performance characteristics will likewise be described.

5. TRANSPORTATION AND MOBILITY CHARACTERISTICS

The transportation of the Mobile Quarantine Facility by ship, aircraft, and truck during the Lunar Recovery Mission imposes limitations on the size and weight of the unit, and the various handling operations likewise dictate the requirements of structural strength. The facility must have a maximum dimensional envelope of 35 feet in length, 9 feet in width, and 8 feet 8 inches in height. The total weight, including six personnel, stocked with consumables, linen, water supply (if any), and support equipment should not exceed 20,000 pounds.

The size of the unit as delivered is: length 35 feet, width 9 feet, height 8 feet 7 inches; it weighs 18,500 pounds stocked with consumables, water, and support equipment.

5.1 Facility Frame

The standard Airstream travel trailer chassis is manufactured from a high-strength steel alloy, and was therefore considered to be adequate for use as the frame for the Mobile Quarantine Facility. The preliminary design concept anticipated only the addition of skids to meet the performance requirements.

The performance specification requires that the facility be capable of being towed or trucked. The facility will be mounted on a skid system. The skid system will have the same side configuration as a cargo pallet identified in specification MIL-P-27443, and will be compatible with the roller system and restraining rails and the C-141 series aircraft. The base of the skid system will also contain hoisting and tiedown rings.

For deployment aboard all recovery ships, but especially ships of the destroyer type, the load of the Mobile Quarantine Facility will be transmitted to the deck over three transverse frames.

The facility structural design will exhibit air transportable qualities for tiedown and crash restraint. Adequate provisions will be incorporated for deck tiedown. Provisions for crane hoist (single hook system) are required. The contractor will provide a hoisting system for each Mobile Quarantine Facility.

The use of the standard chassis in conjunction with a skid system proved unsatisfactory from both the structural considerations and limitations in overall facility height. Melpar believed it was desirable to replace the Airstream chassis with a base frame fabricated of such a width that it mated directly with the aircraft roller loading system. The use of this frame design also facilitated the floor design with respect to the sealing of construction seams thereby improving the biological isolation barrier. Figure 4 presents a sketch of the frame that was used for the Mobile Quarantine Facilities.

The frame is fabricated from aluminum alloy 6061-T6 U-channels welded to form box beams. The large members are 8 inches high and 4 inches wide. The smaller members which support the outrigger structure necessary to extend the frame to the width of the aircraft cargo-holding system are 4 inches wide by 4 inches high. The outrigger structure also provides a convenient method of tiedown onboard ship and aircraft, eliminating the need of specific tiedown rings or hooks, for it is accessible along its entire length. The lift points for the hoisting sling are 6-inch-diameter aluminum pipe with 1/2-inch wall; also 6061-T6 alloy. In all cases, the metal used to fabricate the box beams is 1/4 inch thick. The outside edge of the frame is formed by a rail extrusion designed to interface directly with the aircraft cargo holding system. Two wood runners are attached to the bottom of the outer 4- by 8-inch box beams to afford the necessary skid surface for dragging, or rolling the facility on pipe, during shipboard operations.

During the design of this frame, Melpar conducted a detailed stress analysis to ensure adequate strength of the frame during lifting operations. This analysis established a maximum longitudinal deflection at the center of the frame of less than 3/4 inch when lifted at the hoist points, and loaded to the design maximum at the center.

The frames were purchased by Melpar under a fabrication subcontract with Ravens Metal Products, Inc., Parkersburg, West Virginia, and supplied to Airstream.

In September of 1968, Melpar found a number of small hairline cracks in the surface of the butt welded joints in the box beams. These were observed when modification of the Number 1 unit was started. The technical staff immediately investigated the nature of these cracks, and identified them as "crator cracks" which are common in aluminum welds and, since they do not propagate, do not affect the structural integrity of the weld.

In view of the Manned Spacecraft Center's concern at that time that the Mobile Quarantine Facility specifications do not provide for man rating, Melpar elected to add structural bolts of 1/2-inch stainless steel to the box beam members adjacent to the lifting points to provide an extra margin of safety.

Figure 5 shows the Mobile Quarantine Facility within a C-141 aircraft. The aircraft loading process proved to be an extremely smooth operation. No difficulties were ever experienced with this aspect of the equipment.

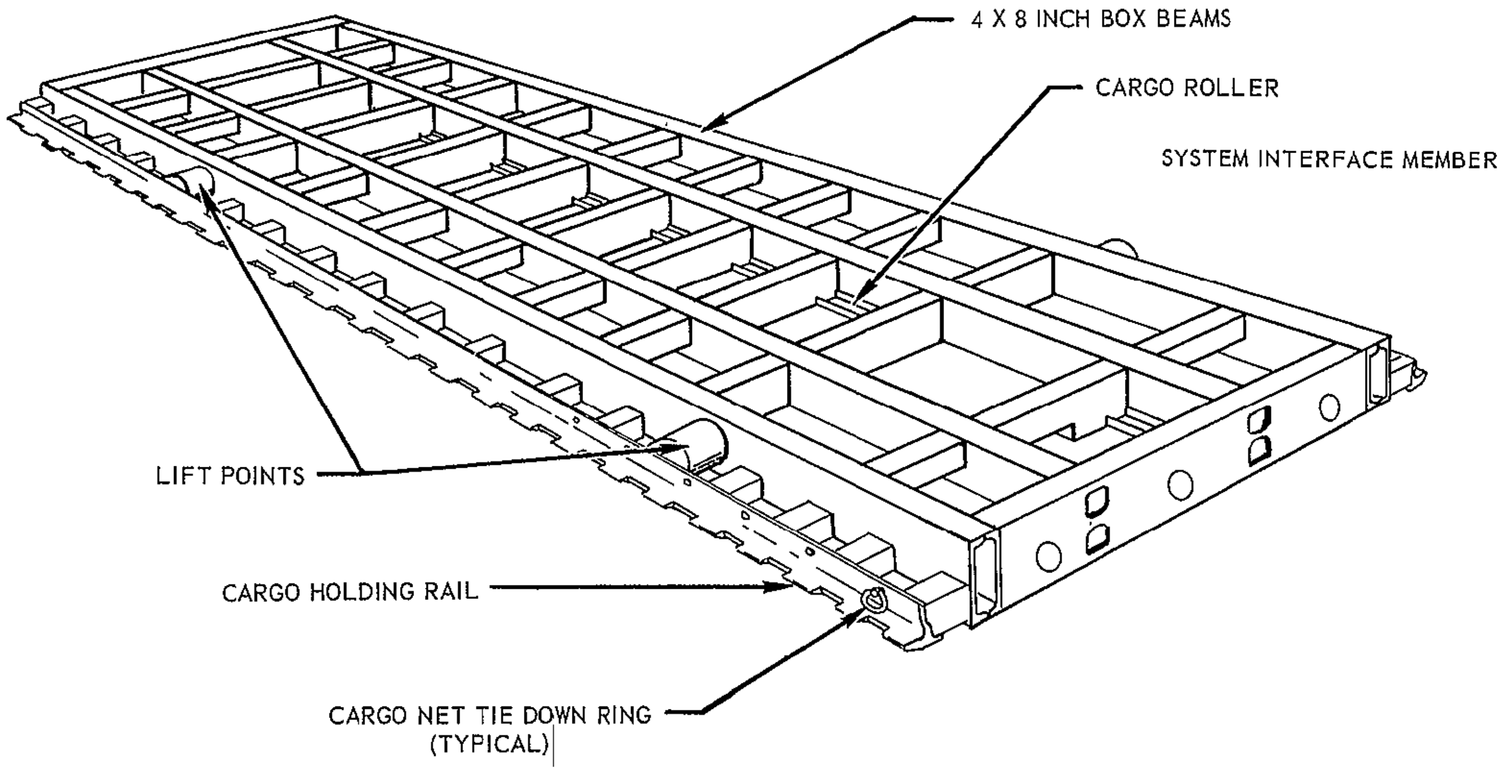

Figure 4. Sketch of Frame

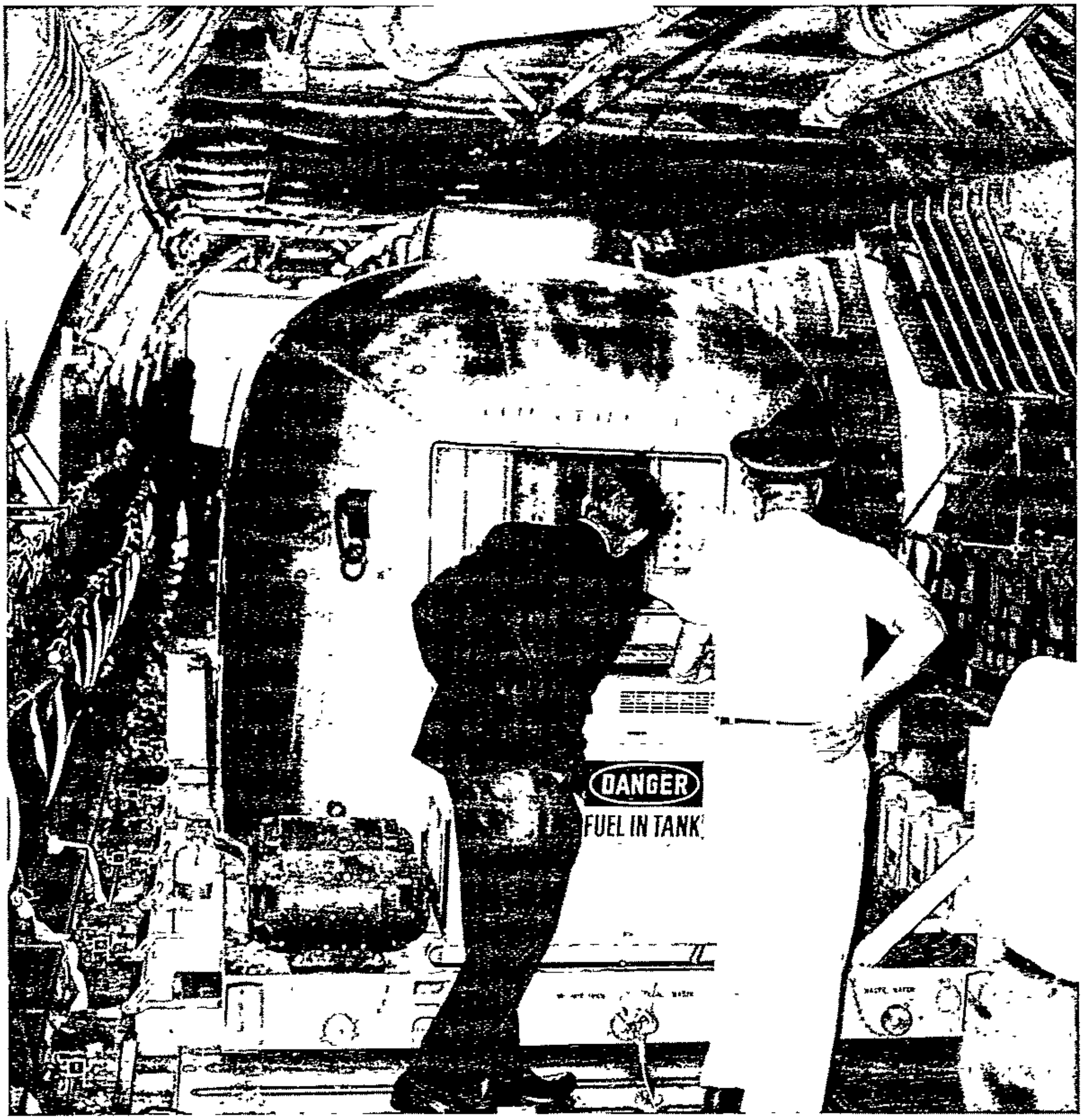

Figure 5. Mobile Quarantine Facility in C-141 Aircraft

5.2 Hoisting Sling

Melpar prepared a specification for a hoisting sling system which was then submitted to various qualified manufacturers for competitive bid. The McWhyte Corporation manufactured a standard unit suitable for this application, and was selected as the supplier for this sling. This sling used four equal legs extending from a single pear link lift point. Two load-carrying spreader bars were supplied with each sling assembly, to hold the legs of the sling away from the sides of the Mobile Quarantine Facility. All assemblies other than the sling cable (pear link, thimbles, turnbuckels, and safeguard slings) were manufactured from heavy-duty galvanized steel to withstand the ocean environment. The sling cables were fabricated from steel which required oil treatment to provide protection from the ocean environment. The sling was designed for a 20,000 pound load, and certified to have a safety factor of 5 by actual test. The sling was load tested to twice its design load.

During the sea trial, the Manned Spacecraft Center determined that it was desirable to add two nonload-bearing spreader bars to each side of the sling assembly, to achieve a nonrendering box-type spreader bar configuration. The decision was also made to replace the sling cables with stainless steel cables. Additionally, Melpar added cable-locating bars on the lift points of the Mobile Quarantine Facility lifting points. These changes greatly improved the operational convenience of the sling assemblies. Figure 6 shows the Mobile Quarantine Facility being hoisted to the deck of an aircraft carrier, demonstrating the adequacy of both the frame and the hoisting sling.

5.3 Flight Safety

Transportation by normal cargo-type aircraft imposes design features which must meet the minimum aircraft tiedown and crash restraint requirements. Personnel inside the facility will be located in the aft end of the facility (orientation when loaded aboard the aircraft) and will be restrained for crash conditions. (Crash conditions: 9.0 g forward, 1.5 g left, right, aft, and up, and 3.0 g down.) Equipment not in the immediate vicinity of the occupants must be restrained to 3.0 g down and 1.5 g in all other directions. In a crash, this equipment may carry forward. Additionally, a folding door will separate the personnel from the rest of the facility during takeoff and landing, and a restraint net (GFE) shall be placed over the forward half of the facility when loaded aboard the cargo aircraft.

A total of 27 steel tiedown rings are provided on the Mobile Quarantine Facility frame to accommodate the aircraft cargo net. Five of these are located on the front end, two on the back, and a total of ten along each side of the frame

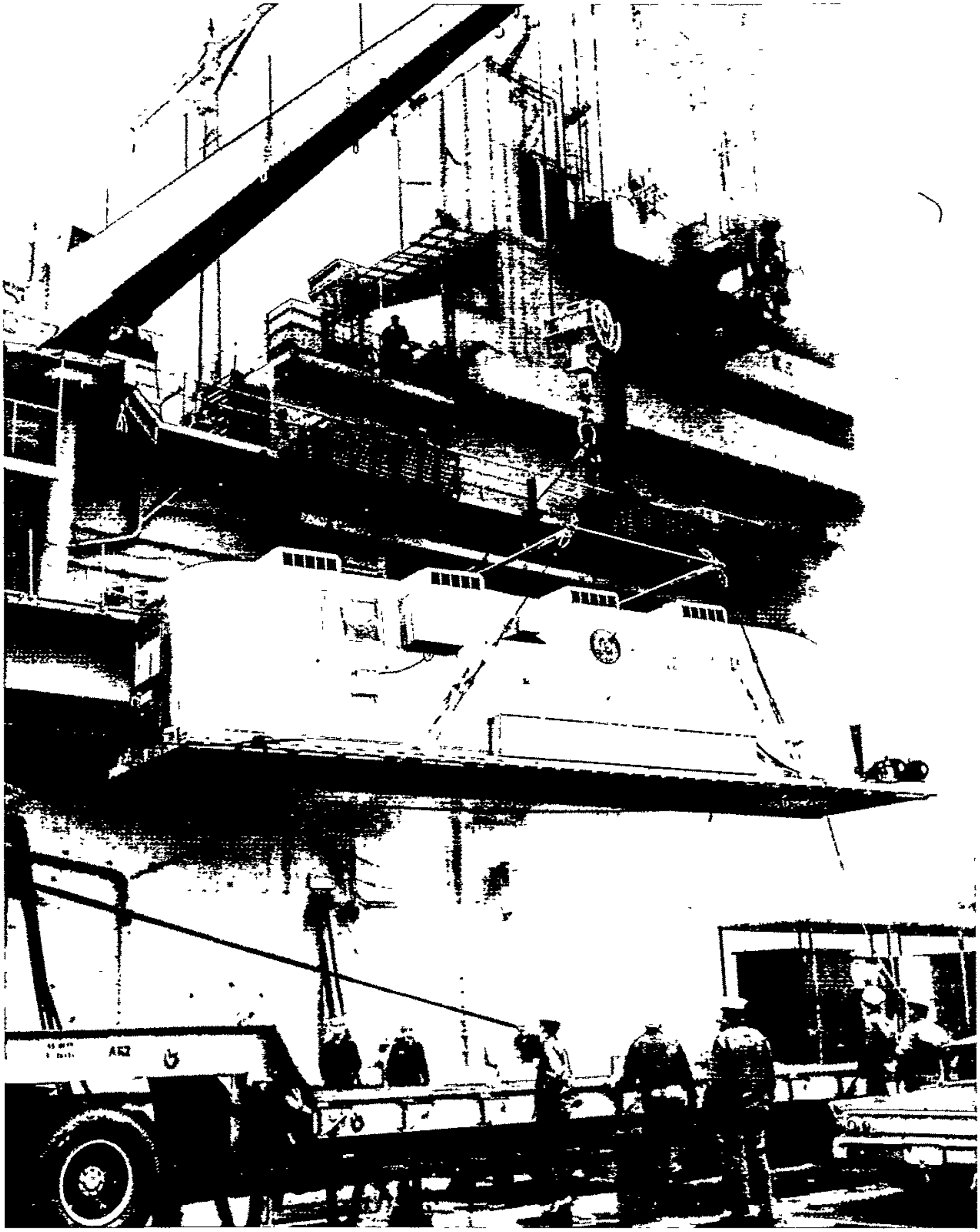

Figure 6. Mobile Quarantine Facility Being Hoisted to Aircraft Carrier
(Photo by Virginia Pilot Newspaper)

at the front end. These rings were free to move in studs attached to the frame by 5/16-inch bolts as supplied with the Number 1 Mobile Quarantine Facility Unit.

During the sea test, the cargo net tiedown rings proved to be too convenient for use as a tow point or other unintended uses, and Melpar elected to add additional strength during retrofit of Serial Number 1 and the final three units by increasing the size of the anchor stud to 3/4 inch. Although the tiedown rings were modified to protect them, they are still not intended for use other than to attach the cargo restraining net.

The abuse of the tiedown rings during the first sea test was primarily a result of the fact that the facility does not incorporate wheels or rollers of any type. In some instances , the procedures used to either skid the facility into place, or move it on pipes proved to be more cumbersome than anticipated. During the design review, Melpar was requested to propose a method of equipping the facility with wheels which could be retracted or removed when the unit was set in place on a ship deck, inside an aircraft, or on a truck.

This design proved to be a difficult task, for the limitations in space available for mounting and retracting mechanisms resulted in a complex item. The lack of design information relative to deck-loading characteristics also delayed completion of the design. Although the final design was capable of meeting all of the operational requirements, the Manned Spacecraft Center elected not to include this capability as an integral part of the Mobile Quarantine Facility.

The original design concept for the Mobile Quarantine Facility provided personnel restraint in the lounge area by incorporating normal seat belts into standard Airstream lounge furniture. This is shown in figure 1. Early in the initial design effort it became apparent that the use of seatbelts with the normal furniture was undesirable because of both comfort and limitations in the passenger mobility.

The design was modified to incorporate normal aircraft seats within the Mobile Quarantine Facility rather than conventional furniture. FAA-certified executive-type seats which met the aircraft restraint specification were selected. These are mounted in sets of three along each wall of the lounge area, incorporating seatbelts for restraint. The seats are mounted on tracks which allow them to be moved forward and aft. They pivot as well as recline for passenger comfort. When the tilt table is set up in the aisle between the two sets of seats, the seats are pivoted inward to provide comfortable seating while eating meals from the table top. In these seats, a high back was chosen for safety considerations. A flame-retardant fabric was selected. Figure 7 shows a photograph of the aircraft seating in the lounge area of the Mobile Quarantine Facility. The grill work on

Figure 7. Lounge Area

either side of the storage locker above the rear door covers the radio speakers. The bulkhead immediately forward of the lounge area is of heavy-duty construction, and contains a sliding door which is closed during aircraft takeoff or landing to separate the lounge area from the rest of the facility. Figure 8 is a view of the bedroom area looking forward from the lounge. The personnel restraint straps are shown in place on the bunks and the reading light and oxygen masks are clearly visible over the right-hand bunk. The air inlet louvers and the air conditioning unit can also be seen, as can the roof lockers and storage space under the bunks.

The cargo space of the aircraft which will be used to transport the Mobile Quarantine Facility is pressurized to an altitude of 8,000 feet, which will allow the personnel inside the unit to breathe normally during flight. The use of pressurized cabins at altitudes of 30,000 feet or more, however, requires that an emergency oxygen system be provided for the passengers within the facility. Additionally, since the Mobile Quarantine system is essentially airtight, it becomes necessary to protect the structure and its passengers from the hazard of the internal pressure, should the aircraft cabin experience a rapid decompression during flight.

The flight plan for air transportation to Houston, Texas, is based upon a nominal altitude of 35,000 feet for the aircraft. In the event of unscheduled loss of cabin pressure, for any reason, the aircraft would descend to an altitude of 8,000 feet. The maximum time for the descent is 30 minutes. Based upon this duration of need, Melpar equipped the Mobile Quarantine Facility with an emergency oxygen system designed to supply six passengers for 30 minutes.

The system is controlled with an automatic opening, altitude-compensating regulator which becomes operative automatically upon cabin depressurization and continues to deliver oxygen until the cabin pressure has returned to a normal flight pressure altitude at which the regulator has been preset to automatically close. A manual override is provided to enable the oxygen to be switched on in the event of failure of the automatic feature. The outlet flow rates vary with altitude; consequently, the system provides high efficiency relative to oxygen consumption. The supply tanks, regulator/controls, and pressure switches are located beneath the lower right-hand aft bunk.

Mobile Quarantine Facility Serial Number 1, as originally delivered contained two warning horn alarms, and 13 oxygen masks (one located at each aircraft type seat, one in the bathroom, and one at each bunk). In the final configuration the oxygen supply, pressure regulator/control, and alarm switch have all been doubled for safety reasons.

Figure 8. Bedroom Area

If during the aircraft flight, the pressure altitude within the Mobile Quarantine Facility reaches 12,000 ± 1,000 feet, the oxygen will automatically be released to each outlet valve and the warning horns will sound (bunkroom, lounge). Upon hearing the oxygen warning horn the passengers must withdraw the detent pins from their outlet valves and place the masks to their faces. The system will automatically shut off whenever the pressure altitude returns to 12,000 ± 1,500 feet.

The warning horns can be shut off by pressing the RED RESET button adjacent to either horn. The warning horn system will automatically reset upon release of all oxygen supply lines pressure. A test switch is provided on the mode panel to check the warning horns.

The oxygen tanks must be disconnected and removed for refilling. This operation should be done only by qualified personnel.

The emergency oxygen system was designed to meet FAA specifications. It has performed as designed under actual tests.

The original design for the protection of the Mobile Quarantine Facility structure from rapid decompression was based upon a system which would automatically release the side door, and allow the window in the front end (bathroom) of the facility to blow out if the aircraft cabin pressure suddenly dropped. Basically, a manometer sensing the cabin pressure controlled a solenoid valve on a nitrogen gas supply which was connected through a series of tubing to the door and window actuators. During acceptance testing, this system worked perfectly every time the pressure level was reduced to the preset altitude.

When the Mobile Quarantine Facility was flown for the first time, the cabin was intentionally allowed to experience rapid decompression. The system failed to work, and the rear door of the Mobile Quarantine Facility was forced open by the internal pressure. Analysis of the failure disclosed the fact that the long length of tubing which connected the nitrogen pressure supply to the controlling actuators introduced a delay or lag time before full actuation pressure was achieved within the system. The response time for the system was approximately two seconds. During this interval, the total load on the door and window resulting from the differential pressure between the aircraft cabin and the interior of the facility introduced a large shear load upon the latching pins of the actuation cylinders. This load was beyond the ability of the actuators to retract the locking pins when full system pressure was obtained. Further study indicated that a response time of 0.2 seconds was representative of the maximum delay which could be tolerated for this system.

Data concerning decompression characteristics of aircraft are limited, and Melpar believed the reliability of any system which depended upon a pressure transducer was questionable. To provide a fail-proof means of protecting the Mobile Quarantine Facility from rapid aircraft decompression, Melpar elected to use the blowout panel technique which is commonly employed in aircraft cargo shipping containers.

The detailed design of the decompression blowout panel for the Mobile Quarantine Facility was based upon a rigorous mathematical analysis. Melpar established the equations which define the time rate of change of the pressure within the facility and the aircraft cabin under rapid decompression. These considered the volume of the aircraft (C-141) and the facility, relating these to the parameters of the atmosphere at flight altitude, as a function of the area of the hole through which the air escapes.

A pressure level of six inches of water was selected as a reasonable stress to impose upon the structure of the Mobile Quarantine Facility before decompression was intitated. Thus, Melpar calculated the size hole in the facility which, at a starting differential pressure of six inches of water, would result in a time rate of change of pressure within the facility identical to that of the cabin when a decompression port (window) is suddenly opened to the flight atmosphere. This hole area (three square feet) represented the minimum unrestricted hole size necessary to prevent a buildup of internal pressure beyond six inches of water pressure.

Under these circumstances, the total differential load on a surface area of three square feet is small (about ten pounds) so it is difficult to construct a mechanical means of holding a blowout panel in place (spring clips) which insures a reproducible release of the panel. Likewise, the panel had to be sealed into the facility body in an airtight manner to preserve the biological isolation. This further complicated the design of a weak spring-loading technique for holding the blowout panel in place.

Melpar selected a rigid panel of closed pore, low density polyurethane foam as a material which would fracture under such a load, and designed a blowout panel system incorporating it as the decompression diaphragm. Since the interior of the Mobile Quarantine Facility is maintained at a negative pressure at all times, it was necessary to prevent it from fracturing into the facility. This was accomplished by backing it up on its inside surface with a sheet of 12 gauge perforated stainless steel. The perforations were chosen to present a 65% open area to the surface of the foam. Two blowout panels, each one foot high by 38 inches wide, are used in the facility, which results in a net opening equivalent to approximately five square feet, larger than the three square foot minimum opening which was calculated.

The foam material (1/2 inch thich) was bonded around its entire outside edge to the perforated metal to provide an airtight seal, and to facilitate handling. This panel was attached to a frame in the side of the Mobile Quarantine Facility by bolts to hold it against a gasket, producing a total seal. A door was provided over the blowout panel which protects it at all times, other than during transportation within an aircraft. This door was lined with sponge polyurethane foam 3/4 inches thick, which presses against the blowout panel to prevent vibration, etc. The two blowout panel assemblies are located in the wall of the facility over the bottom bunk on each side of the facility.

Figure 9 shows a sketch of the total blowout panel assembly. This unit was tested experimentally, by placing the blowout panel assembly into an opening in a chamber. The chamber was then pressurized, and a manometer used to measure the differential pressure at which the blowout panel was forced out of the frame. This pressure was consistently six inches of water, plus or minus one inch. A slow pressurization rate was used to present a worst-case measurement to be sure that the panel would be blown out under dynamic pressurization.

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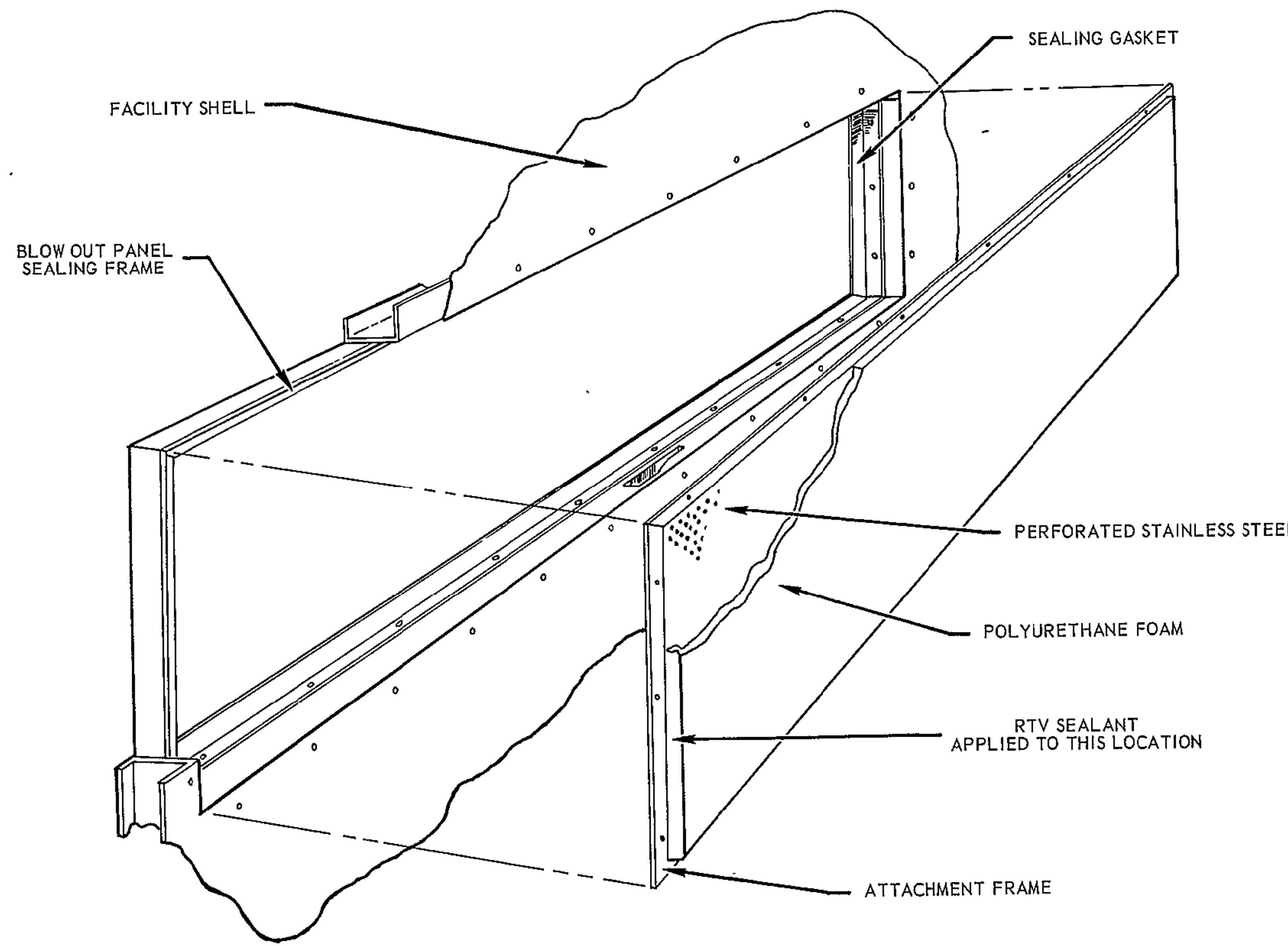


Figure 9. Sketch of Blowout Panel

6. BIOLOGICAL ISOLATION

The primary function of the Mobile Quarantine Facility is to provide biological isolation of the astronauts during transportation to Houston, Texas. In order to achieve this it is essential that the entire structural shell of the facility exhibit air and watertight qualities. The total structural shell of the facility, then, is the primary biological barrier. The actual biological quarantine is accomplished by preventing any air from leaving the facility without suitable filtration to provide suitable decontamination.

6.1 Structural Shell

In addition to the requirement for air and watertight qualities, the shell must have doors, windows, and other penetrations to satisfy its functional objectives. Other original requirements are stated in the following four paragraphs.

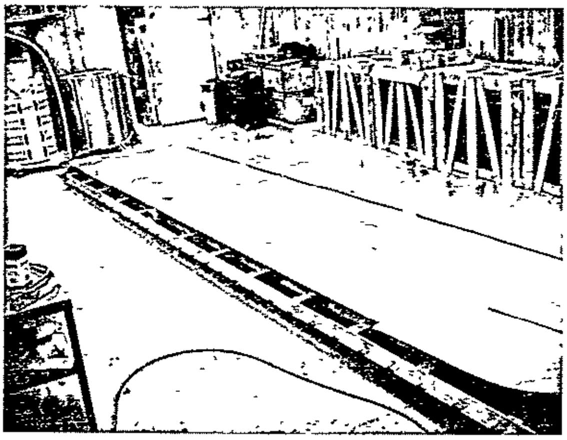
The facility shall contain at least one personnel door. A method of escape located on the end of the facility shall be provided. All doors shall be completely sealable and permit opening and locking from both inside and outside. Also, an alternate method of escape shall be provided.

Metal "surfaces" or flanges required for sealing (tape) the transfer tunnel to the Mobile Quarantine Facility shall be provided both inside and outside the personnel door.

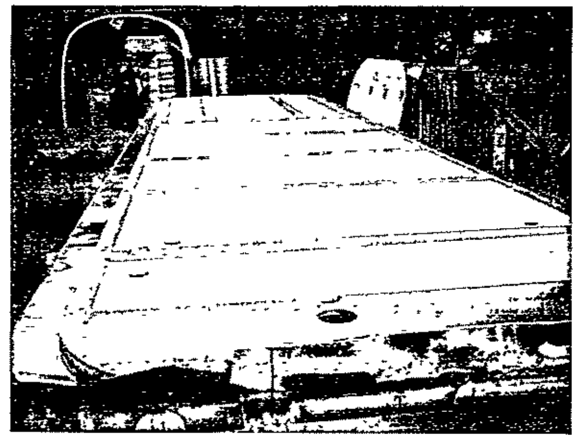
All external openings, replaceable filters, or joints shall be easily accessible and flush with the outside surface of the facility to permit sealing (tape) and isolation, after transfer of the personnel to the Lunar Receiving Laboratory.

All windows located in the facility shall be one piece and shall be of solid safety glass or Plexiglas. The windows and frames shall be sealed air and watertight into the structure. Airtight is defined in this specification as that which is derived from the use of good positive manufacturing processes and the application of bonds and sealants at all joints and overlaps. Outside protective screens shall be provided if glass windows are used.

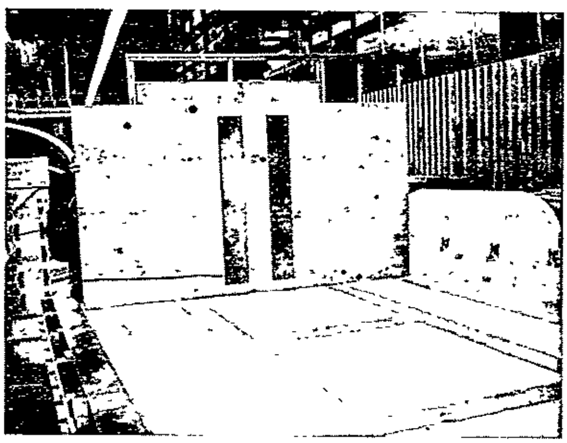
During actual fabrication, the construction techniques and the final configuration of the Mobile Quarantine Facility differed little from the design concept. The first step was to cover the entire top surface of the heavy aluminum frame with a skin of 0.032-inch aluminum, which serves as the "underbelly," or bottom isolation barrier (see figure 10A). All seams were made with a sealing tape in the overlap area. The subflooring, 1/4-inch plywood, was then cut to the size of the total facility floor, and placed on top of the underbelly which extended out some



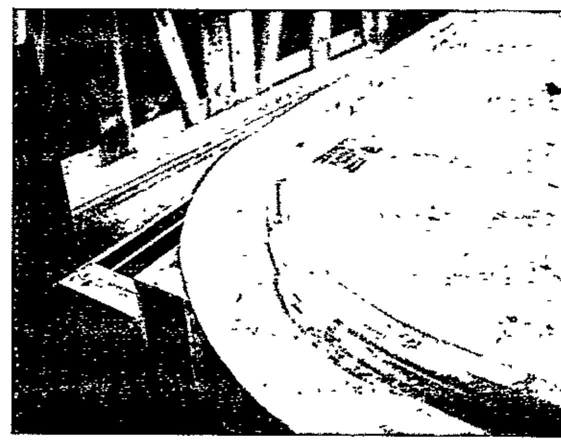
A. UNDERBELLY



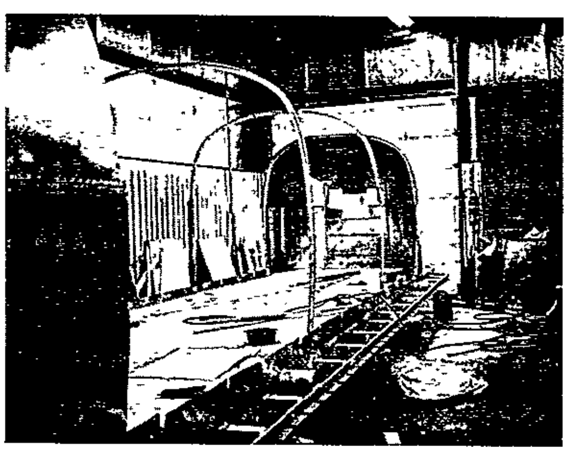
B. FLOOR AND INSULATION



C. LOUNGE AREA FLOOR
REINFORCEMENT



D. U-CHANNEL INSTALLATION



E. END CAP INSTALLATION

F. SKIN INSTALLATION

Figure 10. Shell Construction

six inches beyond the floor. One-inch-thick wood was then used to provide a solid frame at the ends and along the sides of the floor. Additional one-inch beams were installed across the width of the floor. The lounge area has wood beams parallel to the edge toward the middle of the floor under the seat track area. (See figure 10B.) All open spaces were filled flush with the one-inch floor beam with styrofoam insulation. The entire floor surface was then covered with 5/8-inch-thick plywood. (This flooring is reinforced in the lounge area at the location of the tilt table attachment position as shown in figure 10C.)

This multilayer floor was attached to the major structural beams of the frame by the use of 1/4-inch self-tapping screws, 2-1/2 inches long. These screws are located on two-inch centers. The edges of the floor were fastened through a 1 x 1-1/2-inch aluminum channel (see figure 10F) on six-inch centers. This U-channel was used to locate and fasten all of the structural bows which support the shell of the facility. The underbelly skin was then folded up around the floor, extending above the top edge of the U-channel.

The end caps of the facility shell were prefabricated to provide the standard shape. These were the first part of the facility shell attached to the base (see figure 10E). Once the ends were in place, the remaining structural bows were installed, and the entire outside skin stretched over the frame (see figure 10F). In all cases, each overlap seam used a sealing tape between the two aluminum skins, and the attachment to the structural bows used "bucked-rivets."

Each penetration of this skin required framing for both structural support and sealing. These frames are basically fabricated from U-channels, with the legs of the U parallel to the skin and extending behind the opening in the skin, while the bottom of the U forms the inside edge of the opening. In all cases, the skin was attached to these frames with bucked-rivets; sealing tape was used between skins and frames. All windows were fabricated using a double pane construction to improve thermal insulation and safety.

When the final design was being accomplished, the door arrangement was changed from the original concept. A door in the end of the facility high enough to allow entrance without stooping proved to be unsatisfactory because of the curved surface at the top of the shell, and the complexity of the frame and door seals which would be required. In the final design, a four-foot-wide door was provided at the end, which is only four feet high. This is satisfactory for transfer into the Lunar Receiving Laboratory, but not for entrance from the spacecraft. Convenient access to the facility from the Command Module was provided by installing a standard Airstream door in the side of the facility. Both the side and end door provide an airtight seal by compressing a gasket between the edge of the door and the door frame. The doors use a three point crab-lock to hold them closed. The rear door also incorporated a window.

It was possible to use the standard door in the side of the facility, and still realize a seal which was tight, by selecting door assemblies from stock, which exhibited good production tolerance. These were then improved by polishing the sealing surfaces to remove irregularities and thereby increased the uniform sealing surface. A metal flange is installed around the inside edge of the door frame to provide a surface which is used to seal the shipboard transfer tunnel to the unit. The rear door was fabricated specifically for this facility, and the door used on unit number 1 when originally delivered was not structurally strong enough. This door could bow slightly, and was not properly sealed when closed. By the time of the second design review in April of 1967, a redesign had been effected, and the rear door of unit number 1 was retrofitted at Houston, Texas.

When the outside skin assembly was complete, and all penetration frames installed into the facility, the entire inside was sprayed with a Vulkem sealing compound. The electrical wiring harness was then installed on the interior of the unit. Next the interior was covered with fiber glass insulation. The insulation was compressed to the thickness of the bows (1-1/2 inches) with the installation of the interior skin.

The installation of the interior skin was started at the forward end of the facility with the attachment of a molded fiber glass shell which matched the end contour of the facility. The floor in this area, which is the bathroom, was covered with vinyl tile. Starting at the edge of the fiber glass end cap, the interior walls were then covered with a vinyl clad aluminum sheet. Again, the aluminum/vinyl skin was fastened to the structural bows with pop-rivets. A molded fiber glass section was also used in the rear end of the facility, above the top of the door. A section of the end cap protrudes slightly into the interior, and provides a roof locker area, which is covered by sliding doors. This protrusion also houses loud speakers for the sound system. In the case of unit number 1, a clock was mounted in the corner of this fiber glass section.

When the interior skin had been attached, the entire floor was covered with carpet. A technical direction received in December of 1968 required that the carpet be removed for units 2, 3, and 4. These units now have an additional layer of 3/16-inch plywood on the floor, over which a 1/8-inch hardboard was used as the subflooring for the 1/8-inch-thick vinyl asbestos tile.

During the final design, it was necessary to establish a meaningful method to define the term "airtight" with respect to the end item. A test procedure which was established consisted of sealing the filter units, establishing an internal pressure differential, and determining the time interval required for air leaking into the facility to reduce the pressure differential. Specifically, the in-process inspection plan required that the time interval during which a differential pressure of 0.3 inch of water decreases by 0.1 inch of water be determined. Melpar optimistically selected an interval of 15 minutes as the target requirement for acceptance. This proved to be impossible to achieve, and was extremely unrealistic.

Melpar reviewed the operational procedure to determine the maximum time interval, during use, that the Mobile Quarantine Facility might be without electrical power. This could occur when power sources were being changed, during failure of one power source, or when loading into the aircraft. Based upon this type of consideration, a revised specification was established which required that the time interval for the pressure within the sealed unit to increase from a negative pressure of 2.0 inches of water to a negative pressure of 0.2 of an inch of water must be four minutes or greater. The basis for the leakage rate of the revised specification was further substantiated by calculations which showed that a leakage rate of four minutes for a change in pressure from minus 2.0 to minus 0.2 of an inch of water was equivalent to a single hole in the shell, approximately 1/4 inch in diameter. Additionally, the exhaust system of the Mobile Quarantine Facility is capable of maintaining the operational negative pressure of 0.2 of an inch of water with the aft door held open a full quarter of an inch.

All windows in the facilities are fabricated from Plexiglas and match the contour of the shell.

When all exterior assembly of the shell had been completed, the outside surface was covered with a coating of clear lacquer to provide additional protection from exposure to the weather.

6.2 Air Filtration

Gases exiting the facility must be decontaminated. This will be accomplished by using biological filters for all exit air filtering. The filters used must be at least of the high efficiency type which will remove 98 percent, or greater, of all particles 0.5 microns or larger.

An exhaust fan system shall provide continuously, without interruption, a negative pressure on the inside of the facility. A pressure differential equivalent to 0.10 to 0.18 inch of water will be the minimum acceptable, except during transfer through the transfer tunnel aboard ships, when 0.02 inch of water is sufficient. The exhaust system shall be redundant, affording adequate isolation when the fan systems are operated singly. A method of varying inlet airflow and monitoring the pressure differential shall also be included.

Since the shell of the facility is very well sealed, it is essential to have an inlet port to provide make up air to replace most of that which is exhausted to maintain the negative pressure.

The inlet of the conditioning units shall contain a filter composed of two layers of "50 FG glass fiber," or equivalent. This filter shall have the capability of being changed from the exterior only.

Again, the design concept remained unchanged in the final detailed design. Two air inlets were provided in the roof of the facility; one located in the galley area, the other in the bunk area. These are 12 by 24 inches, with high efficiency filters, of the same type that were used to filter exhaust air. This filter can be changed only from the exterior. High efficiency filters were selected as added biological protection, should the cabin pressure during aircraft flight change rapidly, such that the Mobile Quarantine Facility experience a short period of slightly positive differential pressure. The inside of these assemblies contain adjustable louvers, which allow the amount of inlet airflow to be controlled from the inside of the facility.

The decontamination filtering is accomplished by exhausting the air through a biological filter assembly located on each side of the facility. The filters, 12 inches high by 24 inches wide are housed in a sealed filter box, both of which are located in the galley area, one over the sink counter, the other over the counter containing the refrigerator and oven. The exhaust fans are installed on the exterior of the facility, within a closed shroud or duct that directs the airflow to a squirrel cage fan, 7 inches in diameter. These fans are powered by 0.16 h.p. motors manufactured by the Roton Company. While the original design was based upon controlling the airflow by adjustment of the inlet airflow, it was necessary to add a Variac control to the exhaust fans, for the system was too powerful without a reduction in the motor speed.

Each exhaust fan, by itself, is capable of reducing the pressure within the Mobile Quarantine Facility to the required operation level. These are wired on independent electrical circuits. With both inlets sealed and both exhaust fans operating at full capacity, it is possible to reduce the pressure within the facility to a negative pressure of more than 2.5 inches of water..

6.3 Water Supply and Waste System

The biological isolation requirements for the total facility were also extended to the water supply and waste system. The original requirements called for are stated in the following three paragraphs.

Fecal and urine wastes shall be contained and stored in a holding tank, integral with the facility's toilet system. Deodorizers will be required in the system. Fecal and urine wastes are not allowed to be disposed of until delivery, decontamination, and refurbishment of the Mobile Quarantine Facility at NASA Manned Spacecraft Center. The holding tanks shall have the capability of containing waste of six men for at least five days.

Non-fecal waste water (shower, wash, drinking, etc.) shall be exited from the facility through plumbing separate from the toilet plumbing and contained in a holding tank of suitable size. This waste water will be treated with a solution of sodium hypochlorite, held for a specific length of time, and disposed of in a suitable manner. The holding tank may be integrated into the facility's structure or fabricated as a separate unit, stored inside the facility until required for use. The holding tank and plumbing shall be of materials compatible with, and impervious to, the decontaminating agent, and have both inlet and exit connections.

All remaining solid waste materials (garbage, paper plates, etc.) shall be held for the period from spacecraft retrieval through delivery, decontamination, and refurbishment at NASA Manned Spacecraft Center. A method of deodorizing these wastes shall also be provided.

The basic design concept developed prior to the start of the contract was implemented to fabricate the facilities. Those changes introduced were primarily to increase the volume of the holding facilities. Figure 11 shows the plumbing diagram of the Mobile Quarantine Facilities.

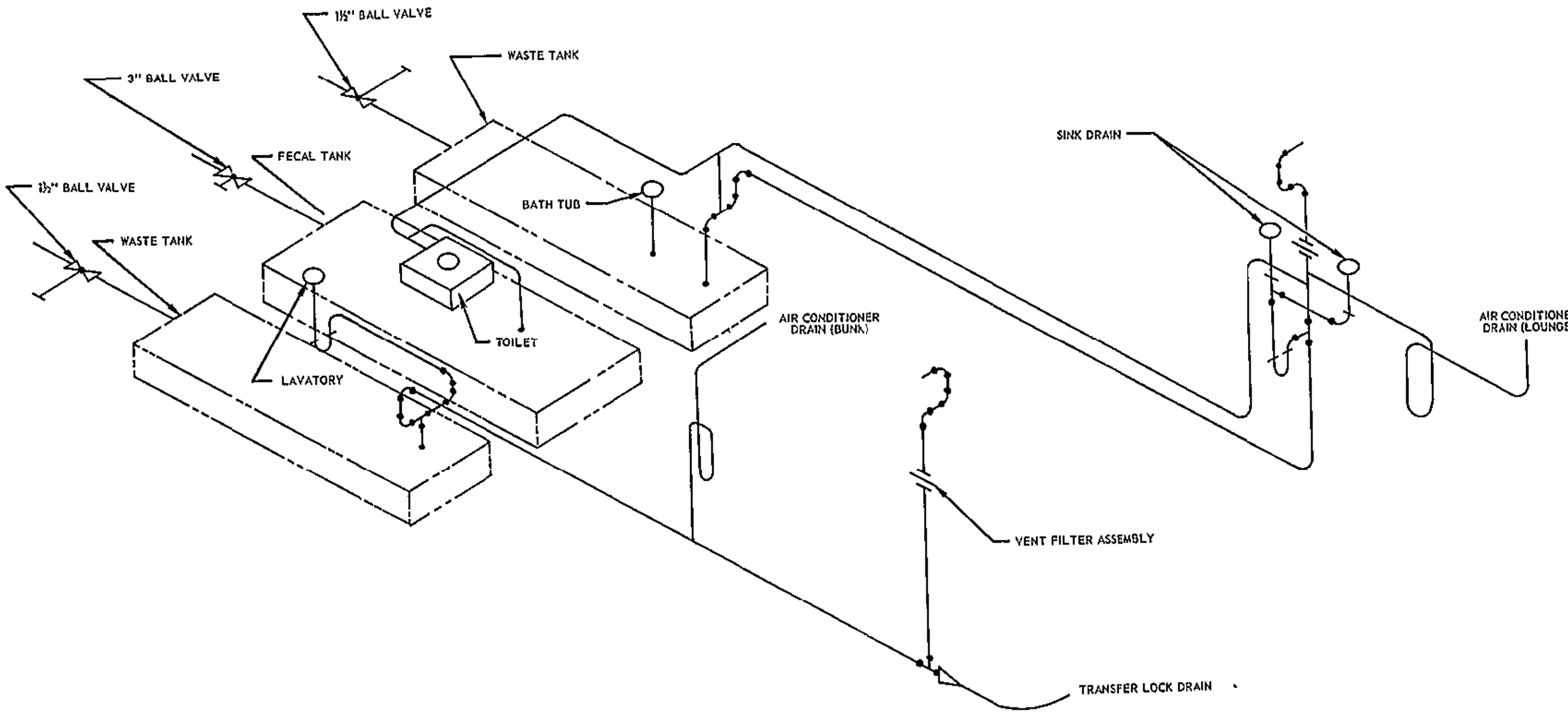


Figure 11. Plumbing Diagram

The water system provides full service, both when connected to an external pressurized supply and when the unit is completely self-contained.

To operate the water system from a pressurized external supply, connect a hose (3/4 or 1-1/2 inch diameter) to the MQF fresh water inlet fitting located on the forward right side of the unit. The inlet section is equipped with a check valve, permitting no internal water to flow out. The system is also equipped with an over-pressure relief valve to protect all internal plumbing from damage. Whenever the system is drained, all air should be bled by opening all faucets (water outlets) during refilling. Special care is needed to bleed all air from the hot water tank before switching ON the heater. The hot water tank, heater, and heater switch are located beneath the lavatory sink.

To operate the water system in the self-contained mode, the 30-gallon tank is filled before disconnecting from the pressurized system. To fill the water tank, the crossover valve is located under the lower forward right-hand bunk is opened. This valve is used only for filling the tank and must be closed at all other times. Upon completion of the filling operation, the pressurized water supply is disconnected, and the supply hose removed; the check valve automatically closes off the unit's internal system. The 3/4-inch cap to the inlet should be replaced and the 3/4 by 1-1/2 adapter (if used) stowed. After the filling operation and disconnection has been completed, the water pump must be turned on. The switch is located in the galley. The water pump switch should be off during the external pressurization operation. The self-contained system is automatic -- the water pump control senses the pressure within the water system, so that, whenever a faucet is opened, the pump will turn on and when the faucet is closed the pump will turn off.

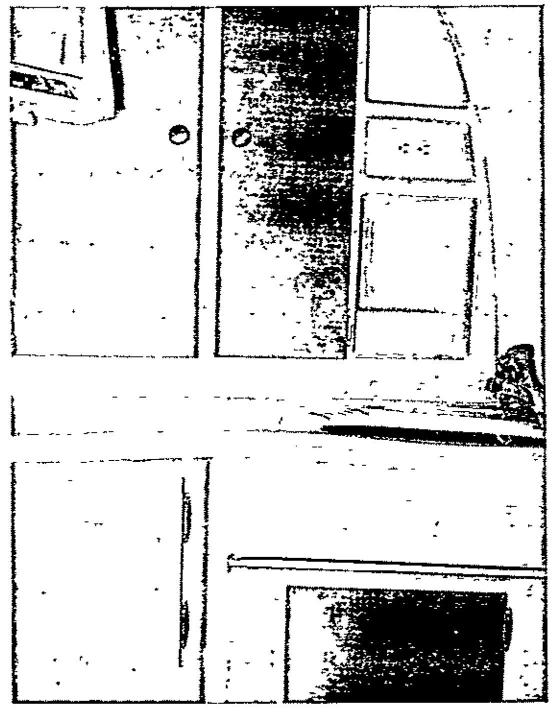
A water filter was provided to filter only the cold water used in the galley sink.

The hot water heater will not operate whenever the MQF is connected to the Aircraft 28 volts dc power.

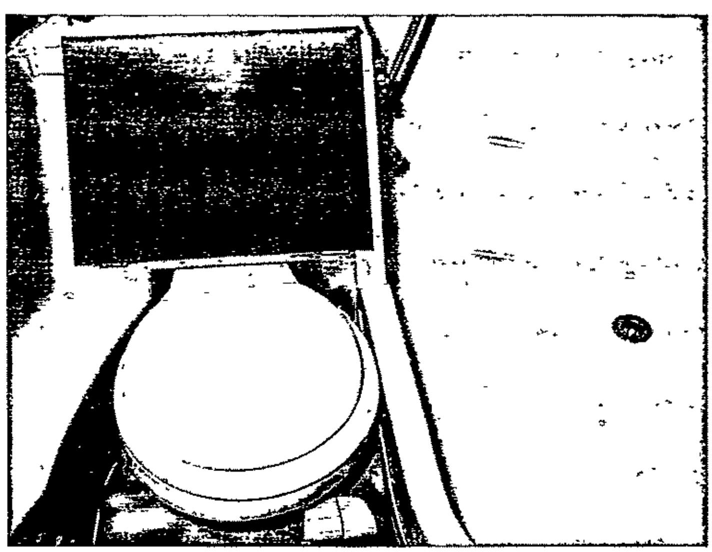
Figure 12 shows a photograph of the sink located in the galley area.

The waste system is fabricated with plastic materials and is divided into three separate parts. The left side system drains and holds waste liquids from the transfer lock, bunkroom air conditioner, and bathroom lavatory. The right side system drains and holds waste liquids from the lounge air conditioner, galley sink, and bathtub. The center system drains and holds waste from the toilet only

A. GALLEY SINK



B. BATHROOM VANITY



C. TOILET AND BATHTUB/SHOWER

Figure 12. Galley and Bathroom Fixtures

The original design of the waste system utilized a fecal holding tank which was much smaller than the side tanks. During the first sea trial, the capacity proved to be inadequate, particularly in view of the fact that changes in operational plans were expected to increase the duration of the trip to Houston, Texas. When fabrication was resumed, the fecal holding tank was increased in size. Following the next sea trial, it was determined that the fecal holding tank capacity was still marginal, and a tank was added into the system on top of the normal fecal holding tank in units 2, 3, and 4.

The two side tanks have a capacity of approximately 17.5 gallons each and the tanks are equipped with a FULL/EMPTY indicating system. To check the condition of a tank, the switch on the Mode Panel, to the desired tank, is pushed; if the tank is empty a light will so indicate, if the indication is FULL, the tank contains approximately 13 gallons of waste liquid. The remaining 4.5 gallons capacity is for the decontamination solution which is to be added before the tanks may be emptied.

The center tanks have a total capacity of approximately 40 gallons: 7 gallons in the "Set-In" tank and 33 gallons in the under floor tank. A deodorizing solution (Aqua Kem) should be added to the "Set-In" tank after the tank has been dumped into the under floor tank and before the toilet has been used.

The galley sink, lavatory, transfer lock, and air conditioner drains are equipped with traps to stop any backflow of gas from the holding tanks. The bathtub DOES NOT contain a trap; therefore, the stopper must be used to keep the gases from the holding tank from entering the bathroom.

The automatic toilet flush has been disconnected and the toilet must be flushed with the hand spray. Therefore, it is necessary to pre-wet the toilet bowl before usage. Users are instructed for urine only; pre-wet slightly; for urine and feces usage, pre-wet and provide enough water for flotation of paper and solids. Figure 12B shows the sink and vanity arrangement; figure 12C shows the toilet and bathtub/shower.

The design of the waste system was based upon the use of standard Airstream slide valves to close the holding tanks to the outside environment. Late in 1968, Melpar was directed to replace these valves with ball valves manufactured from PVC to provide the seal to the outside.

To empty any of the holding tanks, a hose is connected to the desired outlet on the forward end of the unit and the proper Ball Dump Valve is opened. The handles for the side tanks are located on the respective side near the forward end. The toilet waste Set-In holding tank is adjacent to the toilet and has an Easy Slide Valve next to the bathroom floor. The handle of this valve can be reached through the opening in the bottom front of the tank. To empty the Set-In Tank, the Easy Slide Valve handle is unclipped and pulled out. The hand spray may be used to flush the interior of the tank. To empty the underfloor center tank, the unit must be raised sufficiently so that the Center Ball Dump Valve handle can be operated. The MQF must be tilted, forward end down, to completely drain the underfloor tanks.

6.4 Decontamination Transfer Lock

It was required that a double-door pass-through decontamination lock shall be provided in the facility's structure. The lock will be used to pass meals, medical supplies, equipment/supplies into the facility, and packaged lunar samples, flight tapes, flight film, and crew equipment out of the facility for return to NASA Manned Spacecraft Center. The opening size of the lock door required is 20 by 12 inches. The interior depth shall be at least 12 inches for immersion type decontamination. However, if a wipe-down decontamination is employed, the envelope dimensions must be larger. The doors shall be completely sealable. The materials used to fabricate the lock shall be impervious to normal concentrations of the decontaminating agent, sodium hypochlorite. The lock should also have the capability of being completely drained. The lock shall be located in the gallery.

As originally proposed, the type of lock was to be a flood system lock and would contain two doors with openings 20 by 12 inches. The depth of the lock would be 12 inches minimum. Figure 13 depicts the concept of the lock. This lock would be located adjacent to the galley. The lock would be constructed out of 303 or 304 stainless steel and would be readily cleanable.

The lock would operate in the following manner. Starting with a clean lock, the outside door would be opened (inside door closed and locked as only one door can be unlocked or opened at a time), and the item to be transferred placed into the lock. The outside door would be closed and locked then the inside door would be opened and the item removed. No decontamination action would take place. If an item were to be transferred out, it would be placed into the lock, and the inside door closed and locked. Upon locking the inside door the lock would be flooded with the decontaminating agent and held for the required time. The decontaminating agent would be drained and the outside door would be unlocked. The lock will be provided with a "wash-down" spray.

When the detailed design effort for the decontamination lock was initiated, Melpar placed emphasis upon two functional aspects of the lock which resulted in an overly complex unit. Keeping in mind the importance of immediate removal of the lunar samples to be transported to Houston, Melpar felt that the decontamination lock should be a mechanical item, and not rely upon electromechanical activation of the interlock system. Additionally, Melpar believed that it would be desirable to provide a means of controlling the time of immersion of items in the decontaminating solution, since the decontamination procedure was based upon a specific soak time.

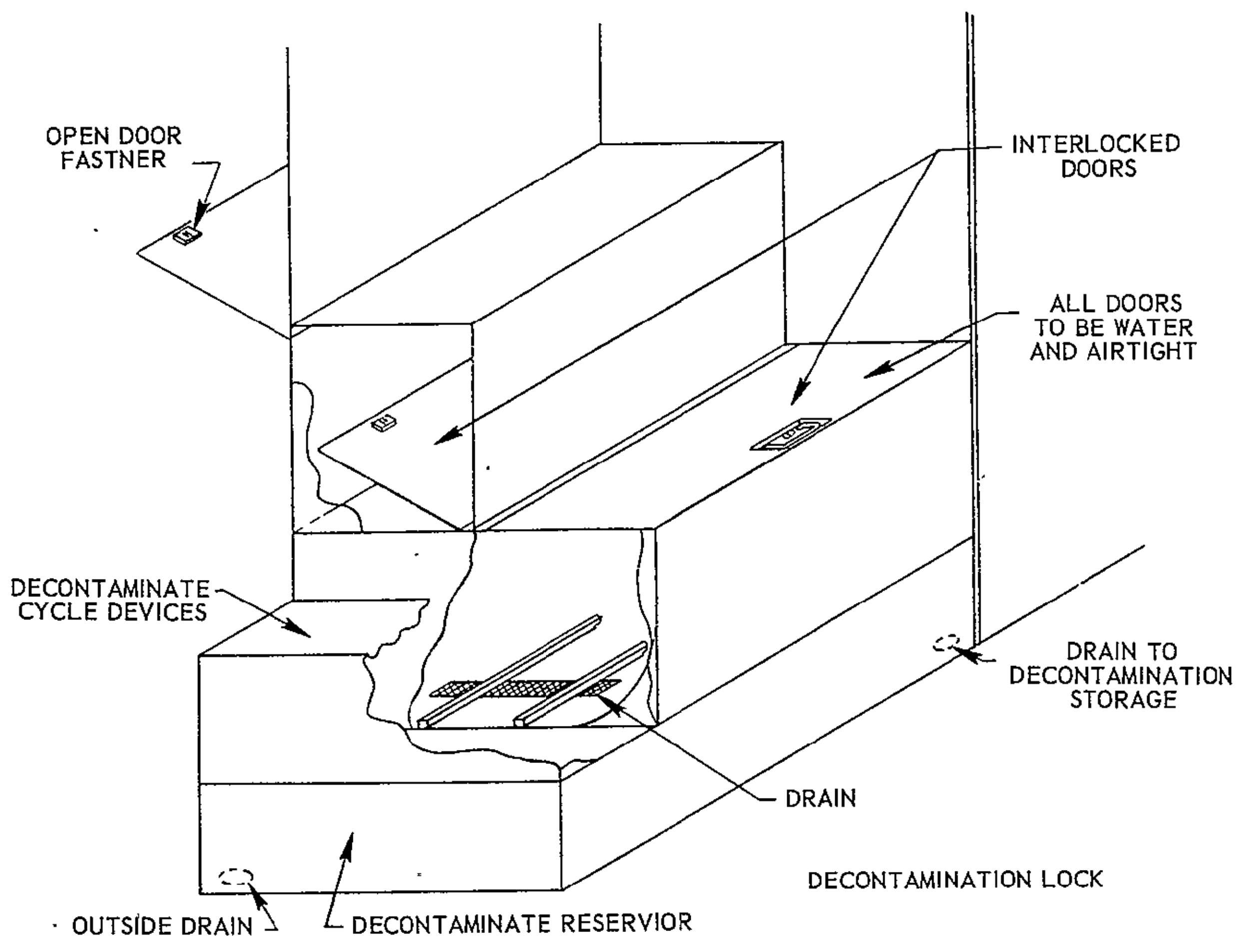


Figure 13. Orginal Concept of Decontamination Transfer Lock

The decontamination lock as used in unit number 1 as originally shipped, then, had a rather complex metering/timing system as an integral part of the door locking mechanism. This control made it impossible to open the door after the lock was filled for a specific time interval of ten minutes. The entire locking mechanism was mechanical in nature, and only the pumping system (which was backed up by a mechanical pump) required electrical power for operation.

During the first sea trial of the Mobile Quarantine System, the decontamination lock proved to be unreliable. The interlock mechanism presented numerous problems, and the operators found that it was necessary to override this control almost routinely. Additional difficulties in operation were experienced from the long time required for the lock to drain, and some leakage was noted around the door seals. It was also noted that the decontaminate caused rusting of the welded joints.

After the design review, following the sea test, it was decided that a timing mechanism was not desirable, and the feature was deleted. The interlocking mechanism was made stronger, and a second pump was added to speed the draining of the tank. Additionally, the design of the gaskets around the doors was improved to prevent leakage. In order to prevent rusting the decontaminate reservoir tank was coated with a neoprene lining (Gacon-200). Similarly, the procedure for use of the transfer lock placed emphasis upon wiping the lock clean after each use, since it was not practical to coat the surfaces of the lock itself.

Figure 14 shows a photograph of the transfer lock as it appears when it is installed in the Mobile Quarantine Facility. Immediately to the right of the transfer lock is the refrigerator. A microwave oven is installed on the countertop over the refrigerator. This equipment was added to allow controlled meals to be prepared within the facility, rather than to attempt to pass preheated meals in through the transfer lock, as originally intended.

To transfer an item into the Mobile Quarantine Facility (assuming that the interior of the lock is in a decontaminated condition, the inside door is locked, and the outside door is open), the outside operator simply places the article on the tray in the lock, closes the door, and engages the locking bar by sliding it toward the edge of the door, and rotates the handle to the position normal to the door.

The inside operator depresses the outside lock button, and opens the inside door by rotating the inside door handle to the position parallel to the door, and sliding it away from the edge of the door. The article is then removed.

Figure 14. Decontamination Transfer Lock

To transfer an item out (outside door automatically locked, or the inside door cannot be open), the inside operator places the item to be transferred on the tray in the lock, closes and locks his door, opens the FILL valve, turns on the fill pump and fill light, and watches to see when the flow of decontamination is observed in the overflow indicator. The decontamination period is timed from the point at which the chamber is full. When the decontamination time has been reached, the operator closes the fill valve, turns off the fill pump and fill light, and opens the solution drain valve. He also turns ON the empty pump and empty light. When all of the solution has been returned to the reservoir, the solution drain valve is closed, and the rinse drain valve is opened. The rinse water valve is opened and closed several times. The rinse drain valve is closed after the rinse water is pumped out, and the pump and light are turned off. The outside door is then unlocked so that the item can be removed from the outside.

6.5 Heating and Cooling Systems

The environments in which the Mobile Quarantine Facility will be used are not representative of long-term exposure to extreme temperatures. The heating and cooling requirements for comfortable living conditions are not difficult to achieve.

It was a requirement that the facility shall be completely insulated for both thermal comfort and sound (noise) level; and that adequate thermal comfort shall be maintained for ambient conditions from 55 degrees to 95 degrees Fahrenheit. The minimum comfort level is 78° F, 75% relative humidity. The noise level shall be reduced to permit normal conversation. (The design goal shall be 40-50 dB.. Dampening of discomforting sounds shall be considered for long duration operation of the facility.

Further, an air conditioning and heating system shall be employed both to provide inlet conditioned air and maintain an acceptable level of comfort. This system shall be redundant and shall afford only minimal comfort when the units are operated singly.

Single unit operation of the air conditioner shall maintain a 78 degree inside environment; two units operating together shall maintain a 72 degree inside environment with the facility located half shaded from the sun's rays and in an ambient environment of 92 degrees.

The heating system shall maintain a 72 degree environment with an ambient outside environment of 54 degrees in a "no sun" or overcast lighting condition.

The Mobile Quarantine Facility is equipped with two air conditioners (standard Airstream 10,000 BTU capacity units manufactured by Armstrong Furnace Company) and two space heaters (1,250 watt units manufactured by Nutone). The air conditioner thermostats are mounted on the bulkheads while the space heater thermostats are mounted with each heater. The bathroom heater and bunkroom air conditioner are electrically interconnected so that only one of the units can be operated at any one time. The lounge heater and air conditioners are similarly interconnected.

The type of unit to be operated is selected at the electrical control panel, but each circuit contains its own OFF/ON switch. The air conditioner has an OFF/ON two-speed switch mounted on its right side. The space heater has an OFF/ON variable switch on its front.

The operation of the climatic conditioning system varies with the type of electrical power supplied to the Mobile Quarantine Facility. Whenever the unit is connected to 440 volts ac the total system can be operated; when connected to 28 volts dc, neither forward nor aft units may be operated. When the APU provides the power, either the forward or aft units can be operated but not both.

This system is capable of maintaining the interior temperature within the limits described in the previous paragraphs.

The noise level within the Mobile Quarantine Facility is low enough to allow normal conversation. Measurements of the noise level showed that unit Number 1 provided nearly 10 dB attenuation of the outside ambient. Units 2, 3, and 4 afforded only a 5 dB attenuation of the outside noise ambient as a consequence of the fact that these units had tile floors rather than carpet.

7. ELECTRICAL POWER AND COMMUNICATIONS

The recovery mission procedures dictate that the Mobile Quarantine Facility have the capability of using a number of electrical power sources to operate the various equipments within the facility. Table I identifies the power available to the Mobile Quarantine Facility during transportation; the table also specifies those equipments which must be operable under each mode of travel.

Table II presents a listing of the operating voltages for the equipment within the Mobile Quarantine Facility. All of the power sources require conditioning to provide the correct power to that equipment. It was necessary to provide a redundant wiring system to ensure that biological isolation would be maintained, even if one source were to fail.

The systems requiring electrical power were arranged in groups to permit connection to five electrical busses. The five groupings are listed below:

Emergency Buss	Essential Buss	Utility Buss
Exhaust Fan No. 1	Exhaust Fan No. 2	Heater
Refrigerator	Activity Lights	Water Heater
Reading Lights		Hot Plate

Main Buss No. 1	Main Buss No. 2
Air Conditioner No. 1	Air Conditioner No. 2
Outlets	

Aboard the recovery ship, two ship power sources provide power for the required system. One ship power source provides power for systems on the emergency buss and main buss No. 1. The second ship power source provides power for the remaining systems, which are grouped on the essential buss, the utility buss, and main buss No. 2. This provides redundant power for the exhaust fan if one power source fails.

During hoisting operations and transfer of the facility from the ship to the aircraft, and also in transfer from the aircraft to the Lunar Receiving Laboratory, an auxiliary power unit provides power for systems on the emergency, essential, and main No. 1 busses.

Redundant power for systems used while the facility is being air transported is provided by two inverters. One inverter provides for systems on the emergency buss, while the second inverter provides power for the essential buss.

TABLE I

POWER SYSTEM

Power Source	440V ac 60Hz 3ϕ	Diesel APU	28V dc 200A	Diesel APU
Use / System	Ship	Transfer from Ship to Aircraft	Aircraft	Transfer from Aircraft to NASA-MSC & LRL
Differential Pressure Fans	x	x	x	x
Air Conditioning	x	(1 unit only)		(1 unit only)
Refrigerator	x	x	x	x
Hot Plate (Oven)	x			
Water Heater	x			
Reading/Activity Lights	x	x	x	x
Tape Recorder	x			
Convenience Outlets	x			

TABLE II

ELECTRICAL POWER REQUIREMENTS

Equipment	Operating Volta
Air Conditioning	117 Vac
Blowers	117 Vac
Refrigeration	117 Vac
Oven	117 Vac
Transfer Lock	117 Vac
Lounge Lights	117 Vac
Alarm System	117 Vac
Space Heater	117 Vac
Water Pump	12 Vac
Chair Lights	12 Vac
Galley Lights	12 Vac
Ceiling Lights	12 Vac
Bunk Lights	12 Vac
Lavatory Lights	12 Vac

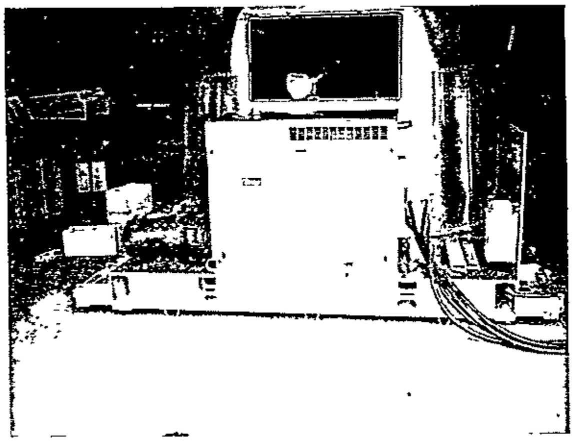
All of the power conditioning equipment is located on a plate, which is attached to the facility frame, immediately in front of the facility shell. Figure 15A shows the overall arrangement. The diesel fuel auxiliary power unit (6 kW manufactured by Onan) is mounted slightly off center, with the two inverters (1500 watt output, manufactured by Carter Motor Company) mounted on one side; the transformers which provide the final operating voltages are mounted on a panel on the other side. Power from each input source is divided into the specific circuits within two junction boxes that contain the circuit breakers; these are also mounted on the panel with the transformers. Figure 15B presents another view of the inverters, and figure 15C shows the transformer and junction box panel.

Power was originally brought into the Mobile Quarantine Facility through four cables sealed by Pyles National Cable Grips. Figure 15D shows these cables as they enter the inside of the shell. When the electrical system was redesigned, it was necessary to increase the number of cables to six. The cables were moved to the side of the end cap for convenience, and also to reduce the need for bending the cables. These cables are connected to a switch panel installed beneath the mirror in the bathroom, as shown in figures 15E and F. This mode panel allows the personnel within the facility to select the appropriate power source for the mode of operation being used. Figures 16A and B show cables prior to installation of the inner skin, while figure 16C shows the wires penetrating the inner skin. Each circuit goes through a standard Airstream circuit breaker panel prior to connection to the individual equipment which it powers. This panel is located below the wardrobe cabinets in the bunk area, adjacent to the bathroom wall, as shown in figure 16D and E.

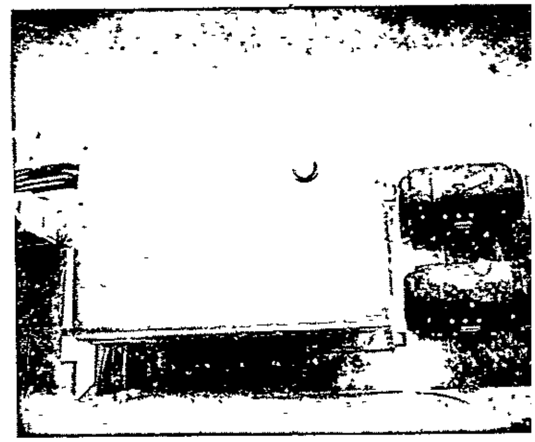
The Mobile Quarantine Facility can be connected to either shipboard or Lunar Receiving Laboratory power through two 125-foot power cables which provide redundant sources. These cables have 440-volt connectors, and are wired directly into the transformer bank. When not in use, they are pulled to the side of the unit and stored in the external storage box. When aboard aircraft, the Mobile Quarantine Facility power connection to the two redundant sources uses two 25-foot cables which are wired into the inverter circuit. These cables are stored in the other external storage box along with the transfer tunnel supply frame.

The controls for the APU are located in the bathroom as shown in figure 16F. The Variacs to operate the exhaust system are located in the lounge area.

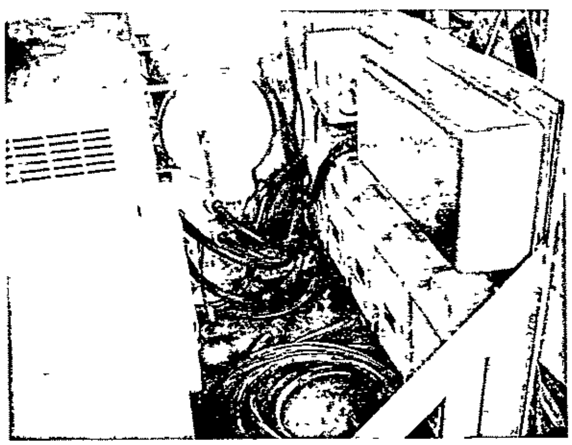
During the first operational test, the electrical system performed as desired; however, it became apparent that the facility electrical system could be controlled better from a centralized control panel. Similarly, an automatic standby emergency power source was added to the unit, which is activated in the event that any of the



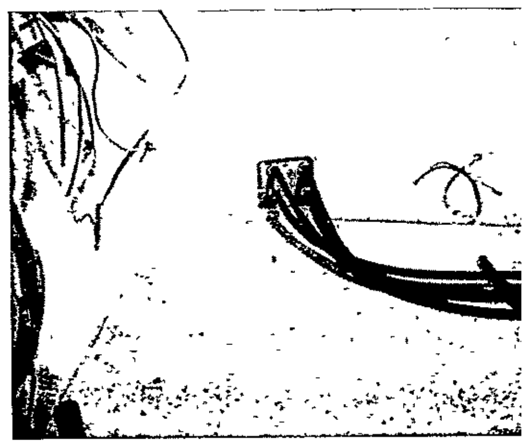
A. POWER CONDITIONING EQUIPMENT



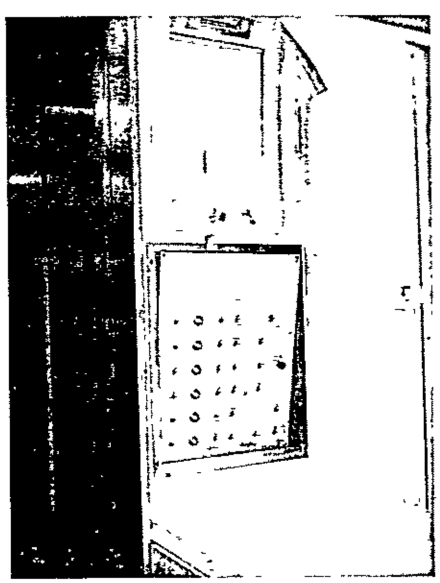
B. APU AND INVERTERS



C. TRANSFORMERS



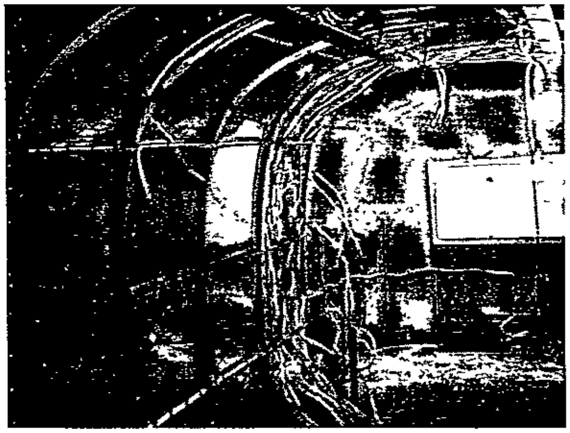
D. CABLES ENTERING SHELL



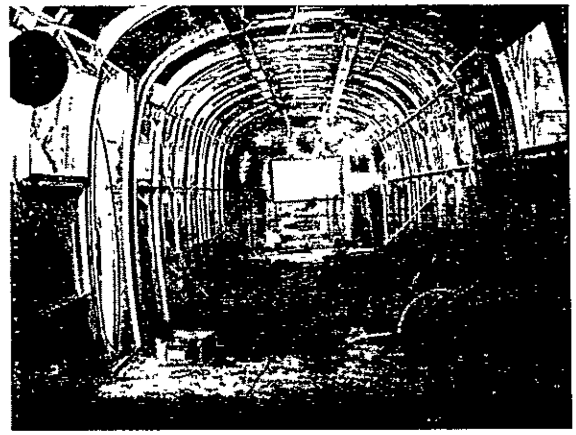
E. MODE PANEL

F. MODE PANEL

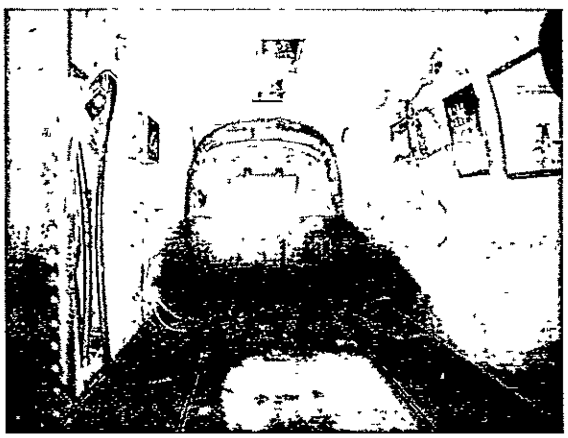
Figure 15. Power Conditioning and Distribution



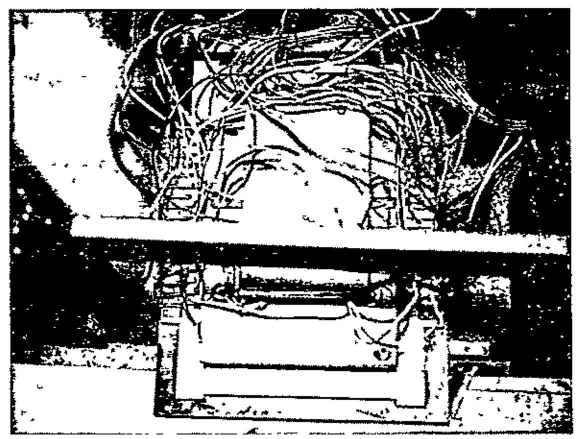
A. CABLES PRIOR TO INSTALLING INNER SKIN



B. CABLES PRIOR TO INSTALLING INNER SKIN

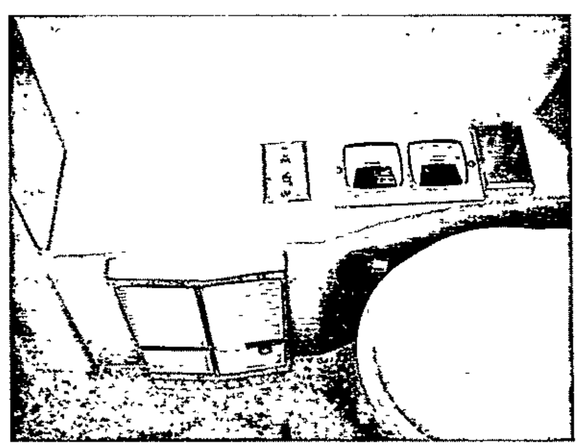


C. WIRES PENETRATING INNER SKIN



D. WIRING TO CIRCUIT BREAKER PANEL

E. CIRCUIT BREAKER PANEL



F. APU CONTROL PANEL

Figure 16. Electrical Wiring

primary power sources fail. Basically, the emergency power source consists of two large batteries which operate two small inverters. Under normal operating conditions, a battery charger provides a constant trickle charge from the 110-volt power. If power from the external source is lost, the battery energizes the inverters which supply power to only the exhaust fans and the alarm circuit.

The entire electrical system was redesigned to provide a single control station and to add the emergency power system. Similarly, the two external junction boxes for power distribution were replaced by a single, large, quick-opening junction box.

Another minor change in the electrical system concerned tank level probes. The standard Airstream probes and sensing circuit proved to be inadequate, and Melpar designed a special circuit and fabricated special probes for this system. Before the first Mobile Quarantine Facility was fabricated, Melpar was directed to add four fluorescent lights into the ceiling of the lounge area above the tilt table, to provide more light for medical examinations.

Figure 17 shows the mode panel as it was finally fabricated. This panel is installed on the right hand forward wall of the lounge area. The circuit breakers are mounted on the mode panel or in a quick-opening junction box.

In order to provide a versatile communication system for the Mobile Quarantine Facility, a communication patch panel is provided in the wall of the lounge area. The patch panel is also visible in figure 17.

The only other addition to the electrical system was an external alarm box. This unit was designed to allow the emergency alarm system to be located at a remote guard station when the Mobile Quarantine Facility is placed into storage, after the crew has entered the Lunar Receiving Laboratory. Since the negative pressure fans will be continuously operated during the quarantine period, it is essential to alert the MSC personnel if the unit starts to lose its negative pressure. This alarm box is simply a small unit which duplicates the audible and visible alarms of the Δp and emergency power circuits. This can be wired in parallel with the internal alarm system through the patch panel and a jumper cable to the mode panel.

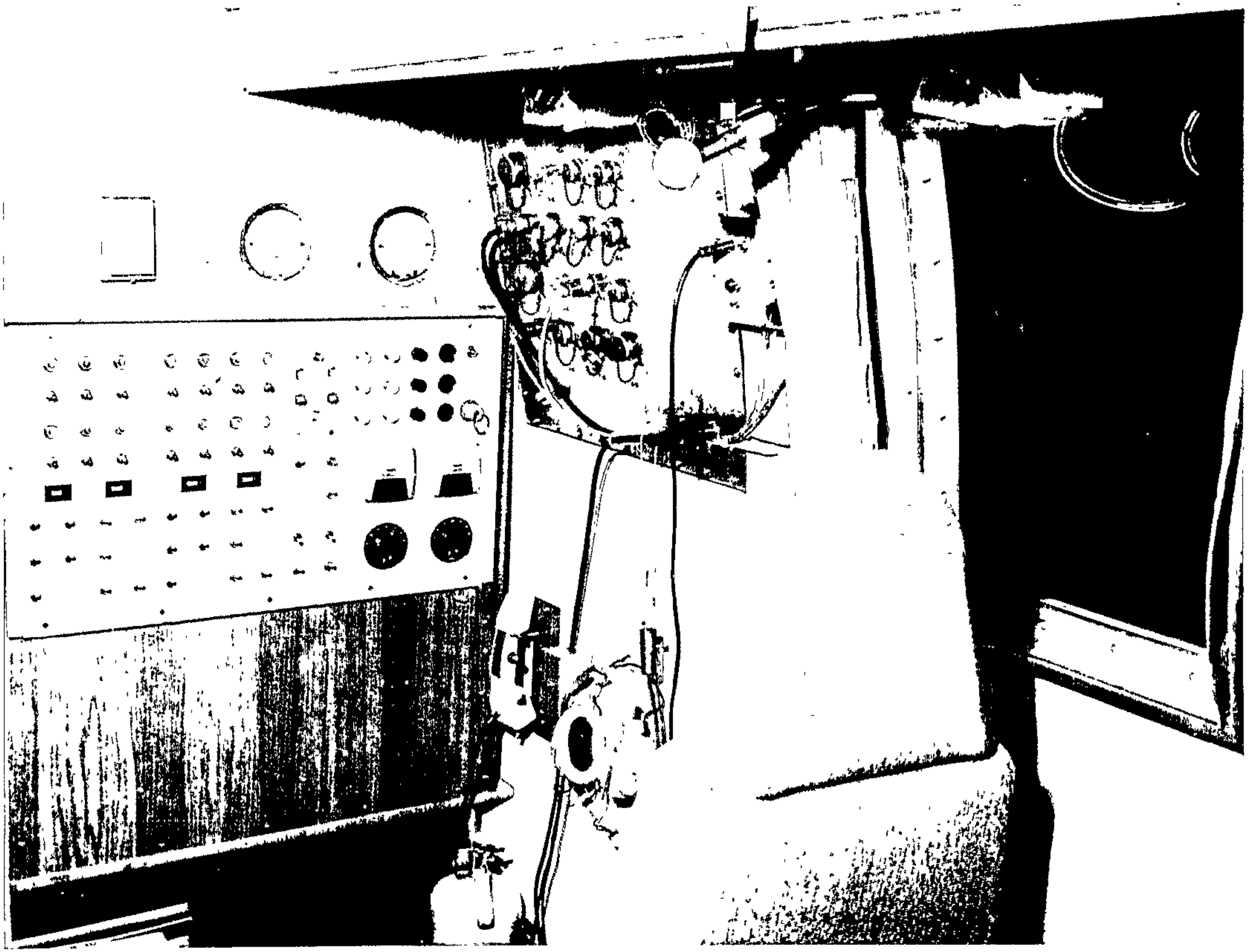


Figure 17. Centralized Mode Panel (Photo by Virginia Pilot Newspaper)

8. TRANSFER TUNNEL

The original concept for the transfer tunnels to allow personnel to enter and leave the Mobile Quarantine Facility in isolation is shown in figure 18. This design assumed that the facility would have only one personnel door, and did not consider the relative height of the Command Module hatch and the facility when the module was mounted on the dolly.

Melpar also considered the use of rather complex methods of fastening the tunnel to the Command Module and the facility, in addition to equally elaborate methods of attaching the tunnel to the supporting frame.

Once the final design effort was initiated, Melpar was able to simplify the overall design significantly, with the result that the final design proved to be easy to set up and take down. The addition of the second door in the Mobile Quarantine Facility resulted in the design of two specific tunnels, one to connect it to the Command Module, and the second to connect it to the LRL.

Figure 19 shows the shipboard tunnel mated with the Command Module. The tunnel is 10 feet 4 inches long. The end which mates to the MQF is 3 feet 9 inches wide, and 7 feet high. In order to mate properly with the capsule, it was necessary to increase the height of the capsule end to 12 feet, the width to six feet, and allow the support frame to pivot in such a manner that the end of the tunnel lies flat over the sloped side of the capsule. The seal to the spacecraft is accomplished by means of a sponge rubber gasket which is pressed against the sides of the capsule around the hatch opening. A tubular gasket is bonded to the tunnel. This tubular gasket is slit longitudinally such that the sealing frame (constructed of tubing which matches the contour of the capsule around the hatch) can be installed into this gasket. Four tiedown points allow this frame to be tightened against the spacecraft to effect the seal.

In figure 19 the open end of the tunnel is clearly seen. This matches the side door of the Mobile Quarantine Facility. The reduced section is simply taped to the metal surfaces around the inside edge of the door, to seal it to the inside of the Mobile Quarantine Facility.

The end of the tunnel has a flap that can be held open to the inside so that the hatch of the spacecraft can be opened into the transfer tunnel. Prior to opening the hatch, it is necessary to allow the exhaust system of the Mobile Quarantine Facility to establish a negative pressure within the tunnel. After transfer has been completed, the hatch will be closed, the outside surfaces of the module and tunnel decontaminated, and the end flap of the tunnel closed and sealed with tape. The gasket sealing frame may then be removed. The tunnel

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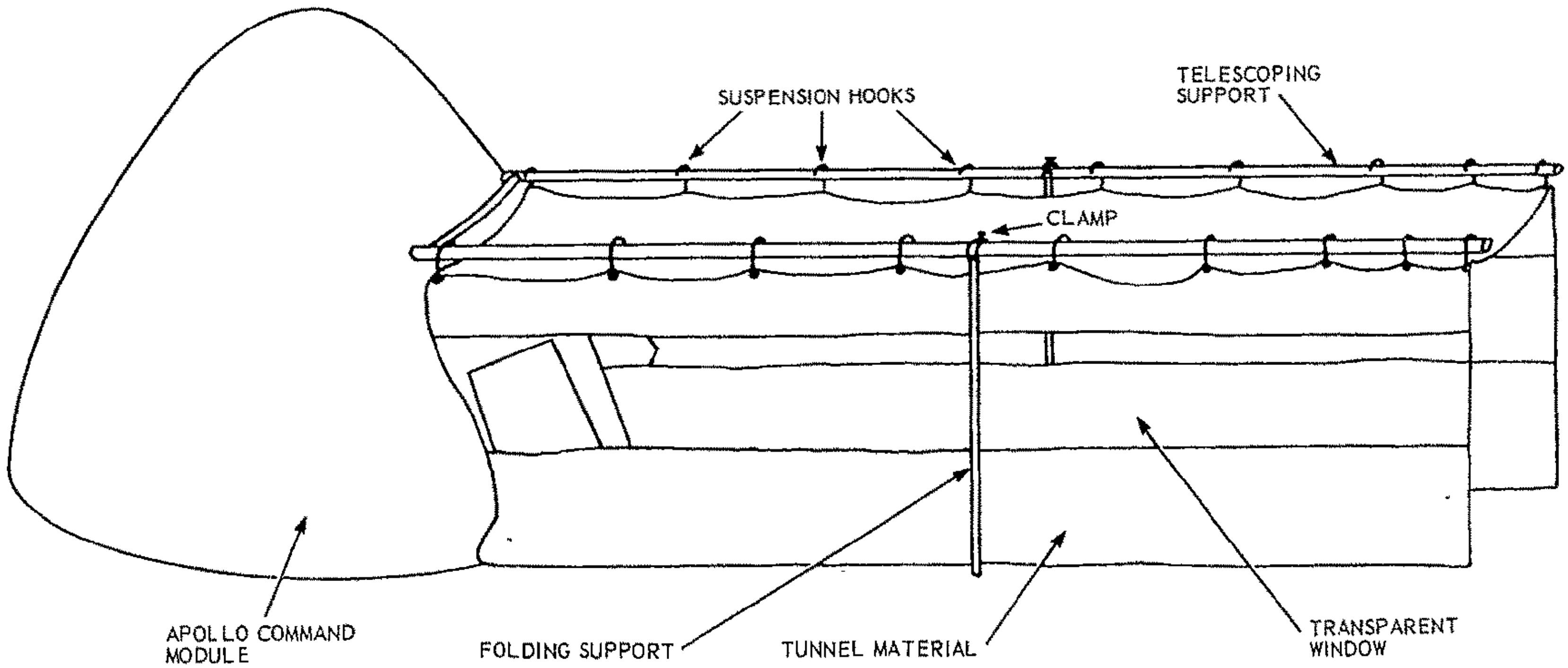

Figure 18. Original Concept of Transfer Tunnel

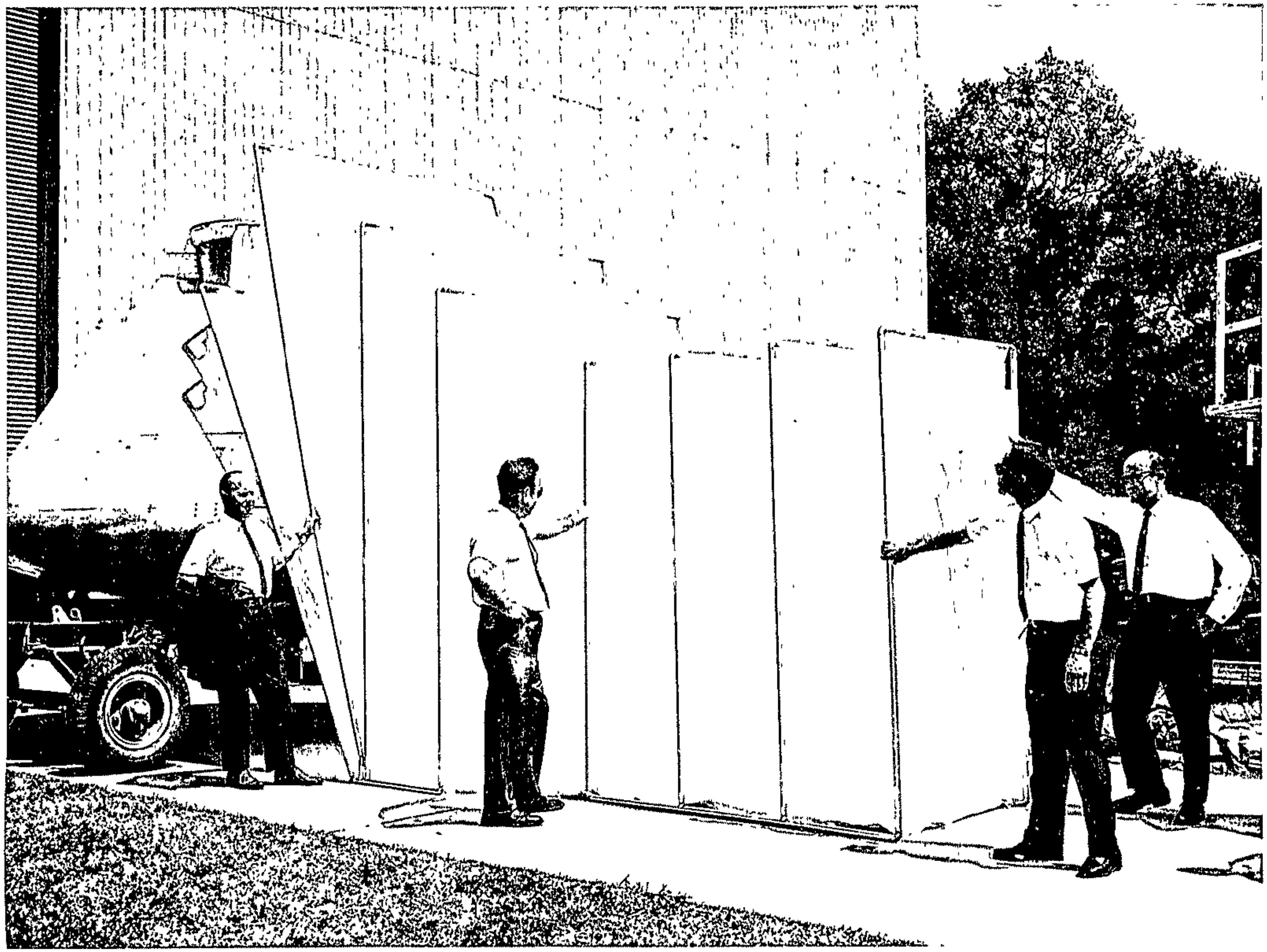

Figure 19. Shipboard Transfer Tunnel

will then be collapsed like an accordion against the Mobile Quarantine Facility. This is to be done slowly, to prevent the loss of negative pressure which would occur if the volume of air in the tunnel were suddenly forced into the facility. The support frames will then be removed, the tunnel pulled into the Mobile Quarantine Facility for disposal, and the door closed and locked until arrival at Houston, Texas.

The tunnel support was accomplished by sliding one-inch aluminum tubes through loops of PVC which had been sealed to the outside of the tunnel. A bottom frame is provided, which has sockets mounted on it to space the vertical support members. The top support tubes were simply attached to the side support tubes with ninety-degree elbows, which were slid into the end of the tubing. The fittings on the bottom frame at the spacecraft end are free to pivot. Tiedown rings are provided on the elbows to allow the entire tunnel to be fastened to the ship's deck.

The shipboard tunnel has a leg pouch on the left hand side facing the Mobile Quarantine Facility. This is simply a flat envelope with the outside end closed, which is sealed around a slit in the side of the tunnel. This was included so that arms or legs could be X-rayed without breaking isolation, or using the equipment inside of the facility.

The tunnel is fabricated from 6 mil PVC manufactured by Union Carbide Corporation. The floor is further strengthened by the use of Herculite manufactured by Herculite Protective Fabrics Corporation. All construction was accomplished by heat-sealing of the seams. It should be noted that the tunnels as delivered did not have clear windows installed in them. During the second design review. three minor changes were requested in the tunnel design. These were made and the modified tunnels were shipped when the Number 1 Mobile Quarantine Facility was retrofitted.

The changes in tunnel design included the addition of a friction fitting to the elbows used to erect the support frame, for these fittings were somewhat loose. A minor change was made in the Mobile Quarantine Facility end of the tunnel and its support frame to allow the door to be moved away from the side of the unit when the tunnel was in place (the original design forced the door so far open that it interferred with the use of the transfer lock). Clear windows were added in the side of the tunnels.

Two other changes were made by Melpar, which represented oversight in design. The facility end of the tunnel was designed to mate to the door opening and the step formed below it by the outrigger of the facility frame. Later in the fabrication of the facility, Melpar elected to add a step on top of the outrigger below the door. As a consequence, it was necessary to modify the ends of the tunnels to match this step. The other change was in the method of attaching the Velcro fastening material at the spacecraft end of the tunnel. Velcro was used as a convenient method of holding the tunnel flap out of the way when the spacecraft hatch was open. When the tunnels were fabricated, the Velcro used was purchased with an adhesive backing to facilitate construction. After delivery, it became apparent that the adhesive was not compatible with the PVC and it was necessary to remove the original Velcro, and bond new Velcro in place of it, with a compatible adhesive.

A total of 20 of the shipboard tunnels which mate the Mobile Quarantine Facility to the spacecraft were delivered to NASA/MSC.

The tunnel used at the LRL was fabricated with the same construction and support design. In this case the tunnel does not have a raised end. The LRL tunnel is 9 feet long, 4 feet wide, and 7 feet in height. The opening at the Mobile Quarantine Facility end was designed to be sealed to the outside edge of the end door with tape, so that the door can be opened into the tunnel. The opening at the LRL end matches the entrance to the LRL quarantine area. Again, the tunnel was taped to the inside edge of the door jam, and the door opened to the outside edge of the tunnel. This allows the door of the Mobile Quarantine Facility to be closed and decontaminated after the transfer has been completed, and the end sealed with a flap similar to that in the shipboard tunnel. Once more the tunnel will be pulled into the LRL, and the door closed behind it.

A total of 15 LRL tunnels was delivered to NASA/MSC.

9. BIOLOGICAL CONTAINERS

Procedures for protection of personnel require that any items transferred out of the Mobile Quarantine Facility, during the mission, be decontaminated. At the same time, it is necessary to preserve the biological condition of these same items for critical laboratory analysis. This means that the transferred items must be placed into biological containers before transfer from the Mobile Quarantine Facility.

Specifically, biological isolation containers are required to allow transportation of lunar samples, flight tapes, flight film, crew and other specified equipment, retrieved from aboard the recovery ship, directly to the Lunar Receiving Laboratory at NASA Manned Spacecraft Center. Additional containers are required to isolate miscellaneous items; tools and equipment, (for example: astronaut life raft, miscellaneous crew clothing, recovery tools which may become contaminated, etc.) after retrieval has been effected.

The performance requirements for these containers are based upon the types of equipment to be protected and the size of the biological container had to be such that it would fit the Apollo Lunar Sample Return Containers. These containers have a maximum outside dimension of 19 inches by 12 inches by 8 inches. The materials used in the biological container had to be non-porous and impervious to scuffing, tearing, and general rough handling. Since a large number of these containers are to be stored in the Mobile Quarantine Facility, it is necessary that they be rolled, or folded, to minimize the space required. The containers have provision for filtration (98-percent, or greater, of all particles 0.45 micron or larger) of air when the bags "breathe" under temperature change or handling. This filter must be covered to preclude passage of the decontaminant while submerged in the transfer lock.

The original concept for the biological containers included one fabricated specifically for the lunar sample container and a smaller pouch. In both cases, a neoprene coated nylon fabric, sealed with a self-sealing zipper was projected as the material to be used. A Millipore filter was to be accomplished by adhesive bonding or heat sealing to insure impermeability.

In the final design, a single size and shape was selected in order to provide a standardized biological isolation container. The design simplified construction, so that the container could be made with the minimum number of seals.

The final biological container is a flat bag, 22 by 36 inches with a self-sealing flexible plastic zipper sealed into one of the 22 inch ends. The zipper is closed by simply mating the convolutions of the two edges together, and pressing them into one another. The material used is Herculite No. 80, manufactured by

Herculite Protection Fabrics Corporation, Newark, New Jersey. This material is an opaque white color, is very durable, flexible and can be reliably heat-sealed.

The zipper is the Toptite unit manufactured by Flexigrip, Inc., New York City, New York. Each unit was pressurized with air, and submerged in water to test for leaks prior to shipment, and all containers were found to be air tight. During the second design review, the MSC technical staff expressed concern about the zippers, and Melpar recommended that additional sealing protection could be obtained by simply running a bead of adhesive along the length of the zipper closure surfaces before the bag was closed. The adhesive was furnished to the agency, together with a polyethylene syringe for use in applying it.

Since most of the commercially available Millipore filters are constructed as molded rigid plastic assemblies of a rather bulky nature, Melpar designed a simple and effective filter unit which was made an integral part of the container wall.

The filter assembly is made by heat sealing a 1.75-inch diameter disk of filter material (TV20A40, Teflon impregnated glass fiber with glass cloth reinforcement, 0.0005 inches thick, manufactured by Pallflex Division, Pall Corporation, Putnam, Connecticut, which has characteristics of filtration exceeding the specification) between two washers of vinyl, also 1.75 inches in diameter, with a one-inch hole (Krene Vinyl film, KDA2076 clear 21 standard, 0.012 inches thick, manufactured by Union Carbide Corporation).

Herculite No. 80 used in constructing the biological bags is a nylon cloth reinforced PVC material. The PVC is removed from a one-inch diameter circle, near the center of one side of the bag, to provide a porous cloth grill. The one-inch diameter opening of the filter assembly is aligned with this grill, on the inside of the bag. It is then sealed in place with a two-inch diameter washer of Herculite No. 80. Again, the PVC has been removed from a one-inch circle in the center of the washer to provide the internal porous cloth grill for support and protection of the filter material.

Protection of the contents of the bag during decontamination is provided by adhesive bonding a 1.75-inch diameter disk to the outside of the bag, directly over the outside grill cloth of the filter assembly. A two-inch tab extends from one edge of the disk. The adhesive is applied in a thin ring around the disk circle of the cover only, such that after the biological isolation container has been removed from the Mobile Quarantine Facility, the cover may be removed by using tab to pull it off.

A total of ninety biological isolation containers was delivered during this contract effort.

10. CONCLUSIONS AND RECOMMENDATIONS

This contract effort was complicated by two factors: the Apollo fire, and the wide variety of operational interfaces that the equipment is subjected to in use. The full impact of the Apollo fire was not experienced until construction of the last three units was nearly complete. It is unfortunate that the stringent requirements for flame retardant protection could not have been anticipated earlier, for the rapidly approaching launch date for the Lunar Landing Mission reduced the time available to select an appropriate coating, or to consider alternate methods of achieving the desired objectives.

A review of the original design concept at the time this effort was negotiated demonstrates a surprisingly accurate appraisal of the mission requirements. Virtually all of the changes, which were ultimately incorporated into the design of the Mobile Quarantine Facility, were given active consideration prior to establishment of the equipment specifications. Those elements of design which were not incorporated, at that time, were representative of compromises made to minimize construction time and cost, since the work statement was prepared at a point in time when it appeared that the Lunar Landing would be far ahead of the nation's goal. If it had been necessary to build the Mobile Quarantine Facilities on the original schedule, there is no doubt that the units would have performed the required quarantine function adequately, but the equipment would certainly have been less convenient to use.

The overall delay of the Apollo program provided time to build the first unit, and to subject it to extensive operational tests before fabricating the remaining three units. This proved to be an excellent decision, and permitted the improvement of both the equipment and the operational procedures. The availability of actual test hardware also resulted in increased participation of other mission activities and responsible organization in the recommendations of design changes. The benefit of broad participation was, to some extent, off-set by the time and effort expended by the MSC technical staff in evaluating the large number of recommendations, and deciding which were to be incorporated into the design. As a consequence, Melpar directed its attention to the design and costing of a number of changes which were later removed from consideration.

Both the MSC technical personnel assigned to monitor this effort, and the Melpar technical staff experienced considerable difficulty in obtaining information, which was required for detailed design, from interface activities. Similarly, recommendations were frequently made by interface groups, apparently with a total lack of consideration for impact upon the effort, or compatibility with the overall recovery mission.

The contract effort was further complicated by the general change in classification of the Mobile Quarantine Facilities. At the time the effort was started, the facilities were considered to be ground support equipment. As the effort continued, greater emphasis was placed upon the air-transportable characteristics, until the facilities were finally considered to be flight hardware. Thus, the units which were intended to be a minor modification of the Airstream travel trailer, became a complex specialized item of equipment.

The final specifications for the Mobile Quarantine Facility are a composite of commercial practice, and rigid adherence to NASA and other Federal specifications. As the number of nonstandard items of equipment within the facility increased, the requirement for test and evaluation also increased. Similarly, the volume of engineering drawings necessary for fabrication of nonstandard items increased to a level which was not anticipated when the effort was started.

The fabrication of the. Mobile Quarantine Facilities was accomplished as a genuine team effort. Melpar, Airstream, and the NASA/MSC technical representatives found it necessary to reflect changes in design as a direct reaction to changes in the operational procedure as it evolved. Had it not been for the close cooperation of the participants, the performance characteristics of the units would have been compromised, or schedules delayed even more.

Recognizing the complications of the recovery mission procedure caused by imposing the requirement for quarantine upon an already complex activity, it is doubtful that the resulting Mobile Quarantine Facility design would have met the needs of the mission if the fabrication effort had not been flexible to changes.

If Melpar and MSC had not realized that the Apollo mission was to be delayed, it would have been in the best interest of both parties to have used a significantly different approach to the fabrication of the Mobile Quarantine Facilities. The design effort should have been a separate cost type effort, allowing Melpar to engineer all elements of the design, including those features which the agency would only include if the costs were minimal. This would have eliminated most of the problems experienced during this contract effort, and would have allowed the final fabrication to be accomplished on a predictable schedule.

Melpar would recommend that future contracts of this type awarded by MSC utilize either a CPFF form of contract entirely, or a CPFF design phase followed by FP fabrication phase.