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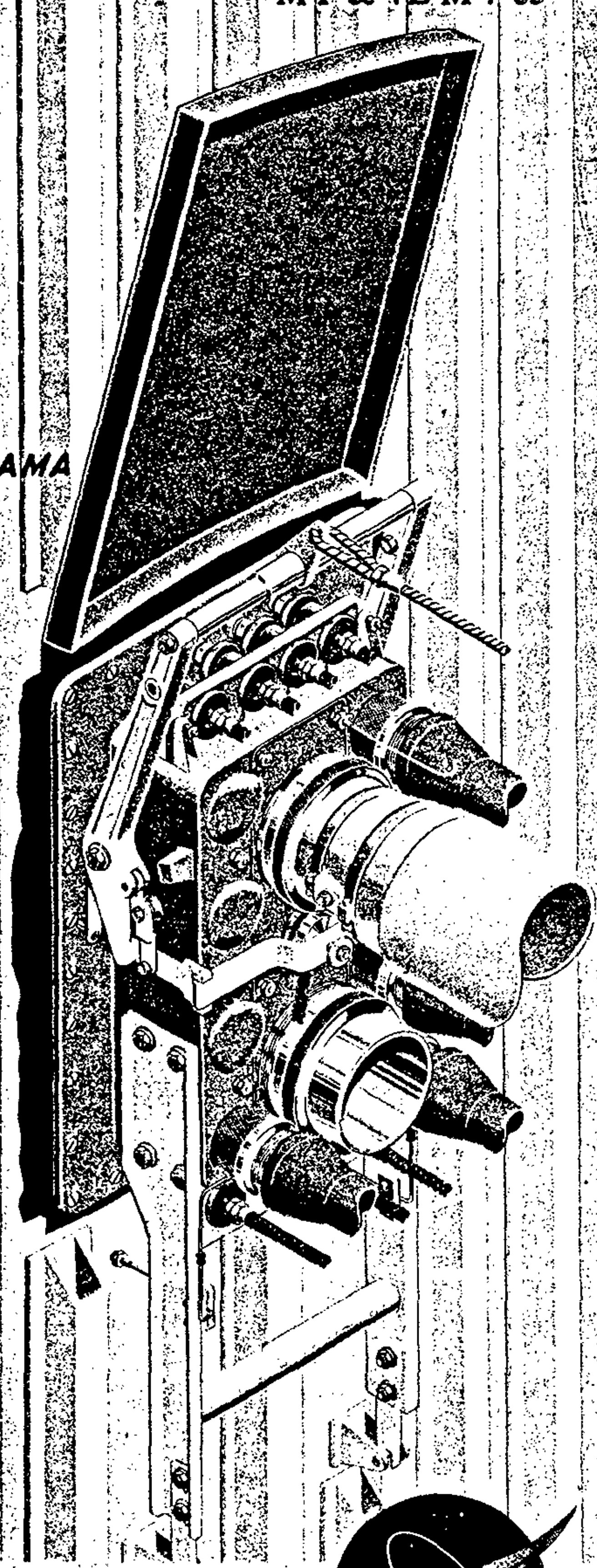

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

# UMBILICAL SYSTEMS

## V-2 TO SATURN V

BY
UMBILICAL AND DISCONNECTS SECTION
GROUND SUPPORT EQUIPMENT BRANCH
VEHICLE SYSTEMS DIVISION
PROPULSION AND VEHICLE ENGINEERING LABORATORY

National Aeronautics and Space Administration



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Fred Jankowski

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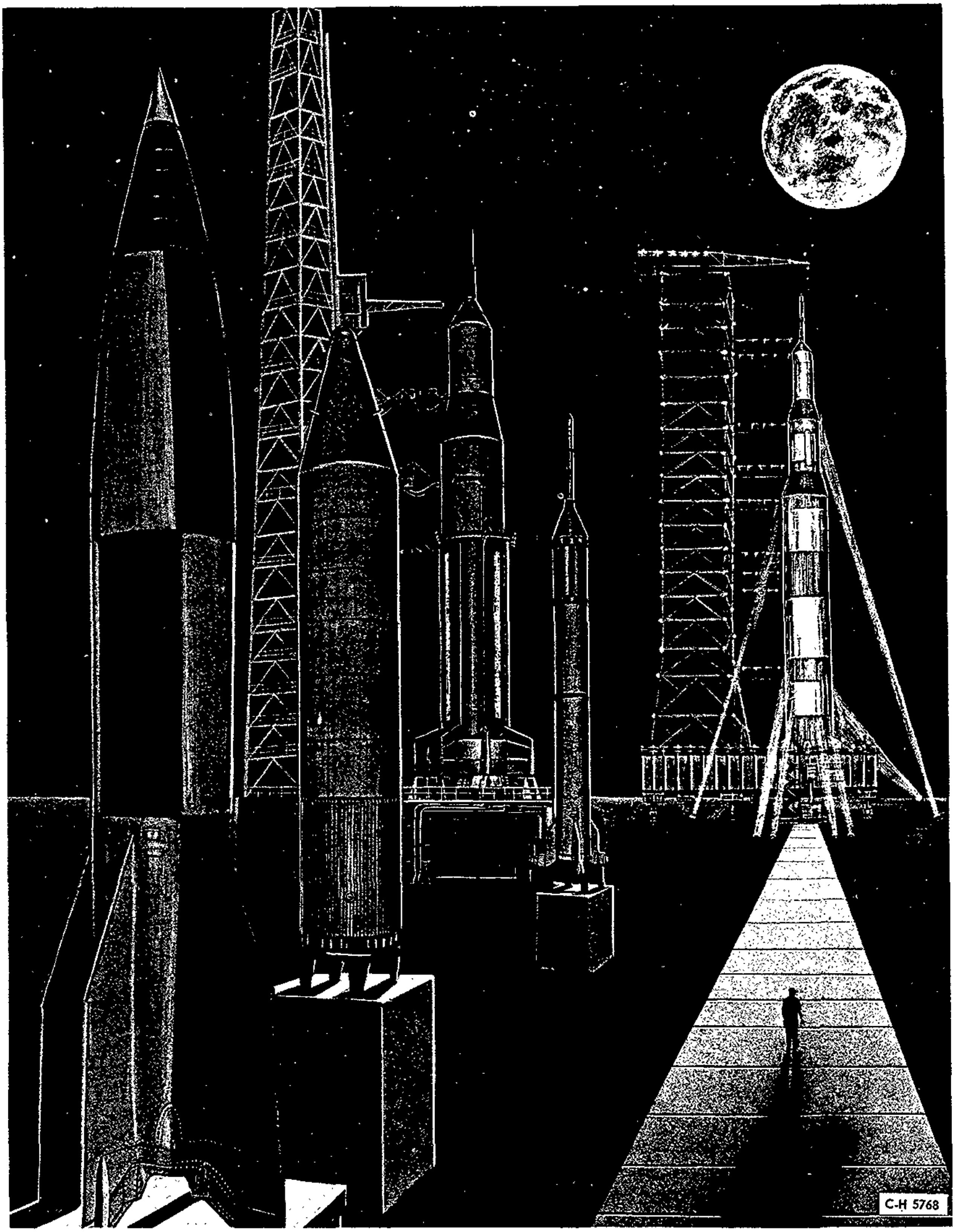
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# FOREWORD

The purpose of this manual is to trace the evolution in design of umbilical connections for the V-2, Redstone, Jupiter, Saturn I (Block I and Block II), and Saturn V liquid propellant missiles and space vehicles. This manual compiles in one document the experience of approximately 20 years of research and development in the design and operation of umbilical connectors. The manual will provide National Aeronautics and Space Administration (NASA) and contractor personnel with guidelines for the future design of umbilical connectors.

Each section of the manual describes the umbilical systems, that is, Fuel, LOX, Electrical, Pneumatic, Hydraulic, Cryogenic, of a particular vehicle and examines the problems encountered in the development of each umbilical system and the solutions to these problems. Advantages and disadvantages of design, material, and techniques are discussed, indicating the equipment that has or has not functioned satisfactorily on the vehicle.

The table contained in the appendix illustrates the evolution in connector housings and release mechanisms from V-2 through Saturn V. This table does not list all of the housings and release mechanisms developed in the past 20 years, but is representative of the major advance and improvements of automated quick-release umbilical connectors.

Information has been obtained from Army technical manuals, Air Force technical orders, engineering drawings, photographs, test and reliability reports, design criteria manuals, and conversations with engineers and technicians engaged in the design and testing of umbilical systems and connectors. References are listed in the bibliography.

Particular recognition is extended to Mr. C. P. Herold of the Launch Operation Directorate for his efforts in advancing the state-of-the-art of umbilical connections and quick-release mechanisms. Mr. Herold is a pioneer in the development of quick-release mechanisms for rocket vehicles, and his inventiveness has provided the ball lock and release mechanisms, used from Redstone through Saturn, for which he holds the patent. In addition, his work in the development of the sphere and ball-type coupling for fueling and cryogenic connections has advanced the state-of-the-art so that it is not only possible to have automatic connection and disconnection of these operations, but also automatic reconnection. The authors wish to extend their sincere appreciation to Mr. Herold for his help in compiling and sequencing the information contained in this manual.

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# LIST OF ILLUSTRATIONS

## LIST OF ILLUSTRATIONS (Cont'd)

# INTRODUCTION

What has been learned in the twenty years of development of umbilical systems for liquid propellant rocket vehicles and their quick-release mechanisms? From V-2 to Saturn V, the umbilical systems that feed the vehicle during its preparation for flight have evolved with the complexity of the vehicle, its mission, and the more automated operation of the launch systems.

Fueling of the V-2 was a manually controlled operation wherein the fueling lines for liquid oxygen (LOX), alcohol, hydrogen peroxide ($H_2O_2$) and sodium permanganate were manually connected to the vehicle; and, when the required amount of each fuel was loaded, the fueling lines were manually disconnected and removed from the launch area. This left the electrical and pneumatic connections and the LOX topping line as umbilical connections to the vehicle. The electrical connections to the instrument compartment were electromagnetic so that when the ground supply lines were de-energized the cables dropped off the vehicle. The LOX topping line and the ground supply pneumatic lines were attached to the launcher platform and connected to the vehicle with vertical quick-disconnect couplings. Umbilical separation occurred as the vehicle lifted off the launch platform.

During the Hermes project it was found that it was desirable to cool or heat the instrumentation compartment of the vehicle in order to obtain added life and reliability of the electrical and electronic components. Consequently, in the Redstone project, an external heater-cooler tank assembly was used to maintain a controlled temperature in the instrument compartment while the vehicle was prepared for launch. The releasing of this unit from the vehicle at launch was the first step in the United States' development of remote controlled, quick-release mechanisms for rocket vehicles.

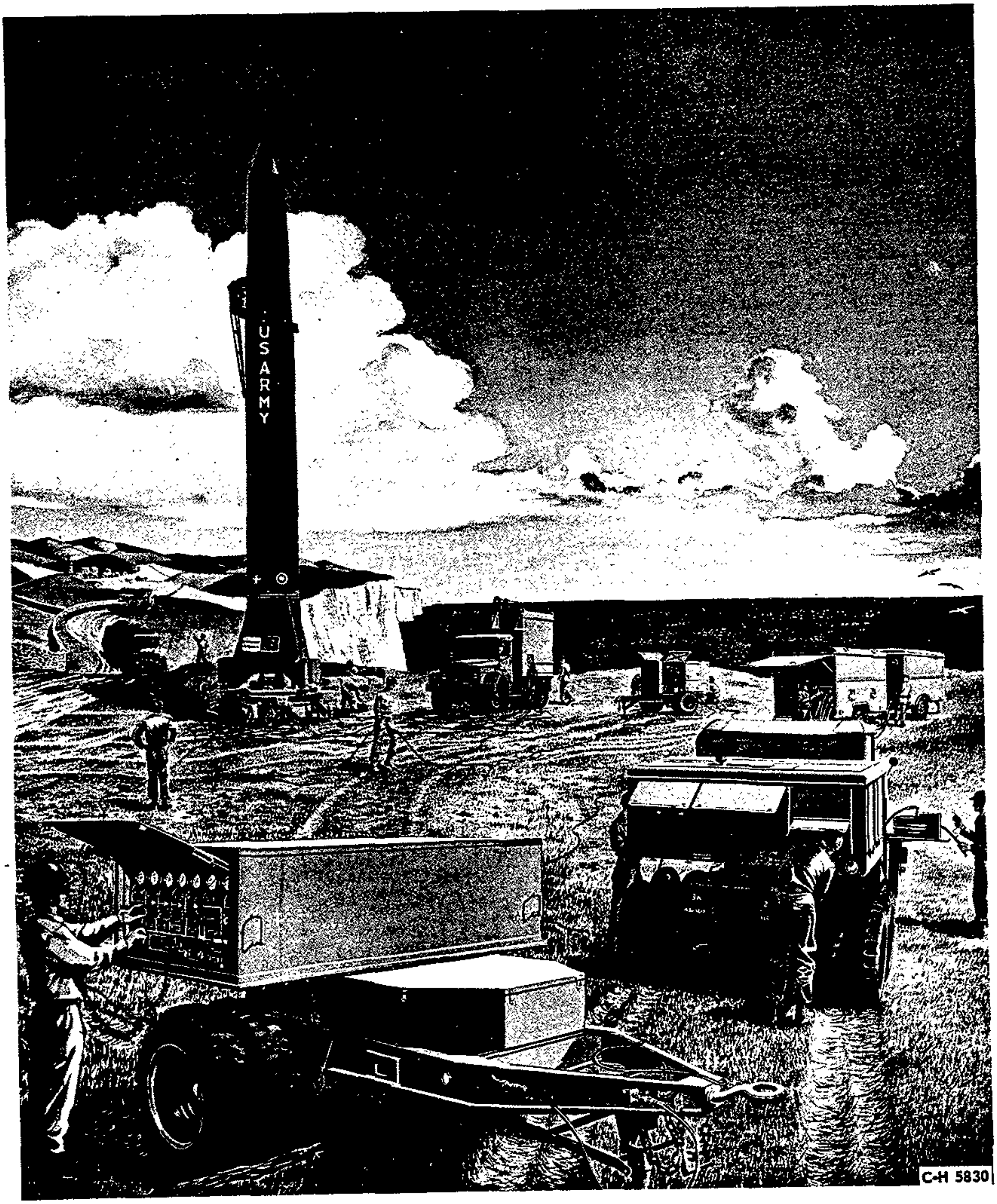
In an effort to develop a fully automated system (from fueling to launch) for the Jupiter vehicles, much designing and testing was undertaken, and many problems were overcome in the development of quick-release mechanisms for the electrical, pneumatic, heater-cooler, fuel, and LOX connections.

The experience gained during the development of umbilical connectors for the Jupiter was applied to the larger and more complex Saturn I vehicles. Most of the basic techniques employed on the Jupiter were utilized on the Saturn I, Block I vehicles. An exception to the basic design used on the Jupiter was a redesign of the LOX and fuel couplings for Saturn I. A ball-and-sphere type of coupling was used on Saturn I, instead of the cylindrical or sleeve-type of coupling used on Jupiter. The ball-and-sphere type of coupling overcame critical alinement, sealing, and freezing problems - problems which were encountered with the Jupiter couplings. Where alinement and cryogenic sealing problems are involved, the ball-and-sphere type of coupling is considered the optimum design.

The ball-lock release has proven to be a very reliable and adaptable design in the employment of quick-release mechanisms and was first used on a Redstone research and development (R&D) vehicle. This basic principle and design was used on the tactical Redstone and Jupiter missiles and is used on Saturn I and V quick-release umbilical connections.

An increase in the number of vehicle electrical and pneumatic umbilical connections from the V-2 to the Saturn has resulted from attempts to reduce vehicle weight by removing internal checkout systems and combining them with the ground support equipment. At the same time, another primary objective in the design of umbilical connectors and quick-release mechanisms has been to combine as many umbilical connections as possible in one housing, requiring only one quick-release mechanism. For example, with the exception of the $LH_2$ vent, the S-IV stage of Saturn I has all of the umbilical connections contained in one housing, including: fueling, purging, air conditioning, pneumatic and electrical connections. By reducing the number of quick-release devices on a vehicle, the number of failures or malfunctions is minimized.

# SECTION II
# REDSTONE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# SECTION II

# REDSTONE

## INTRODUCTION

The Redstone missile was basically the same type of vehicle as the V-2, with an increased payload and range. The major Redstone umbilical connection advances were in the electrical connections, the development and use of ball-lock release mechanisms, and the addition of a heater-cooler drop tank assembly.

One of the significant differences of the ground power supply electrical wiring between the Redstone and the V-2 was the electrical cabling to the instrument compartment. The wiring on the Redstone was routed through the vehicle, from connections on the launch platform. The instrument compartment of the V-2 received its electrical ground power supply from cabling external to the missile. The V-2 method had the advantage of reducing vehicle weight and providing for easier maintenance and troubleshooting of this portion of the electrical ground power supply. One series of Redstone research and development (R&D) vehicles used a long cable mast to provide ground power supply electrical wiring to the instrument compartment. This umbilical connector and release device will be described later in this section.

Most of the umbilical connections were made when the vehicle was raised to the vertical position on the launcher (figure 2-1). Exceptions to this were the heater-cooler drop tank assembly and the multiple pneumatic coupling connector, which were attached while the vehicle was in the horizontal position.

The umbilical connections between the Redstone missile and the ground support equipment consisted of fueling, venting, replenishing, pneumatic, and electrical connections, and the heater-cooler tank assembly connection.

The Redstone tactical missile had only one automatic, quick-release mechanism operating an umbilical connection. This was the heater-cooler tank quick-release mechanism. Other umbilical connections were connected and disconnected manually, or were of the cone or slip type of coupling located on the launcher at the base of the missile, and were disconnected by missile liftoff. This section will discuss in detail all umbilical connections of the Redstone tactical missile.

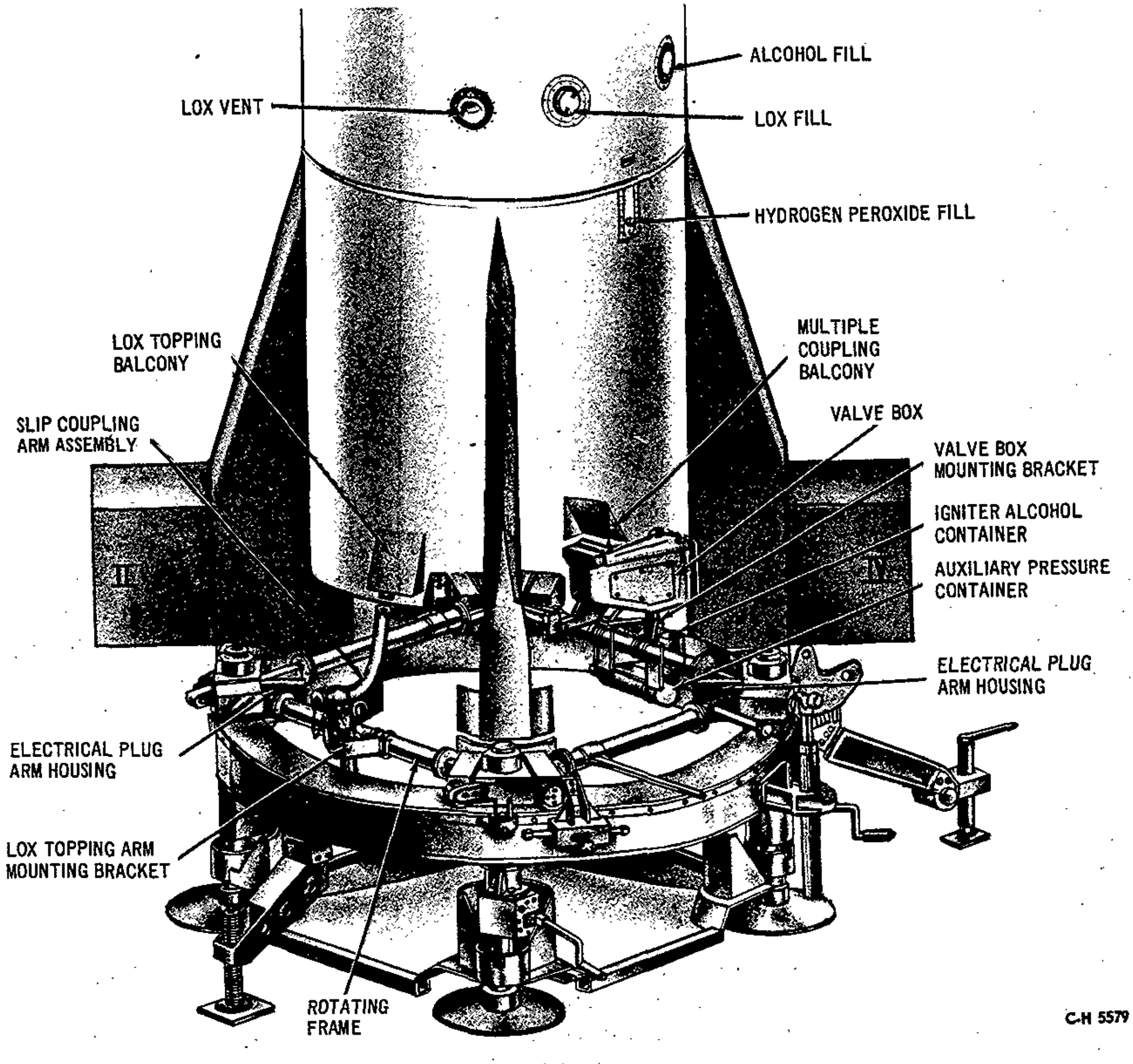



Figure 2-1. Umbilical Connections

## FUELING

Alcohol. The alcohol fill and drain valve was manually attached to a normally closed, spring-loaded valve located on the missile skin at fin IV, near the aft bulkhead of the center section (figure 2-2). The valve was provided with clamp-type couplings: one end provided a coupling to the missile and the other end provided a coupling for the intermediate hose extending between the missile and the fueling ladder (figure 2-3).

A hose from the pump on the alcohol trailer was coupled to the base of the fueling ladder. The fueling ladder's tubular structure provided for the transfer through it of alcohol on one side and LOX on the other side (figure 2-2). An intermediate hose provided the connection between the fueling ladder and the missile (figure 2-3).

Protective caps were removed from all valves, hoses, the fueling ladder, and pump couplings in the alcohol fueling system. The lines were interconnected manually by either clamp-type or threaded couplings and the intermediate hose was manually connected to the missile.

Before alcohol filling, 20 gallons of an inert fluid (lithium chloride) was pumped from a tank through a hose into the vehicle alcohol system, through a quick-disconnect coupling located beneath the alcohol fill and drain valve (figure 2-1). The lithium chloride entered the system below the main

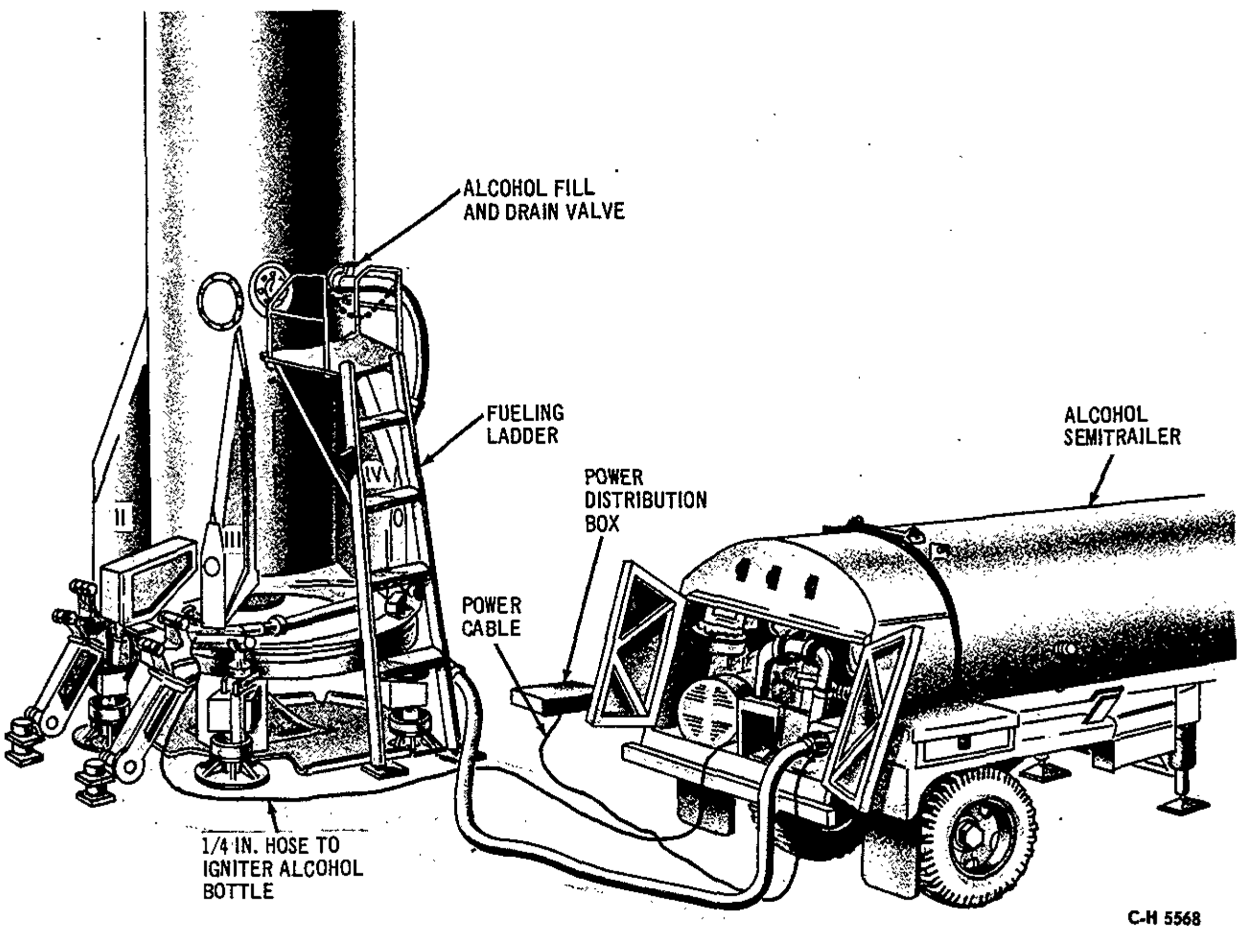



Figure 2-2. Alcohol Filling

alcohol valve and flowed into the alcohol manifold surrounding the thrust chamber. The inert fluid provided for smoother ignition. After the lithium chloride had been loaded and the main alcohol valve had been closed, the connection from the lithium chloride tank and pump was disconnected and the alcohol filling operation began. The alcohol was metered as it was pumped into the missile. In addition to filling the missile with alcohol, an igniter alcohol container (located on the launcher, figure 2-1) was filled through a 1/4-inch hose by gravity flow from the alcohol trailer emergency valve.

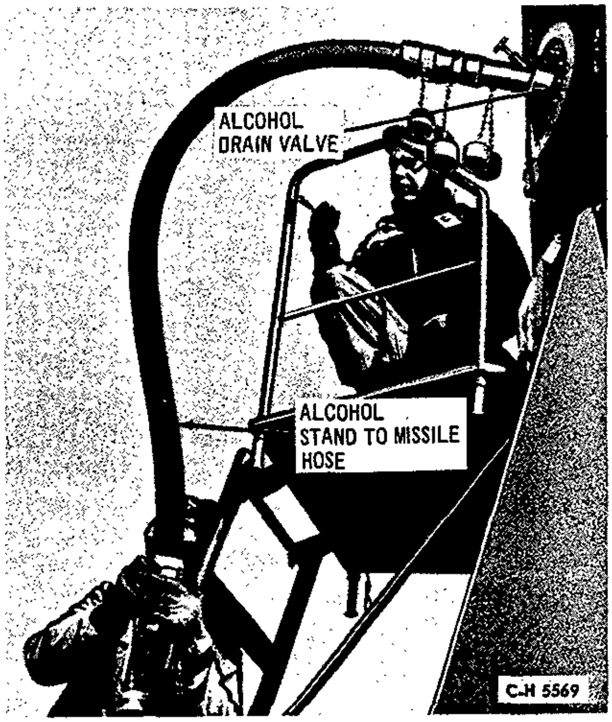



Figure 2-3. Alcohol Fill and Drain Valve

When alcohol filling was completed, the mechanical couplings were manually disconnected, protective caps were replaced, and the alcohol trailer was moved from the area. No problems were encountered with this type of umbilical connector.

Liquid Oxygen (LOX). The LOX fill and drain valve was manually attached to a normally closed, spring loaded valve, located on the missile skin at fin III near the aft bulkhead of the center section (figure 2-4). This valve was provided with threaded couplings: one end provided a coupling to the missile, and the other end provided a coupling to the intermediate hose extending from the fueling ladder to the missile.

Two LOX trailers were used for LOX filling. Hoses from the pumps on the LOX trailers extended to a Y-fitting, and the base of the Y-fitting was interconnected to the fueling ladder by a hose that was coupled near the base of the fueling ladder. An intermediate hose provided the connection between the fueling ladder and the missile (figure 2-4).

Protective caps were removed from all valves, hoses, pump couplings, and the fueling ladder. The lines were interconnected manually with threaded couplings. When the lines from the LOX trailer to the missile were manually coupled, LOX filling could begin. LOX was metered while being pumped into the vehicle.

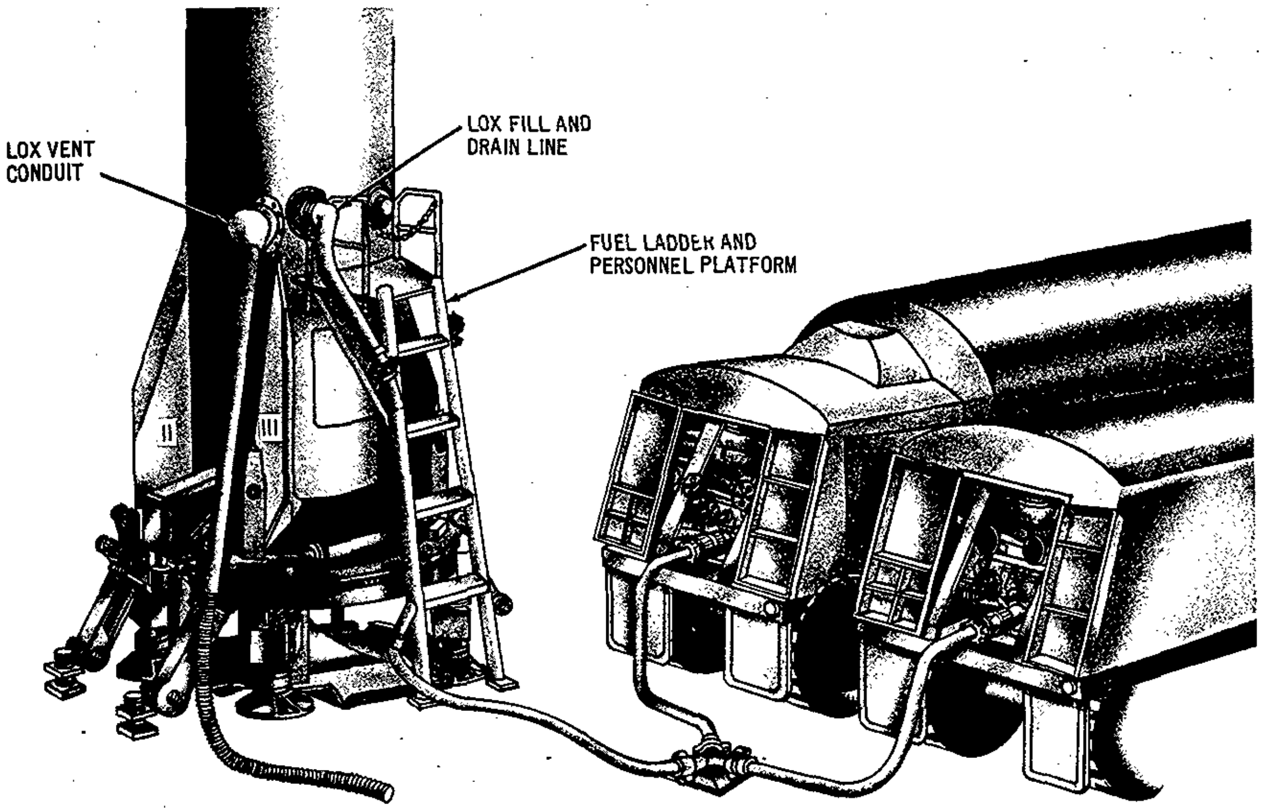



**Figure 2-4. Lox Fill and Venting**

When LOX filling was completed, the mechanical couplings were manually disconnected and the protective caps replaced. One of the LOX trailers was removed from the area and the other moved to a distance of approximately 150 feet from the missile. A LOX replenishing line was then connected between the missile and the LOX trailer. No problems were encountered with this type of umbilical connector.

Hydrogen Peroxide ($H_2O_2$). The mechanically actuated hydrogen peroxide fill and drain valve was located between fins III and IV on the missile skin, just aft of the aft ring of the center section. An extension hose extended from the peroxide truck to the fueling ladder, where it was secured and supported, and from the ladder to the fill and drain valve (figure 2-5).

The connection from the hose to the hydrogen peroxide fill and drain valve was manually coupled and uncoupled. An overflow and vent valve was located at the bottom of the hydrogen peroxide tank. During the filling operation, a hose was connected to the overflow and vent valve and directed into an overflow tank with water in it. This was done to prevent spontaneous combustion due to probable contact with oxidizable organic materials during overflow of the tank (figure 2-5).

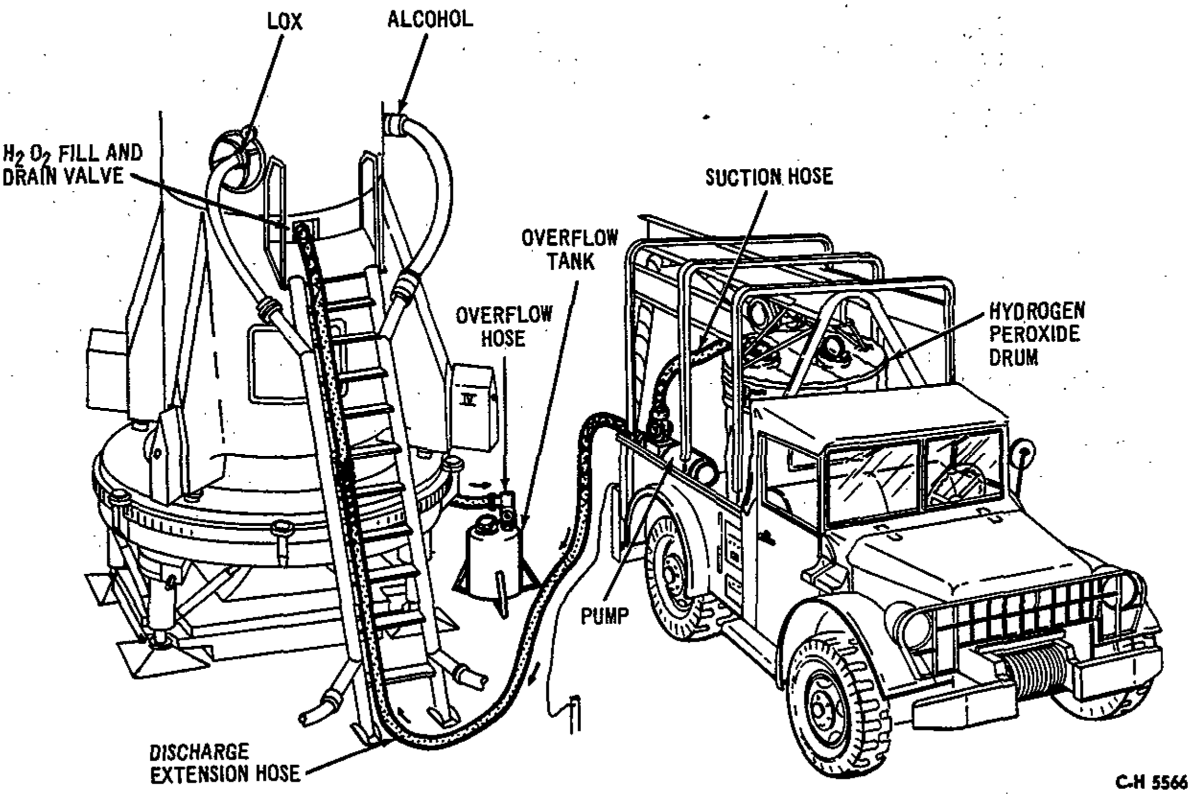



Figure 2-5. Hydrogen Peroxide Filling

When the hydrogen peroxide tank had been filled, the mechanical coupling to the fill and drain valve was manually disconnected and the hydrogen peroxide truck was moved from the area. The overflow hose and tank were also disconnected and removed upon completion of filling. No problems were encountered with this type of umbilical connector.

## LOX VENTING

The LOX venting and overflow valve was located above fin III, on the missile skin, near the aft bulkhead of the center section (figure 2-6). A LOX vent conduit was mounted on a bracket on the launcher platform and extended up the side of the vehicle to the LOX venting and overflow valve.

A flexible line was connected to the lower end of the LOX vent conduit near the mounting bracket. This flexible portion of the vent line extended along the ground away from the base of the vehicle and vented on the ground.

The connection from the vent conduit to the venting and overflow valve on the vehicle was mechanically secured (figure 2-6). The vent conduit was alined with the vent port on the vehicle and attached with the aid of hooks and turnbuckles.

LOX tank venting was pneumatically controlled by a solenoid valve actuated from the propulsion control and remote firing panel.

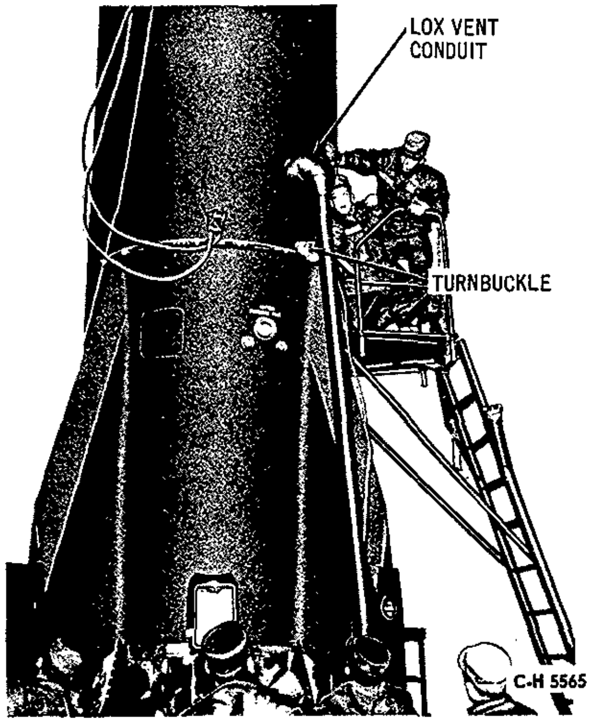



Figure 2-6. Lox Vent Conduit Installation

This solenoid valve is normally open, and 750 psi kept the vent valve open. When the solenoid valve was closed, pressure was cut off from the vent valve and it closed. During the period that the vent valve was open, LOX vented through it into the conduit, and onto the ground. Prior to launch, the conduit was manually disconnected from the vehicle and removed from the area. No problems were encountered in connecting or disconnecting the LOX vent conduit.

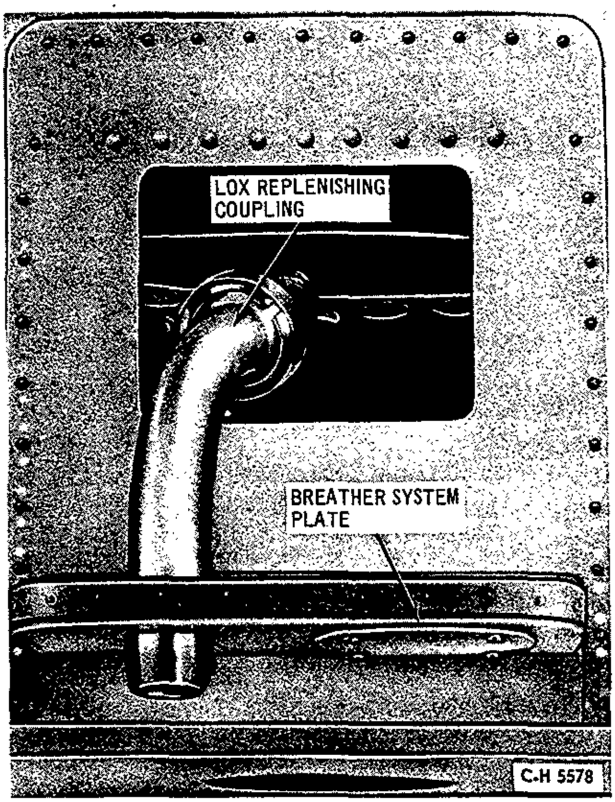



Figure 2-7. Lox Topping Balcony Assembly

LOX TOPPING (REPLENISHING)

The LOX topping connection was a balcony assembly, on the outer surface of the missile skin, between fins I and IV at the aft end of the tail unit (figure 2-7).

A LOX topping arm, located on the rotating frame of the launcher, was connected to the LOX balcony coupling by alining the slip-type cone coupling of the LOX topping arm and adjusting the height and tension by a manual screw adjustment. LOX topping was controlled by the operator at the remote firing box, where a replenishing switch controlled replenishing. One of the LOX trailers was located approximately 150 feet from the missile and was interconnected by a hose to the missile LOX topping arm.

Tightness of this connection was achieved by manually actuating the screw adjustment (figure 2-8). The slip-type cone shaped coupling did not provide a consistently leakproof seal between the mating surfaces. Evidently, this leakage was not enough to create a malfunction, for this basic design was used on the V-2, Redstone, and Jupiter missiles. Disconnect and release were achieved when the missile lifted from the launcher. No major problems were encountered with this type of umbilical connector.

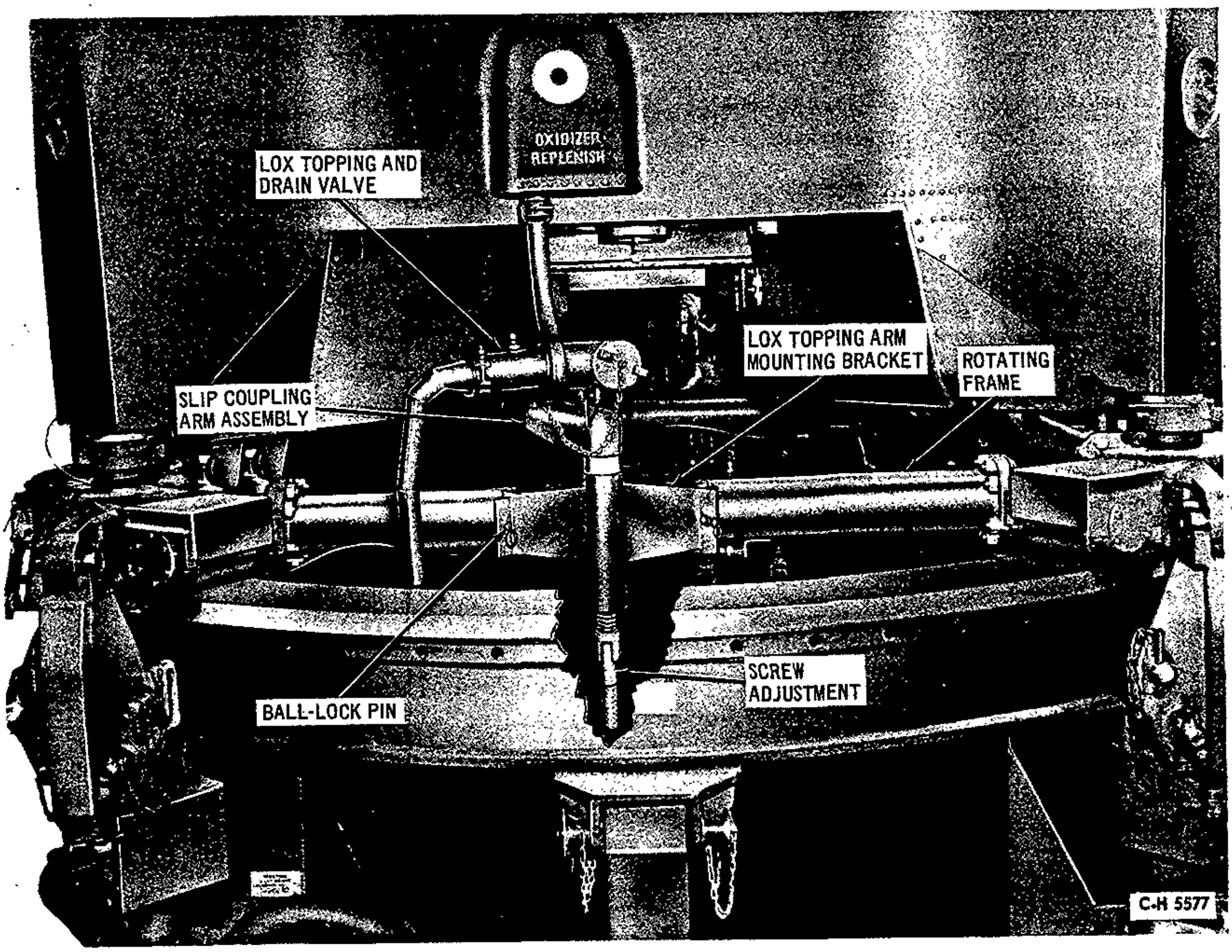



Figure 2-8. Lox Topping Assembly

PNEUMATIC

The multiple pneumatic coupling connector (figure 2-9) was located in a balcony housing on the lower outside of the tail unit between fins II and III. The coupling provided for ground control of on-board pneumatic systems, including fill of the high pressure spheres, pressurization of the LOX tank, LOX replenishing control, alcohol bubbling line, pressurization of igniter alcohol tank, LOX vent control, and LOX sensing. The balcony also housed the alcohol injector purge line and the alcohol seal drain line.

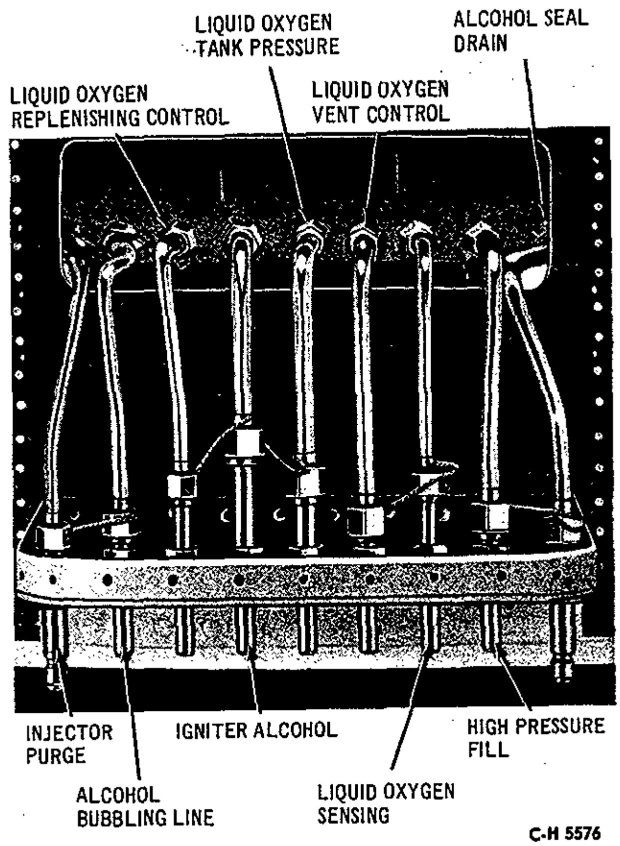



Figure 2-9. Pneumatic Couplings Balcony (Cover Removed)

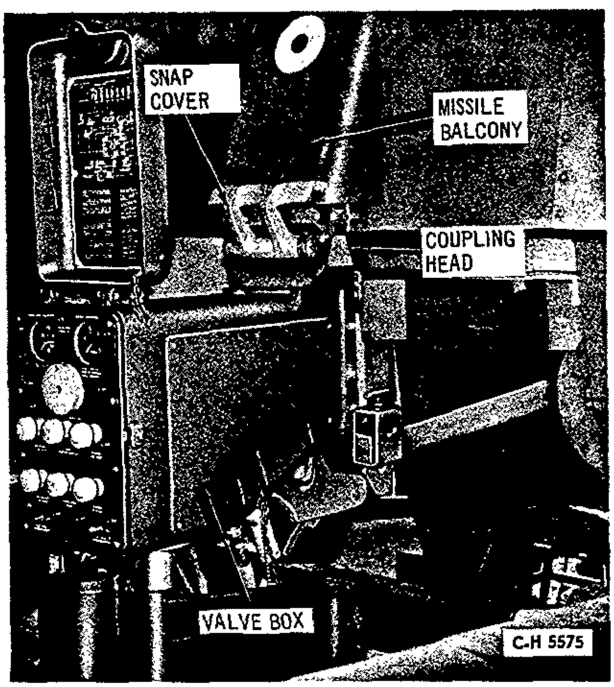



Figure 2-10. Valve Box Installed

The pneumatic couplings on the missile connected to the ground supply through the multiple coupling head of the valve box (figure 2-10). The valve box was post-mounted on the rotating frame of the launcher while the vehicle was in the horizontal position. It had pneumatic connectors for the main pneumatic line to the ground supply, a line to the auxiliary pneumatic supply, and a connection to the igniter bottle. It had one 14-pin electrical connection to which the cable from the electrical relay box was connected. The relay box furnished the control and power for the solenoid operation of valves in the valve box during pneumatic checkout, fueling of the vehicle, and pneumatic operation of the LOX replenishing valve.

The pneumatic connections were slip-type couplings with the seals contained in the female connections (figure 2-11) of the multiple coupling head on the valve box. The system was almost identical with the V-2 system. Adjusting the height adjustment screw on the bottom of the valve box mounting bracket tightened the seal. The multiple coupling head had a snap cover that protected the coupling from blast of the rocket during liftoff; the valve box had a manually closed cover that protected it from rocket blast.

The pneumatic ground supply remained connected to the vehicle until liftoff. There was no locking mechanism in the connection; at liftoff, the vehicle moved away from its launcher counterpart.

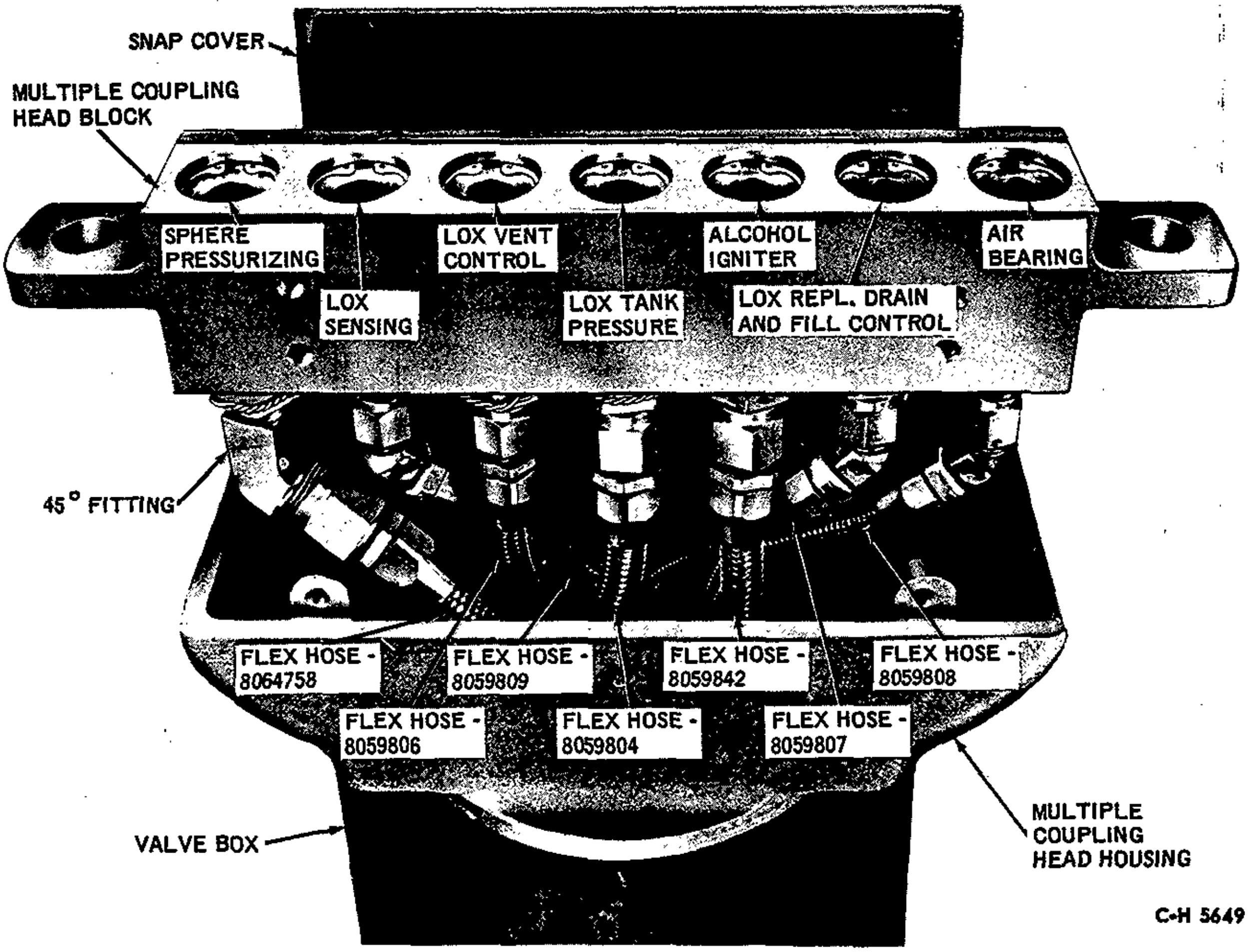



Figure 2-11. Valve Box Multiple Coupling Head

## ELECTRICAL

The electrical connections were located at the base of fins II, III, and IV. These were AN-type connectors fitted with snap covers that closed at liftoff. These connectors provided ground support power to the following: AC and DC supply, tactical networks, payload, measuring distributor network, guidance, and emergency cutoff (figure 2-12).

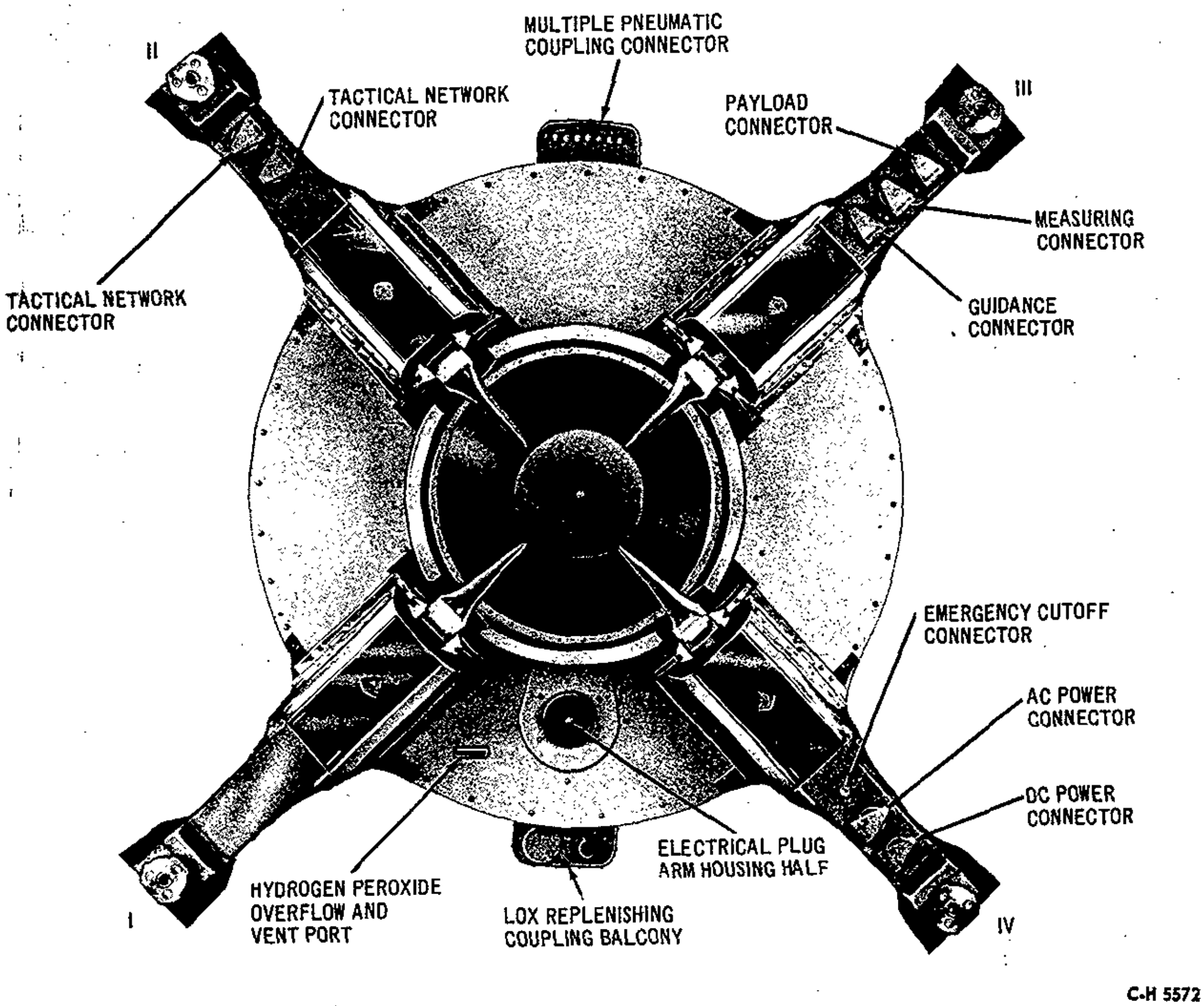



Figure 2-12. Vehicle Electrical Ground Support Connections

The ground support connections were located on three electrical plug arm housings that were mounted on the rotating frame beneath fins II, III, and IV of the vehicle (figures 2-13 and 2-1). The housings had snap covers that closed at liftoff to protect the connectors from blast.

The electrical plugs were manually connected to the AN-type connectors of the vehicle and the housing halves on the electrical plug arm housing (figures 2-14 and 2-13).

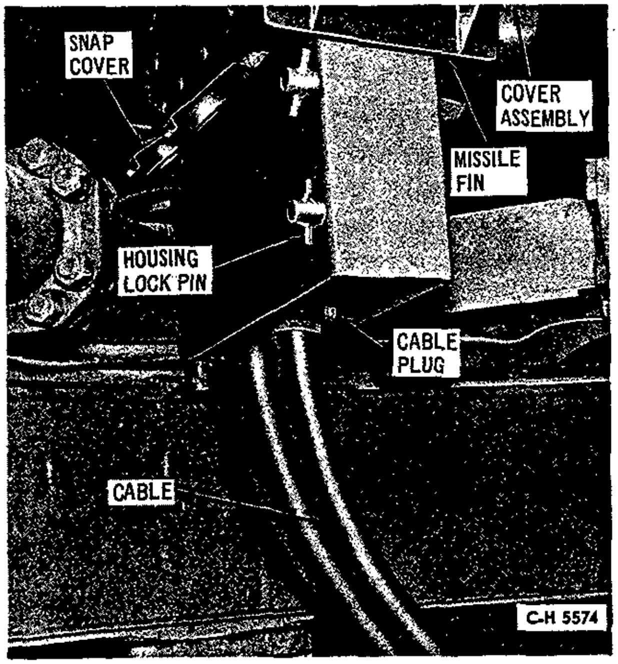



Figure 2-13. Electrical Plug Arm Housing

Disconnect and release were accomplished by missile travel (liftoff). After a short distance of missile travel the snap covers on the vehicle and the launcher closed. There was one failure on the first Mercury-Redstone flight, due to incorrect pin lengths in the plug arm housing; this, however, could not be considered attributable to faulty design. It was caused by improper assembly or size of pins. No failures of record, of the tactical vehicles, have been attributed to these umbilical connectors.

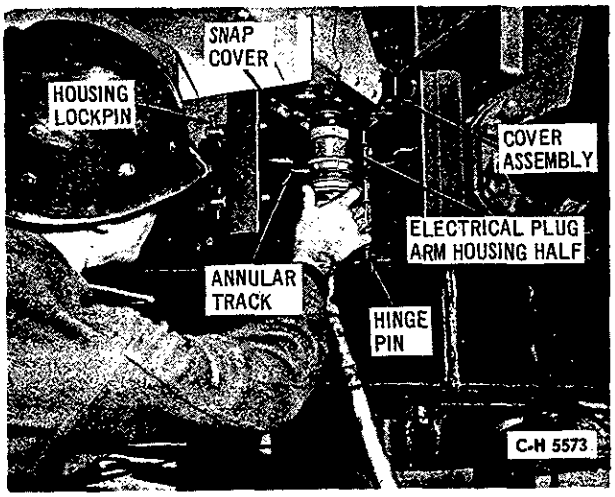



Figure 2-14. Installing Electrical Plugs

## HEATER-COOLER TANK ASSEMBLY, BLOCK I AND BLOCK II

Hot and cold air duct openings and an electrical receptacle (figure 2-15) were located between fins II and III at the lower end of the instrument compartment. The couplings on the missile consisted of one electrical receptacle and a receiver plate with two inlet holes (duct receptacles) which received the hose couplings of the heater-cooler tank assembly (figure 2-16).

The heater-cooler tank assembly, liquid nitrogen line, and electric cables were attached to the missile while it was in a horizontal

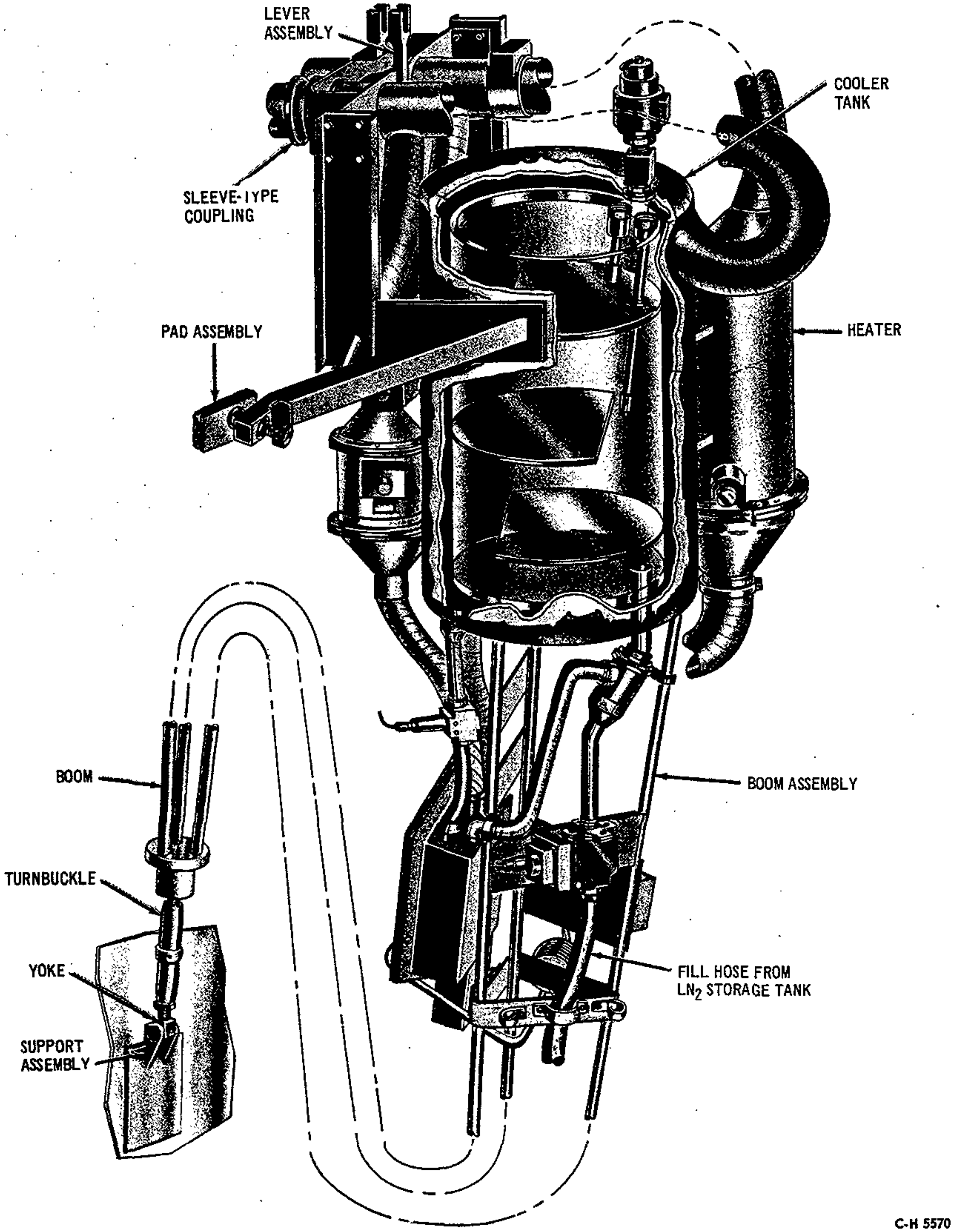



Figure 2-15. Heater-Cooler Tank Assembly

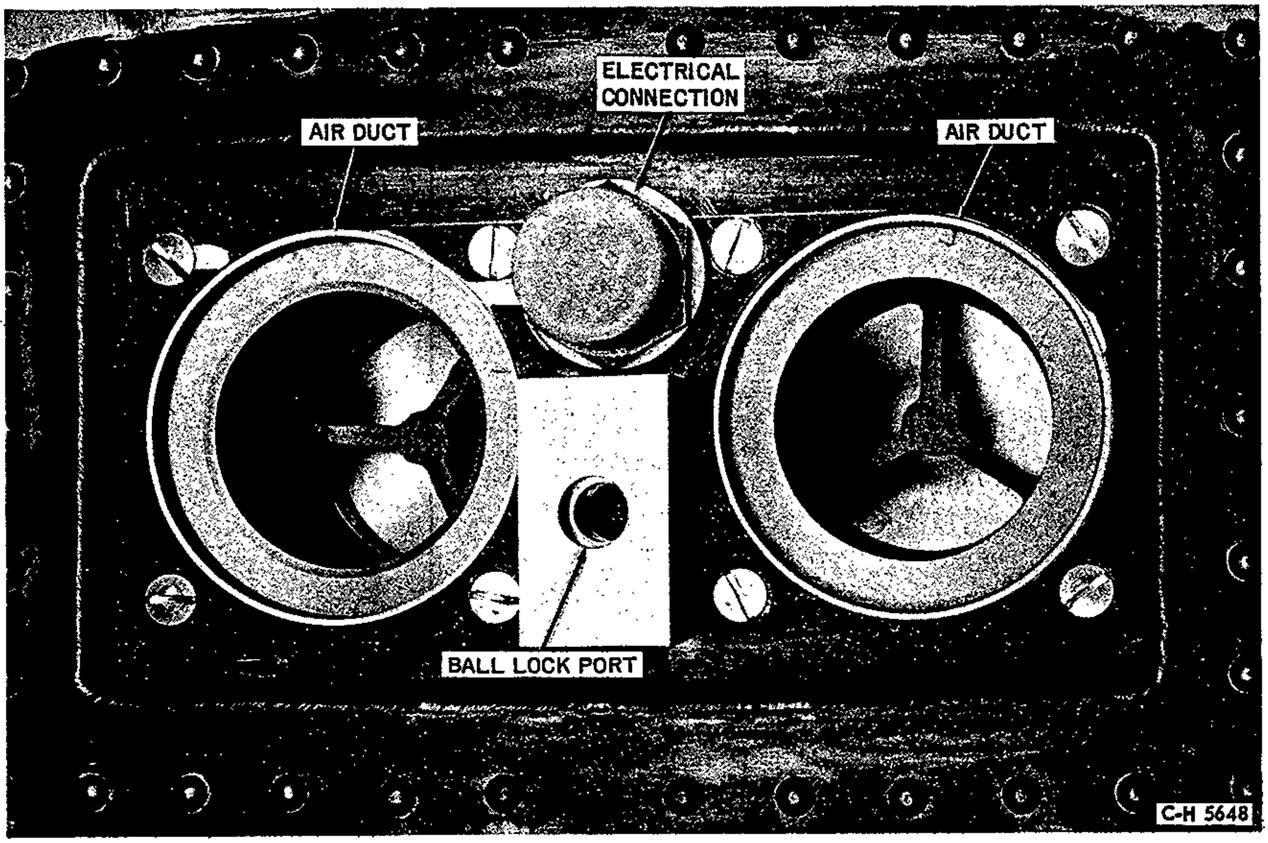



Figure 2-16. Vehicle Receiver Plate

position. The heater-cooler tank assembly (figure 2-15) was attached to the missile and supported by a boom with a pivot point at the aft end (yoke and pin) and a retaining lock assembly (quick-release mechanism) at the forward end of the mast. The quick-release mechanism was actuated by an explosive squib (figure 2-17). This was the first automatic, remote controlled lock and release mechanism developed and used by the United States. The mounting plate on which the retaining lock assembly was mounted also had one hot and one cold air duct, a cylindrical shaped slip coupling, and an electrical plug that mated with the receptacle on the receiver plate on the missile. At installation, careful attention had to be given to the adjusting of the boom turnbuckle at the lower end of the boom and to the alinement of the air duct couplings (figure 2-16).

Factors that had to be compensated for by proper adjustment of the turnbuckle were: missile expansion during pressurization of the missile fuel tank in which the missile length increased but not the boom length, contraction of the heater-cooler tank assembly when filled with dry ice (Block I) or when liquid nitrogen was flowing through the cooler system (Block II), and boom deflection caused by weight of the heater-cooler tank assembly. After

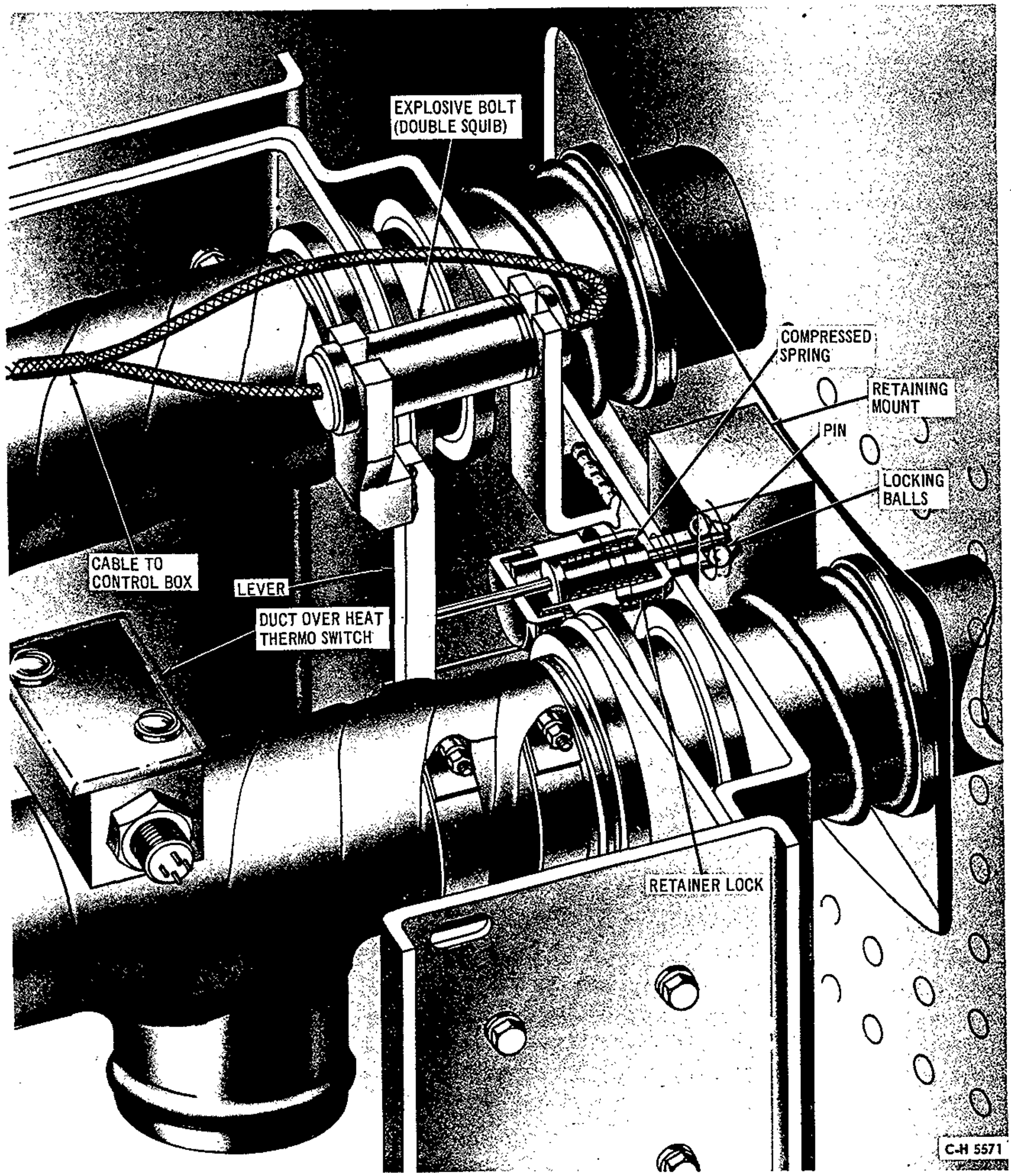



Figure 2-17. Quick-Release Mechanism Heater-Cooler Tank Assembly

experiencing field failure of the heater-cooler tank to release, extensive tests were conducted to determine the correct alinement procedure and turnbuckle adjustment to be made at the time of installation of the heater-cooler tank assembly.

On the Block I vehicles it was determined that the dry ice should be loaded into the cooler tank before final adjustment of the turnbuckle. Proper adjustment was then accomplished by tightening until the yoke on the boom was seated firmly against the pivot pin, and then tightening the turnbuckle an additional two turns. This was done to preload the boom and compensate for deflection caused by the linear growth of the missile during fuel tank pressurization, thermal contraction of the heater-cooler tank assembly, and deflection of the boom under load.

Alinement was a critical factor also due to the design of the couplings (sleeve and cylinder type), and because there was no provision for lateral adjustment at the lower end of the boom. On occasion, due to misalinement of the air ducts (cylindrical, sleeve-type couplings), the heater-cooler tank failed to disconnect after the release mechanism had functioned satisfactorily. The result was that the ground control cable pulled the heater-cooler tank free after liftoff; or, in some cases, the heater-cooler tank remained attached and flew with the missile. In an effort to overcome this, the ends of the air duct couplings were chamfered, and a bungee cord and rope were attached to the heater-cooler tank assembly and staked on the ground. This assisted in pulling the heater-cooler assembly off the missile when the release mechanism had functioned but the air duct couplings had remained connected.

During the automatic firing sequence, the explosive squib assembly was detonated 5 seconds before launching and the heater-cooler tank assembly fell free of the missile. Upon detonation, the explosive squib (figure 2-17) released a linkage that in turn released the ball-lock mechanism and allowed the compressed springs in the duct housings to push the heater-cooler tank assembly away from the vehicle. This was the intended method of operation, but failures did occur as previously stated. Efforts were made to salvage the heater-cooler tank during testing by catching it as it fell away from the missile. Bungee cords and nets were used for testing, and for research and development type vehicles. Tactical missiles had no provision for salvaging the heater-cooler tank assembly.

## HEATER-COOLER TANK ASSEMBLY, LONG CABLE MAST

The long cable mast, with a heater-cooler tank assembly and an electrical ground power supply housing attached at the top of the mast, provided temperature control and ground electrical power to the satellites and space capsules for several R&D vehicles, and Jupiter-C vehicles. A long cable mast also provided electrical connections to the Mercury-Redstone capsule (figure 2-18). The first application of the long cable mast by the United States was on a Redstone R&D long range vehicle. Location of the long cable mast is shown in figure 2-19.

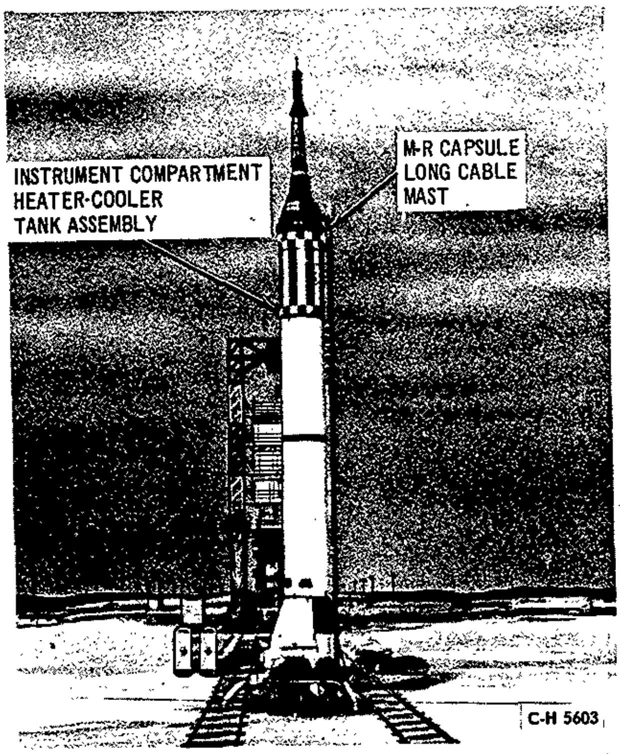



Figure 2-18. Mercury-Redstone

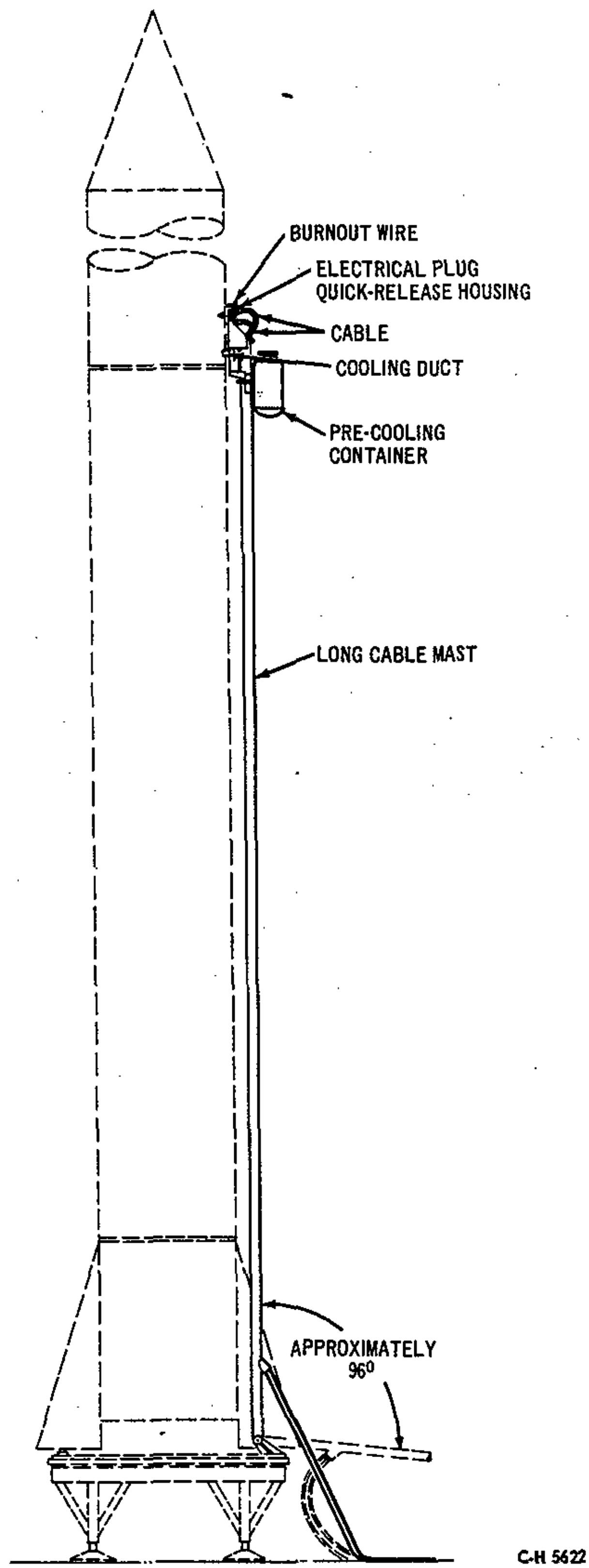



Figure 2-19. Long Cable Mast Redstone R&D Vehicle

Figure 2-20 shows the mast head, of the long cable mast with the heater-cooler tank assembly, the air ducts coupling assembly, and the three-plug electrical housing.

The long cable mast and the mast head were manually attached to the vehicle when it was in the vertical position. The base of the mast was attached to the launcher.

During the automatic firing sequence, a burnout wire released a locking bolt that permitted the ball-lock mechanism to release; and the compressed springs on the electrical plug housing pushed the mast head away from the vehicle, beyond its center of gravity, and the mast fell to the ground (figure 2-20). No attempt was made to catch or salvage the long cable mast and masthead assembly.

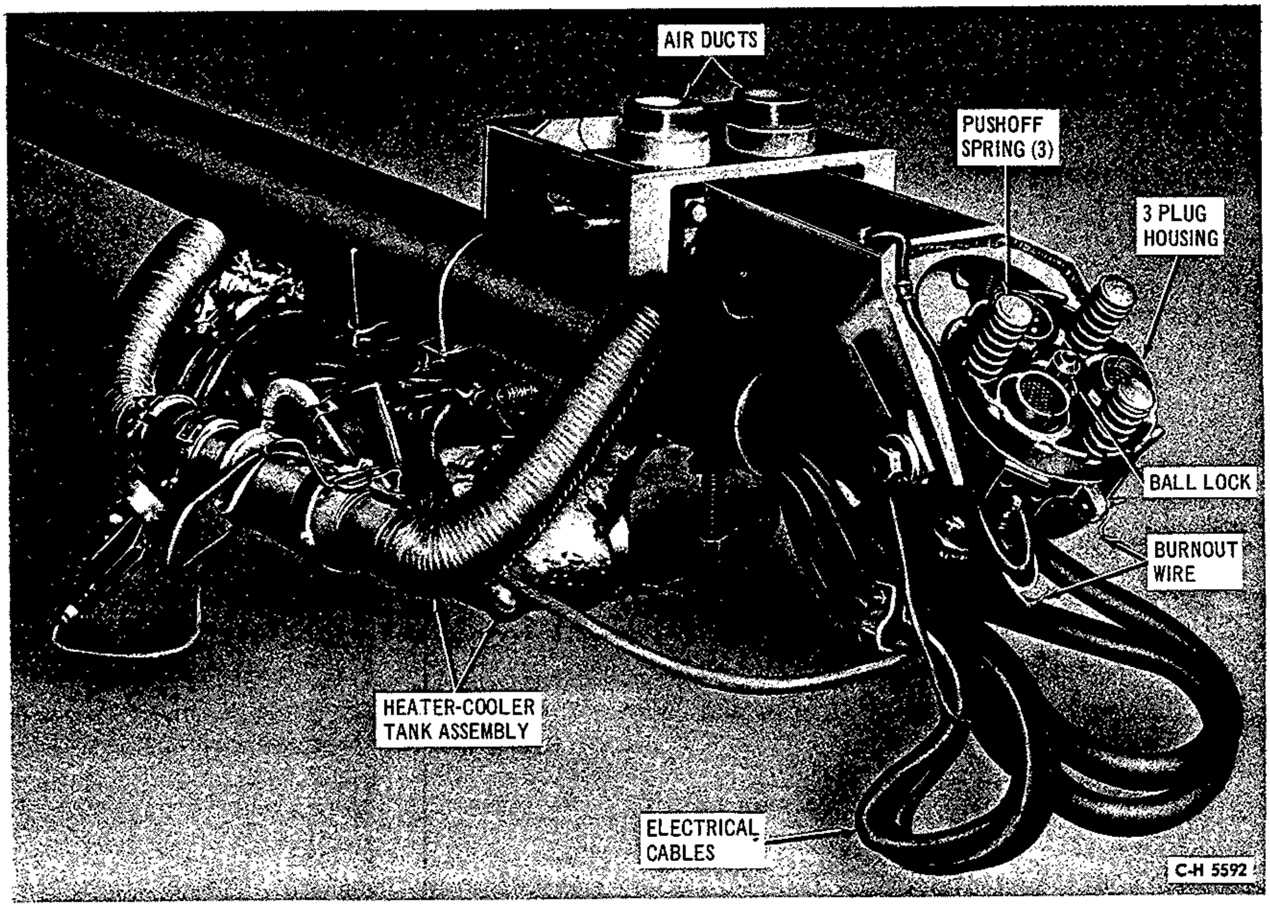
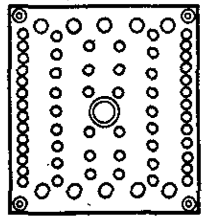
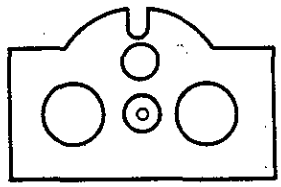
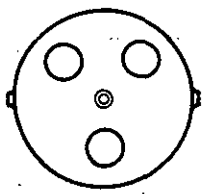
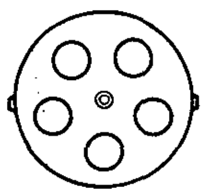
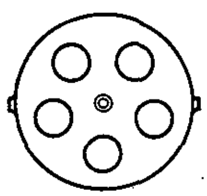
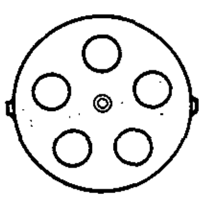



Figure 2-20. Long Cable Mast After Release

# Appendix

| USED ON | HOUSING ASSEMBLY | RELEASED BY |
|---|---|---|
| V-2 TACTICAL MISSILE CABLE MAST |  GROUND CONNECTION SOCKET | MAGNETIC LOCK SPRING RELEASE |
| REDSTONE TACTICAL MISSILE BOOM ASSEMBLY |  HEATER-COOLER TANK CONNECTION | EXPLOSIVE SQUIB BALL LOCK SPRING RELEASE |
| REDSTONE RE-ENTRY AND SATELLITE CABLE MAST |  | BURNOUT WIRE |
| JUPITER NO. 1A, 1B, 1 & 2 QUICK RELEASE CABLES |  | EXPLOSIVE LINK |
| JUPITER NO. 3, 3A & 4 LONG CABLE MAST |  | EXPLOSIVE LINK |
| JUPITER NO. 4 - 8 SHORT CABLE MAST |  | 1/8 INCH ALUMINUM SHEAR PIN |

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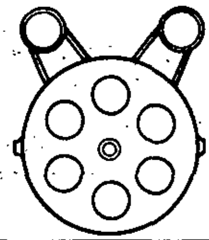
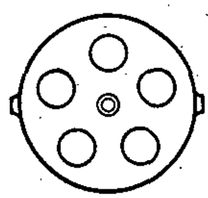
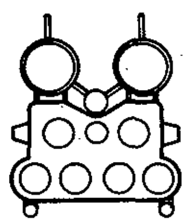
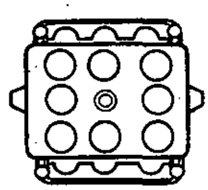
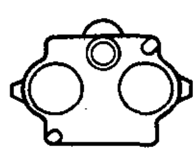
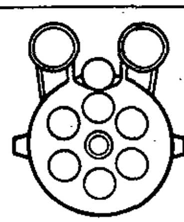
Appendix

| USED ON | HOUSING ASSEMBLY | RELEASED BY |
|---|---|---|
| JUPITER TACTICAL<br>LONG CABLE MAST |  | AIR PRESSURE<br>750 PSI |
| JUPITER TACTICAL<br>SHORT CABLE MAST |  | PULLOUT PIN |
| SATURN I, BLOCK I<br>LONG CABLE MAST<br>SA-1 & 2 WITH LONG CABLE MAST<br>SA-3 & 4 WITH SWING ARM |  | AIR PRESSURE<br>750 PSI |
| SATURN I, BLOCK I<br>SHORT CABLE MAST |  | AIR PRESSURE<br>750 PSI |
| MERCURY-REDSTONE TEST<br>TAIL CABLES |  | AIR PRESSURE<br>200 PSI |
| MERCURY-REDSTONE<br>LONG CABLE MAST |  | AIR PRESSURE<br>750 PSI |

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# APPROVAL

## UMBILICAL SYSTEMS

## V-2 TO SATURN V

The data contained in this publication was prepared under Task Order No. M-P&VE-M-7-63, Contract NAS8-4016 by Chrysler Corporation, Space Division, Huntsville Operations. Preparation is in accordance with the style and format previously determined best suited for presenting an historical evaluation of Umbilical Systems by the Ground Support Equipment Branch.

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