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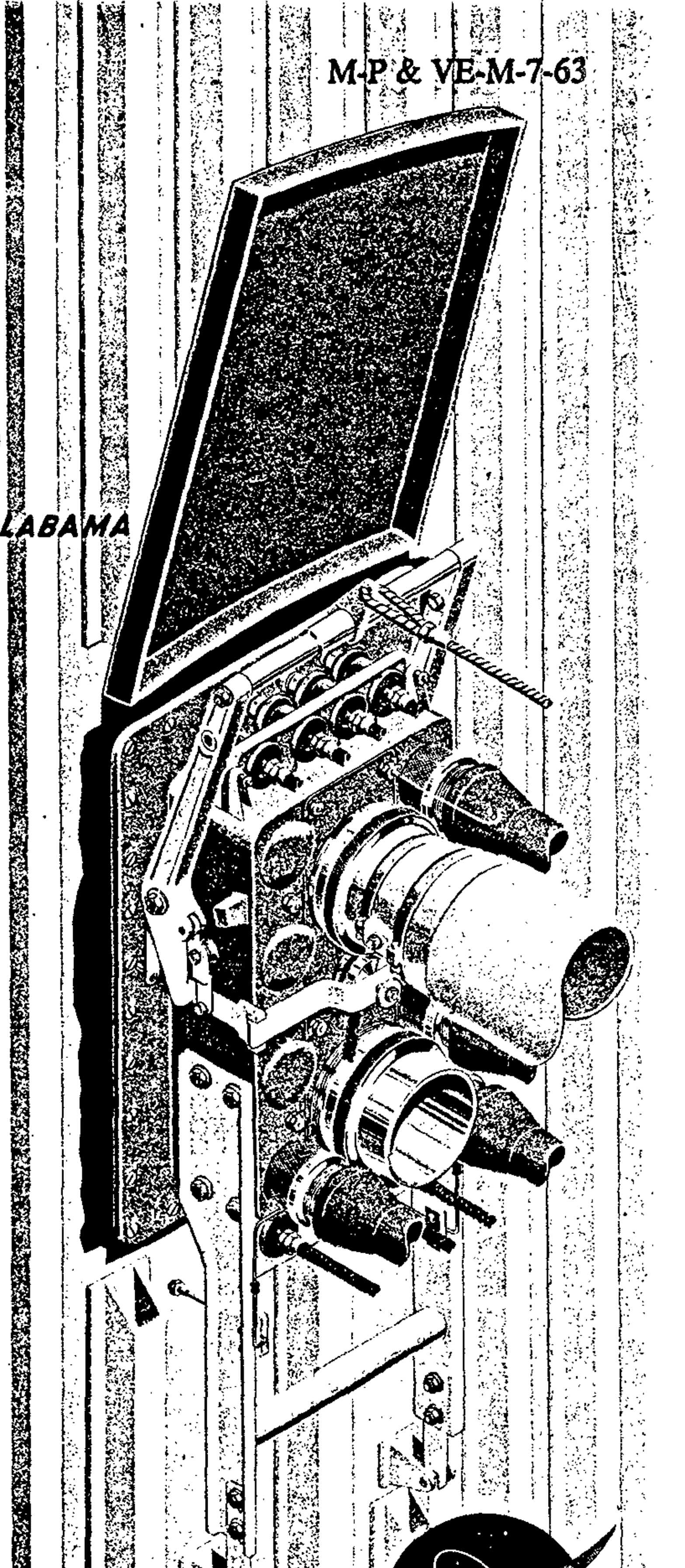

UMBILICAL SYSTEMS
V-2 TO SATURN V

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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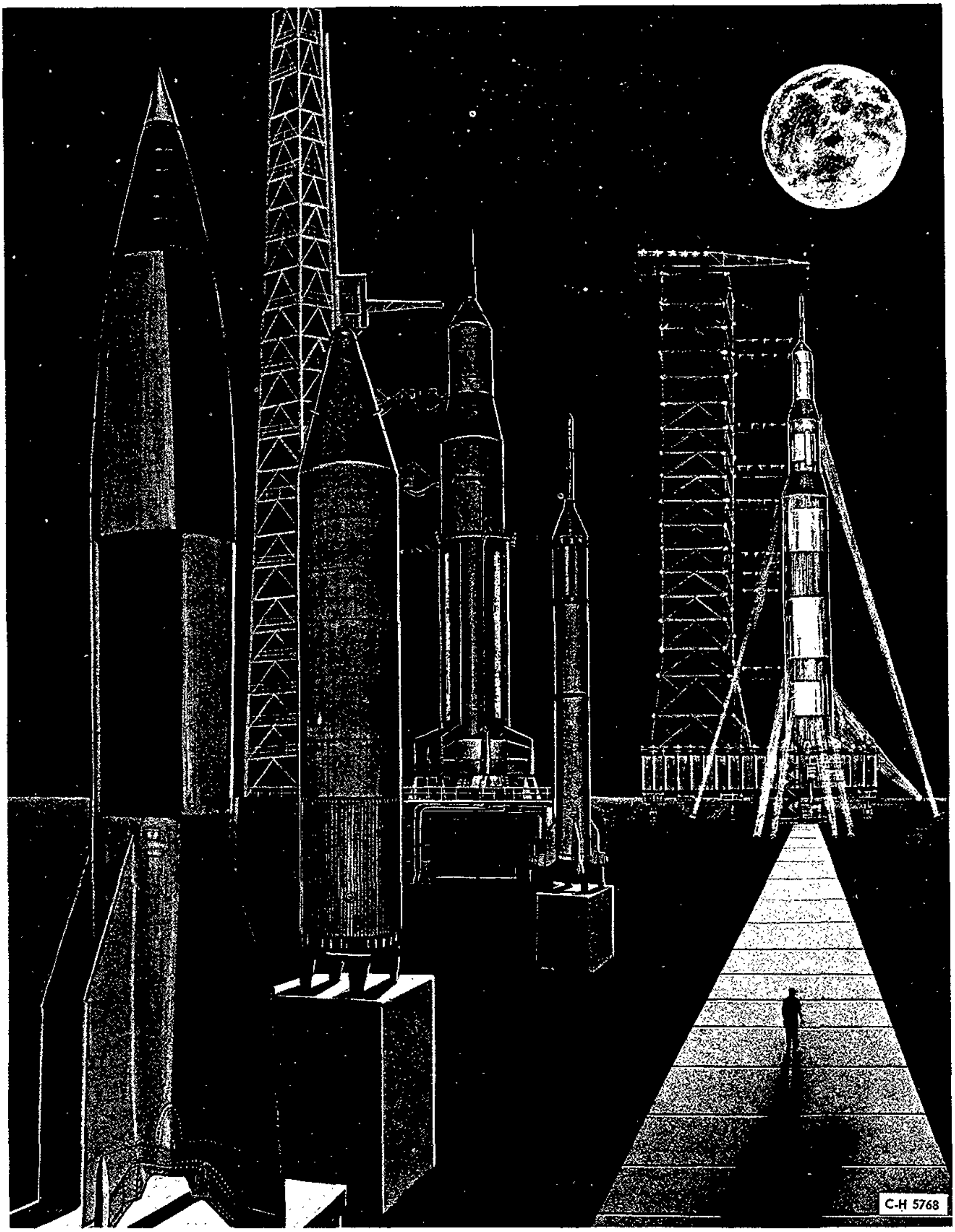
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FOREWORD

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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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.

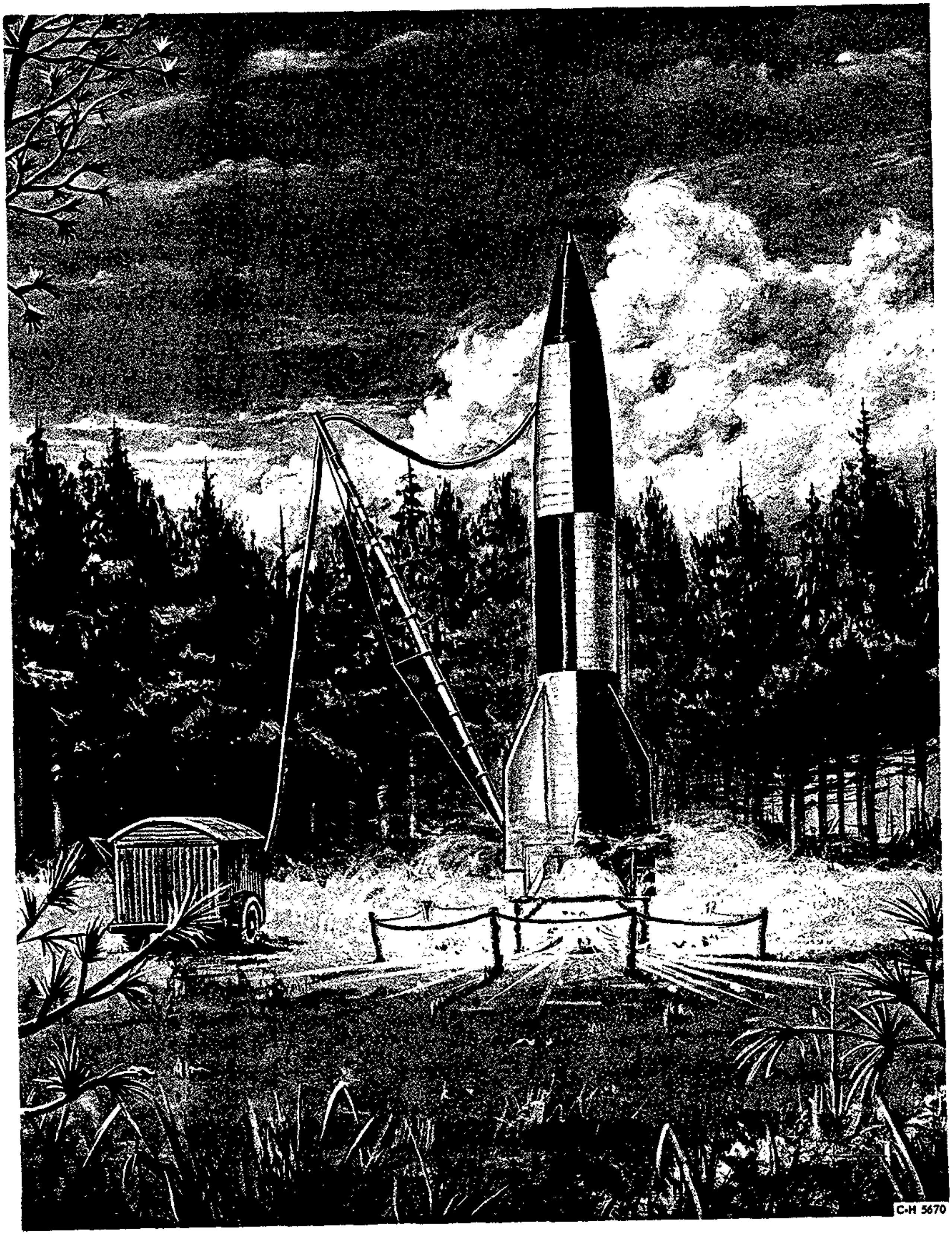
In an effort to develop a fully automated system (from fueling to launch) for the Jupiter vehicles, much designing and testing was undertaken, and many problems were overcome in the development of quick-release mechanisms for the electrical, pneumatic, heater-cooler, fuel, and LOX connections.

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 I
V - 2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SECTION I

V-2

INTRODUCTION

A-Stoff, B-Stoff, P-Stoff, T-Stoff, Z-Stoff--Was ist los? "On this earth planet you are living in an age of guided missiles--a sky ship in the universe--a peace deed and a dream of mankind may fascinate the century someday. But today we must master a weapon still unknown due to its top secret classification called in short, the A-4 Device." (A-4 Fibel)

The A-4 Device (called the V-2) was a bipropellant liquid fueled rocket designed as a highly mobile, long range, ballistic weapon. When raised to the vertical position in preparation for launch, a number of connections were made between the missile and the ground support equipment. Because of the state-of-the-art at the time, most of these connections were made manually. Disconnect of the connections before launch was also manual; however, there were some connections that were made at the launcher, and disconnect was accomplished as the vehicle left the launcher.

Umbilical connections between the missile and the ground support equipment provided for fueling, LOX venting, LOX topping, pneumatic pressurization, and electrical power. This section will discuss these connections in detail.

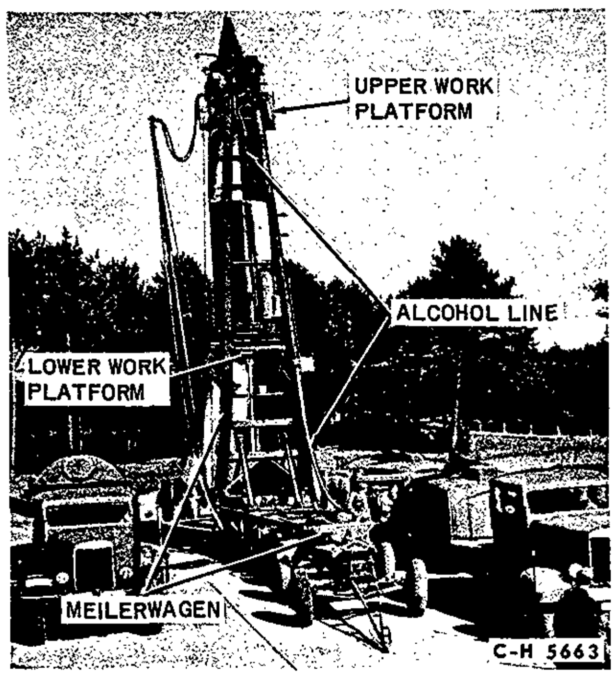


Figure 1-1. Alcohol Fueling

FUELING

Alcohol. The alcohol fueling connection was located on top of the alcohol tank. Access to it was through the number three instrument compartment door, located on the forward section of the vehicle along fin line 3 (figure 1-1).

Alcohol fuel lines from two tank trucks were interconnected through the alcohol pump. A single line then connected the pump and the lower end of the intermediate pipe, located on the Meilerwagen. A short line connected the upper end of the intermediate pipe to the alcohol fueling connection on the vehicle.

The threaded male connection on the vehicle was covered with a threaded protective cap that was removed during the filling operation. The alcohol fueling line was manually connected to the vehicle with a threaded, hex, female connection.

There being no shutoff valve in the system, the amount of alcohol to be tanked was determined by the mission and preset at the pump. When the required amount of alcohol had been pumped, the pump automatically stopped, completing the alcohol fueling process. The filling lines were then manually disconnected from the vehicle and the Meilerwagen, the protective cap was replaced on the vehicle connection, and the alcohol lines and pump were loaded onto the tank truck and removed from the launch area.

<u>Liquid Oxygen (LOX)</u>. The LOX fill and drain connection was located at the extreme upper part of the tail section, between fins 2 and 3. Access to the connection was from the lower work platform of the lift frame (figure 1-2).

The LOX tank trailer connected the LOX pump trailer with a 100-millimeter (mm) hose. A 70-mm hose connected the LOX pump to the lower end of the intermediate pipe on the Meilerwagen, and a short hose connected the upper end of the intermediate pipe to the LOX fueling connection on the vehicle (figure 1-3).

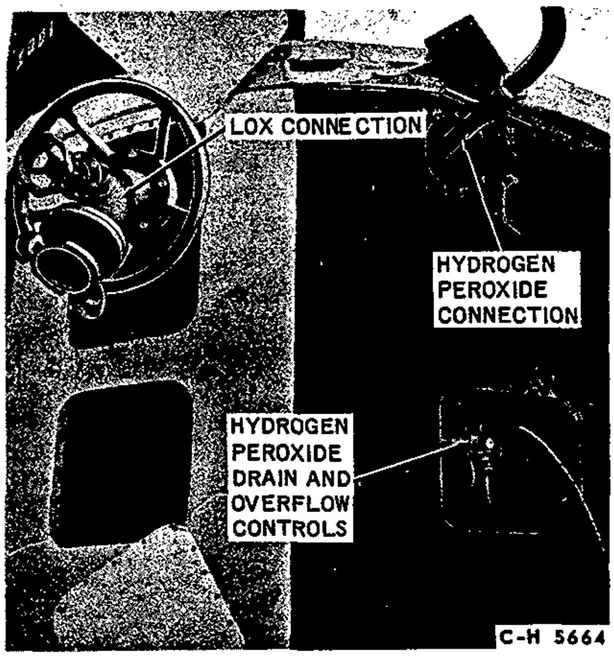


Figure 1-2. Lox and Hydrogen Peroxide Fueling Connections

The LOX fueling connection screwed onto the threaded end of the LOX fueling valve, aided by a large hand wheel. A small hand wheel on the end of a piston, an integral part of the connection, opened the LOX fueling valve (figure 1-3). During the filling operation, the small hand wheel was constantly rotated, keeping the piston from freezing or sticking.

When LOX fueling was completed, the small hand wheel was used to close the LOX fueling valve. The LOX in the filling hoses drained through the pump onto the ground, and the hoses and the LOX filling connection were manually disconnected and loaded onto the LOX trailer. The protective cap for the LOX fueling valve was replaced.

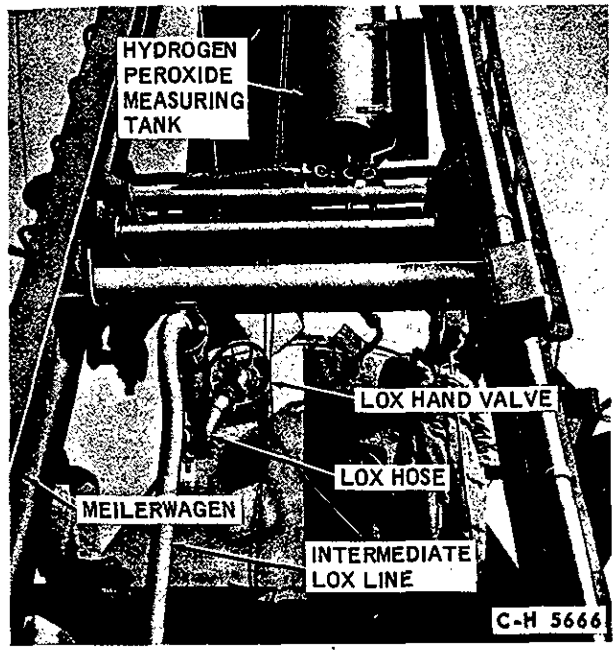


Figure 1-3. Lox and Hydrogen Peroxide Fueling

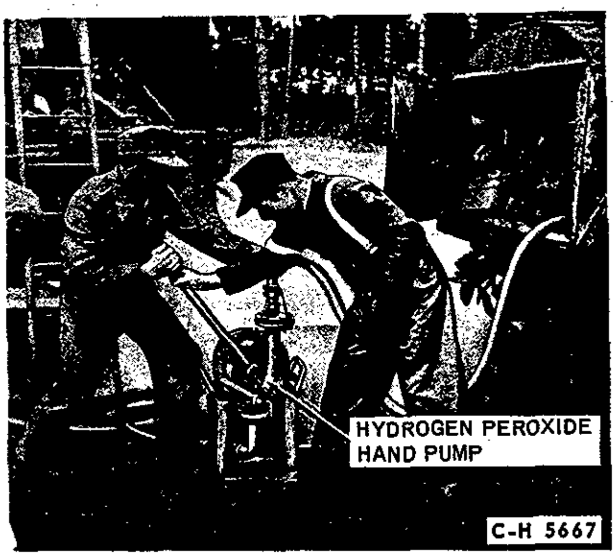


Figure 1-4. Pumping Hydrogen Peroxide to Measuring Tank

The LOX trailer was moved and LOX connections were made from it to the LOX topping connection on the launch platform.

Hydrogen Peroxide (H_2O_2). The H_2O_2 fueling connection was located at the upper part of the tail section between fins 2 and 3, next to the LOX fueling connection (figure 1-2). The H_2O_2 tank truck connected to the measuring tank on the Meilerwagen through a hand pump on the ground (figure 1-4); another line connected the measuring tank to the connection on the vehicle (figure 1-3).

After the protective cover was removed from the vehicle H_2O_2 connection, a long connection on the hose from the measuring tank was threaded onto the vehicle connection (figure 1-2). H_2O_2 was pumped into the measuring tank; then a cock on the bottom of the tank allowed the H_2O_2 to gravity-flow into the vehicle.

A sight glass in the fueling line indicated when H_2O_2 ceased to flow, and the fueling connection was then removed and the cover on the vehicle inlet was secured. The hoses from the measuring tank and the fueling connection were disconnected, lowered to the ground, and stowed in the tanker, as was the hose from the Meilerwagen to the tanker. The tanker was then removed from the area.

Figure 1-5. Hoisting Sodium Permanganate Tank to Fueling Level

Figure 1-6. Fueling Sodium Permanganate

Sodium Permanganate. Access to the sodium permanganate connection was through a hatch located directly beneath the LOX fueling connection (figure 1-2). A can containing the sodium permanganate was raised by a rope from the ground to the lower work platform (figure 1-5). The protective cap was removed from the tank inlet, and a funnel was held to the inlet by one man while sodium permanganate was poured into the tank by another man (figure 1-6).

When the vehicle sodium permanganate tank was full, the funnel was removed and the protective cover replaced on the inlet. The sodium permanganate container and funnel were lowered to the ground in a bucket of water.

LOX VENTING

The pneumatically-operated LOX vent valve was located in the bottom of the LOX tank, with a pipe extension that exited at the lower end of the tail unit between fins 1 and 2. During the filling operation an extension was slipped over the end of the LOX vent pipe (figure 1-7) and was held in place by a clamp mounted on the launch platform. Just before launch, this extension was unclamped and removed from the area.

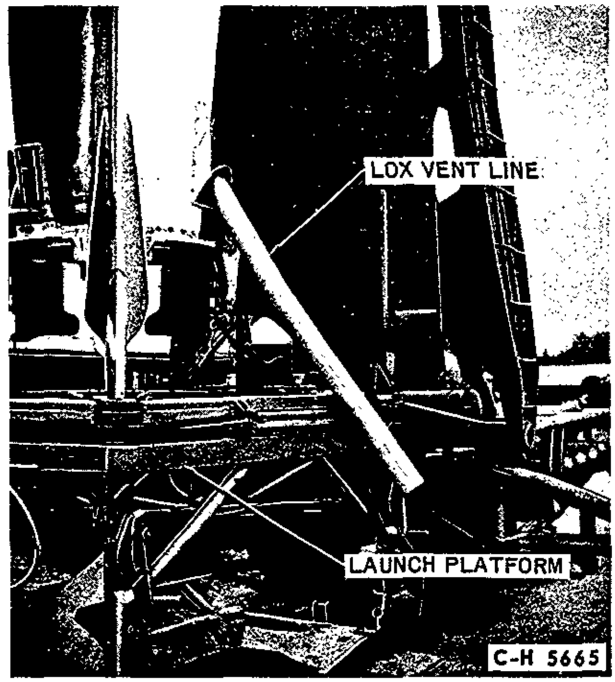


Figure 1-7. Lox Vent Connection

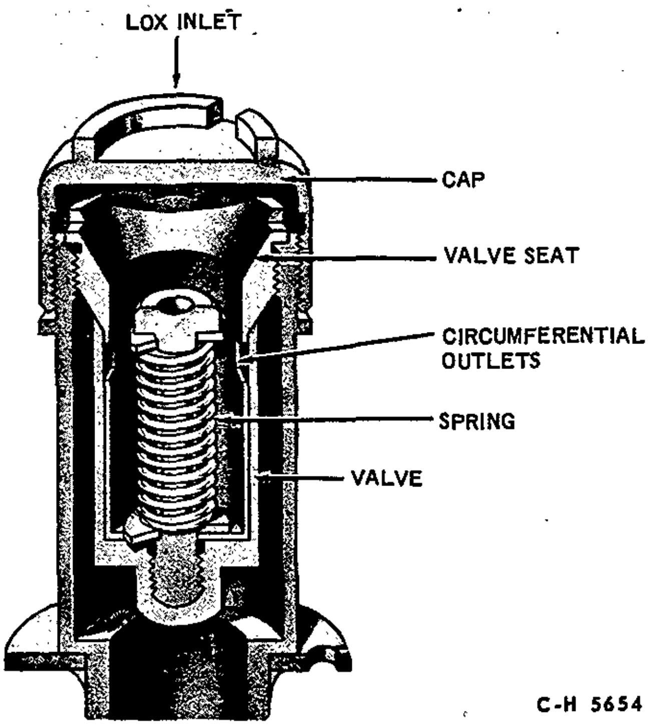


Figure 1-8. Lox Topping Valve

LOX TOPPING (REPLENISHING)

The LOX topping valve (figure 1-8) was located at the base of the tail unit between fins 1 and 4. It was designed to receive the cone-type fitting of the LOX topping connection that was mounted on the launcher. The valve was operated by a pneumatically-actuated plunger in the LOX topping connection.

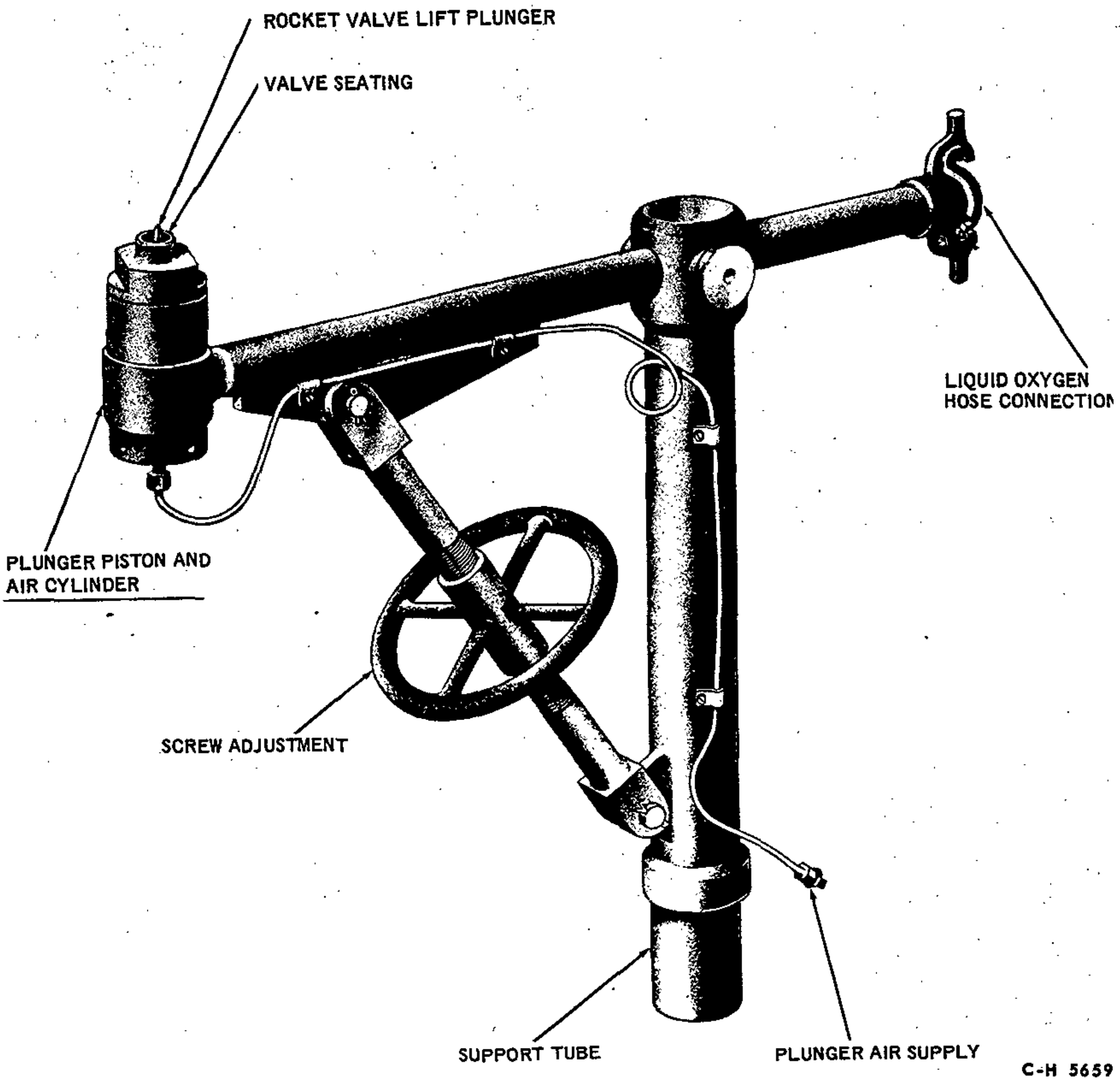


Figure 1-9. Lox Topping Connection

The LOX topping connection (figure 1-9) was mounted in a socket on the rotating ring of the launch platform (figure 1-10). The LOX replenishing hose connected to the arm, and the plunger connected to a pneumatic line from the valve box, which controlled opening and closing. When necessary, the LOX topping system was also used to drain small amounts of LOX from the vehicle. (Complete draining was accomplished through the LOX fill and drain system.) The LOX topping connection had a tapered seat that fit into

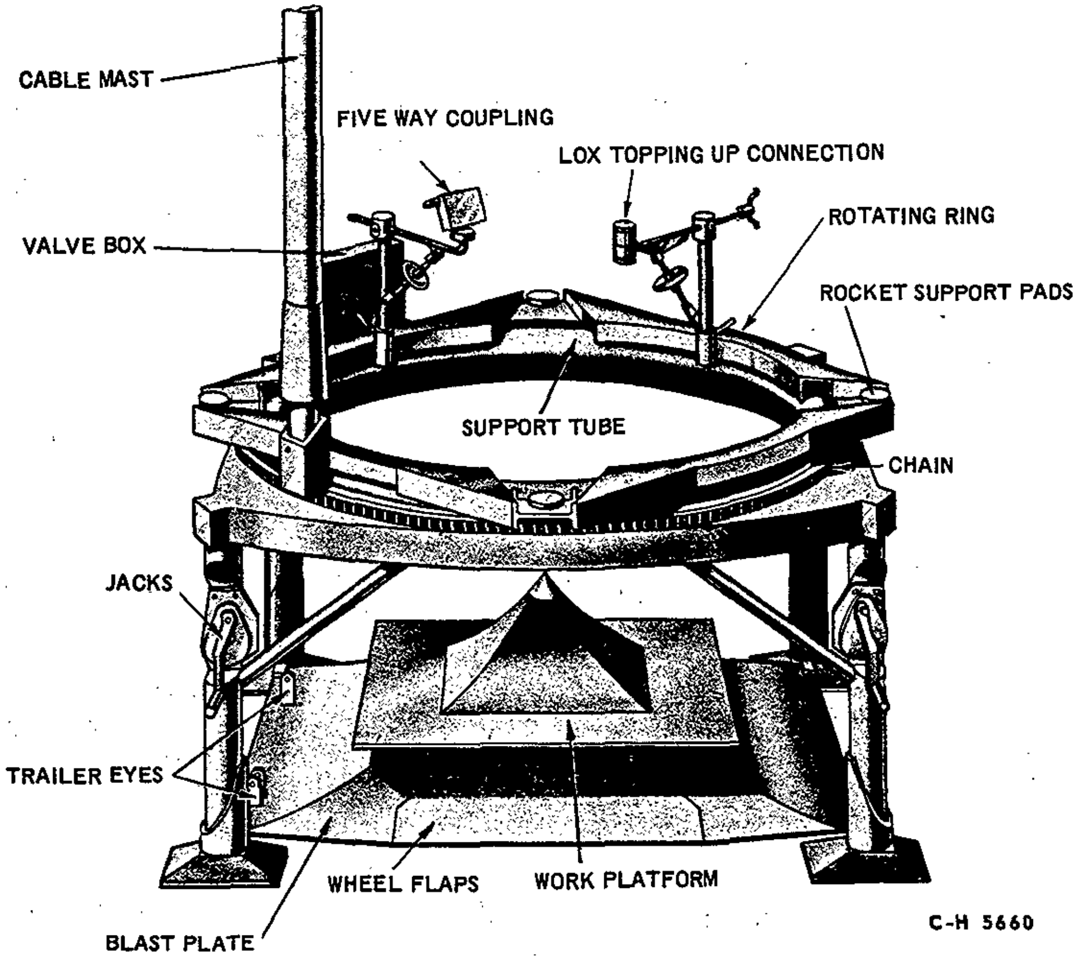


Figure 1-10. Launch Platform with Umbilical Connections (Position of Long Cable Mast and Valve Box Reversed for Clarity)

the LOX topping valve. A screw adjustment obtained a seal between the LOX topping connection and its counterpart on the vehicle.

The LOX topping system was a true umbilical system in that the LOX ground supply was connected to the vehicle until liftoff. There was no locking mechanism in the connection; at liftoff, the vehicle merely moved away from the launcher counterpart. The cone-type slip connection, with no moving parts, proved to be very reliable and was later incorporated into vehicle systems developed in the United States; however, leakage of this type of coupling cannot be prevented. It can be assumed that the air-operated LOX topping valve lift plunger may have had some freezing troubles because of its having had moving parts in a LOX environment.

PNEUMATIC

The five way, pneumatic slip-coupling (figure 1-11), located at the base of the tail unit between fins 2 and 3, provided for pneumatic pressurization of the LOX and alcohol tanks and the on-board pneumatic tank, ground operation of various valves, purging of the alcohol pump bearings, and vehicle gage and safety control cutoff to the ground equipment.

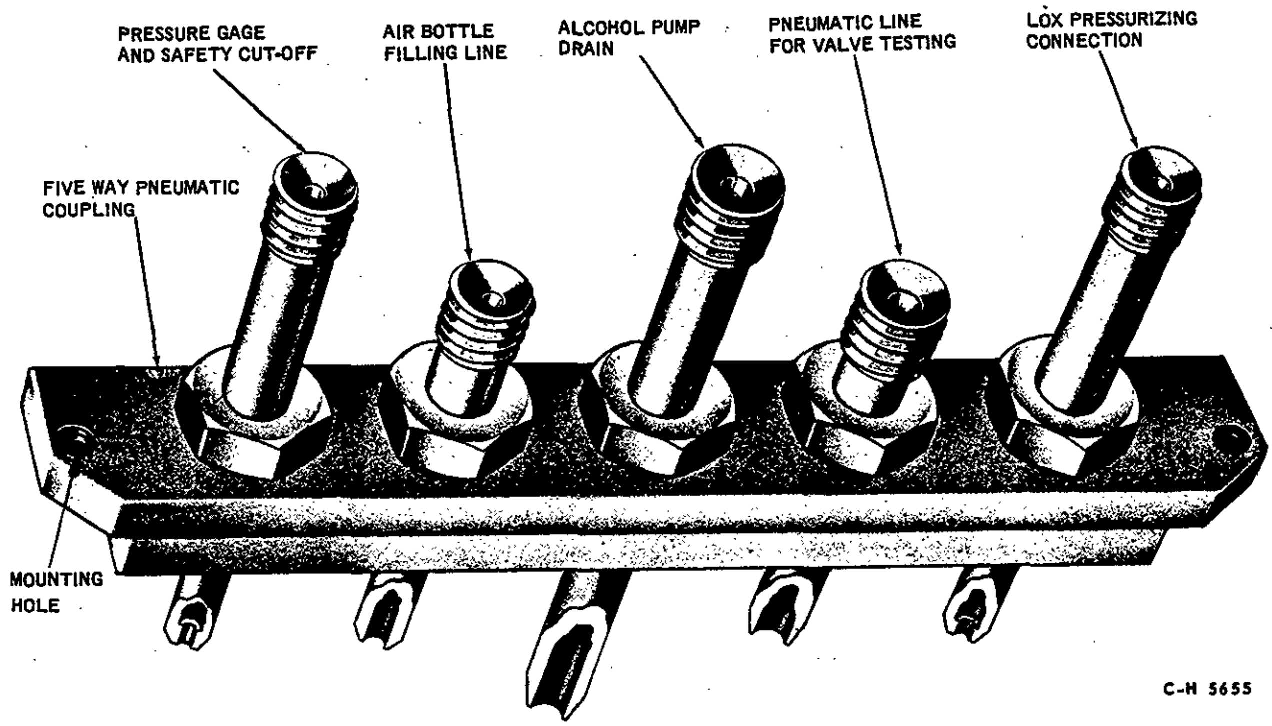


Figure 1-11. Vehicle Pneumatic Five Way Coupling

The pneumatic service manifold ground connection (figure 1-12) was socket mounted on the rotating ring of the launch platform (figure 1-10). Lines from the connection ran to a valve box (figure 1-13), also mounted on the platform. A single pneumatic line connected the valve box to the air compressor trailer. In addition, a 14-pin electrical connection joined the valve box to the electrical test box. The test box operated the valve box solenoid valves for pneumatic checkout and fueling of the vehicle and for pneumatic operation of the LOX topping valve.

The pneumatic connections were slip-type couplings. The seals, contained in the female ground connection head, were tightened by adjusting the

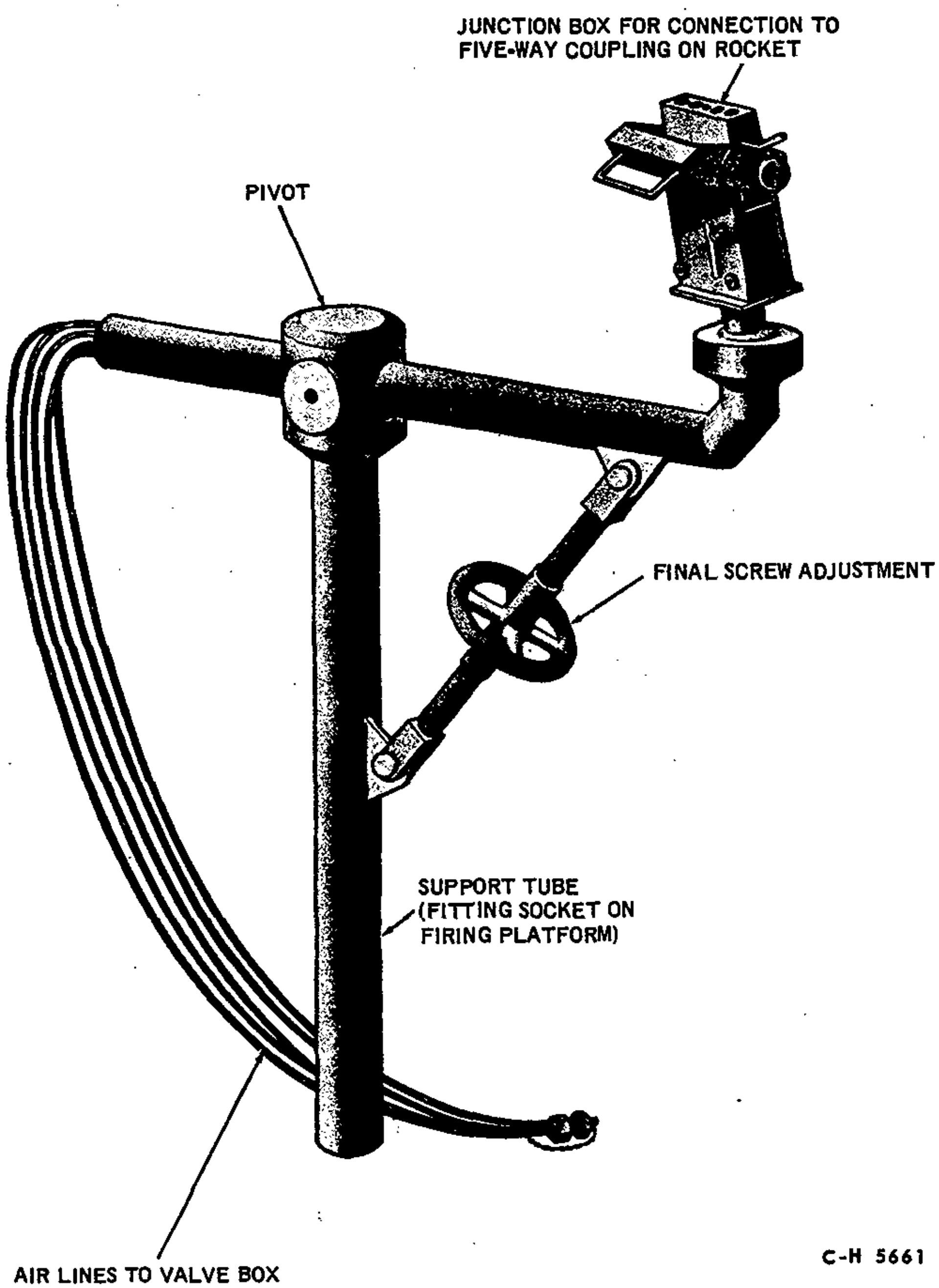


Figure 1-12. Ground Connection Pneumatic Service Manifold

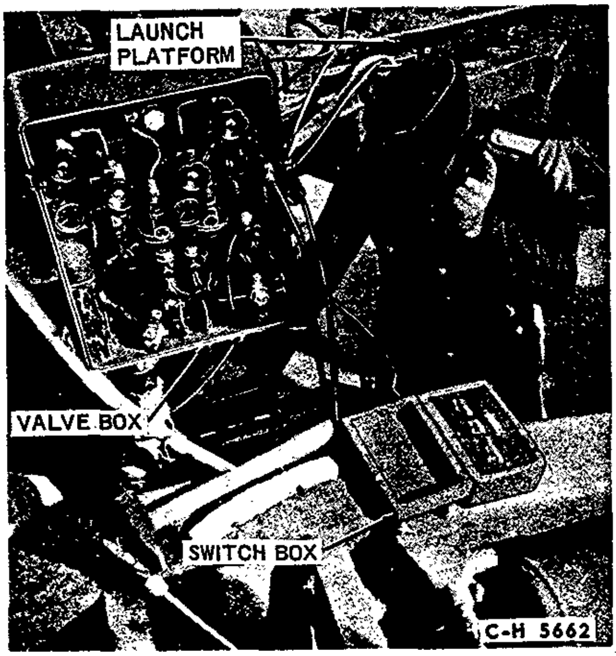


Figure 1-13. Prelaunch Pneumatic Checkout

final screw adjustment hand wheel. A snap cover closed protecting the ground connection seals from heat during liftoff; a manually closed cover protected the valve box 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.

ELECTRICAL

Two Stotz ground-connection sockets and plugs gave access to the internal vehicle circuits from the ground control desks, which were used for testing the operation of the guidance and control system and the solenoid-operated valves in the vehicle.

The plug portions (figure 1-14) were located in the vehicle, in instrument control compartment number two, in the forward section of the vehicle along fin line 2. Access to them was through a spring-loaded hatch. Plug number 1 had 58 pins of the same size: 56 pins for ground test of the guidance and control system, and 2 pins for the electromagnetic lock in the socket. Also, plug number 1 had seven larger pins for the main ground power supply and other heavy current loads. Plug number 2 had 66 pins of the same size for valve control and rocket motor tests.

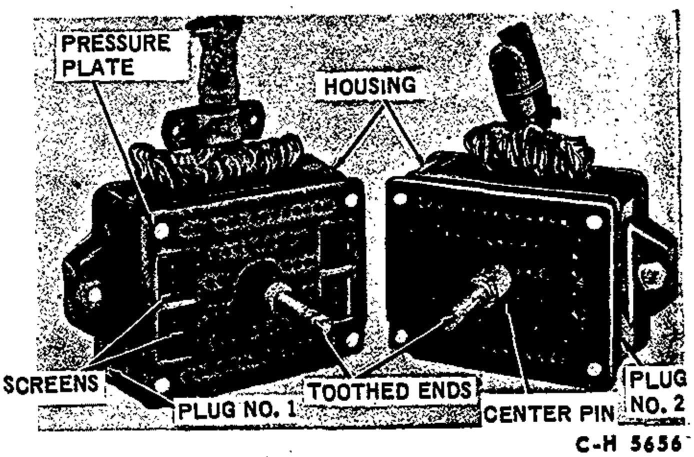


Figure 1-14. Vehicle Ground Connection Plugs

The socket portions (figure 1-15) were located on the ground supply cables, which ran directly from the generator to the vehicle (figure 1-16). Socket number 1 attached to a 67-wire cable, for test of the guidance and control system, and to two 2-wire cables, one for the 27-volt direct current (dc) supply and one for the 220-volt alternating current (ac) supply. Socket number 2 attached to a 67-wire cable that controlled the solenoid valves and rocket motor controls during ground testing and fueling.

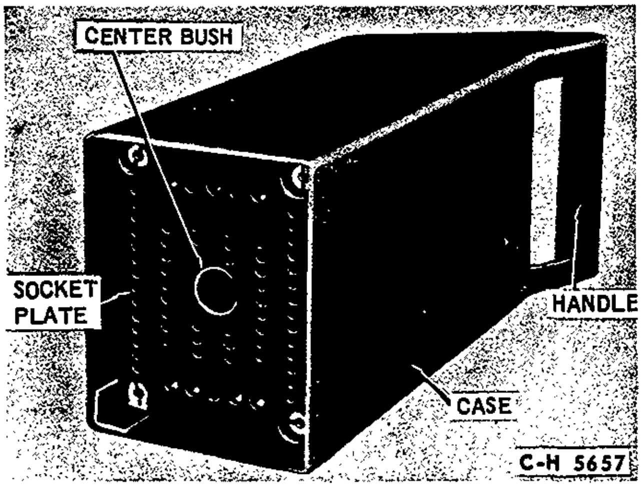


Figure 1-15. Ground Connection Socket

An electromagnetic lock held the plug and socket connections together during checkout and launch (figure 1-17). A bushed hole through the center of the socket accepted the steel center pin of the ground connection plug (figures 1-14 and 1-17). Teeth on the end of the center pin engaged similar teeth on a detail of the socket assembly and moved an armature towards the pole pieces of an electromagnet. As the armature approached the pole pieces, a contact in series with the magnet coil closed, energizing the magnet and locking the pin. Disconnect was accomplished by de-energizing the electromagnet, releasing the armature that held the center pin of the plug. The spring-loaded pressure plate on the plug then kicked away the socket unit.

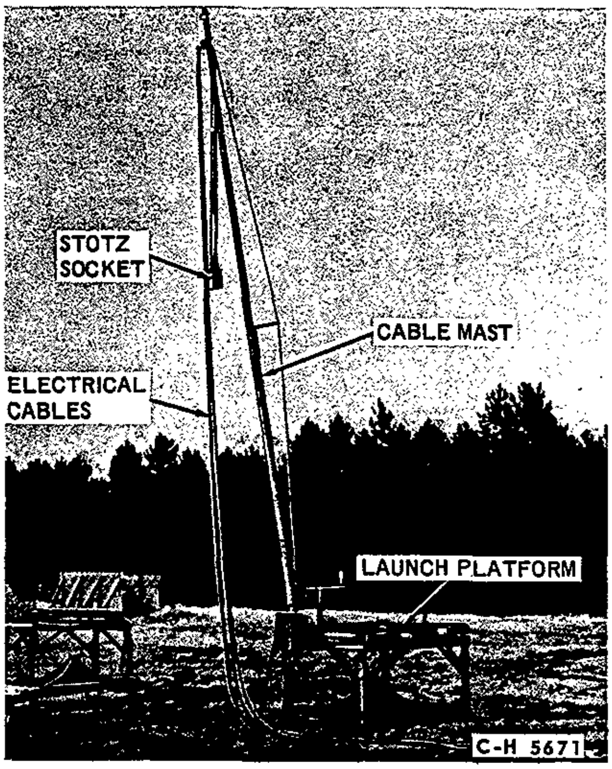


Figure 1-16. Ground Support Electrical Cables

This was the beginning of remotely controlled, quick-release mechanisms for umbilical connections to rocket vehicles. The electrical connector was a good one.

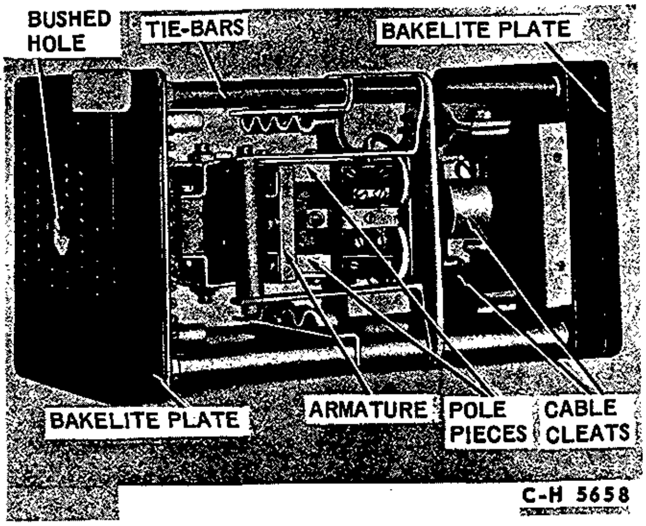
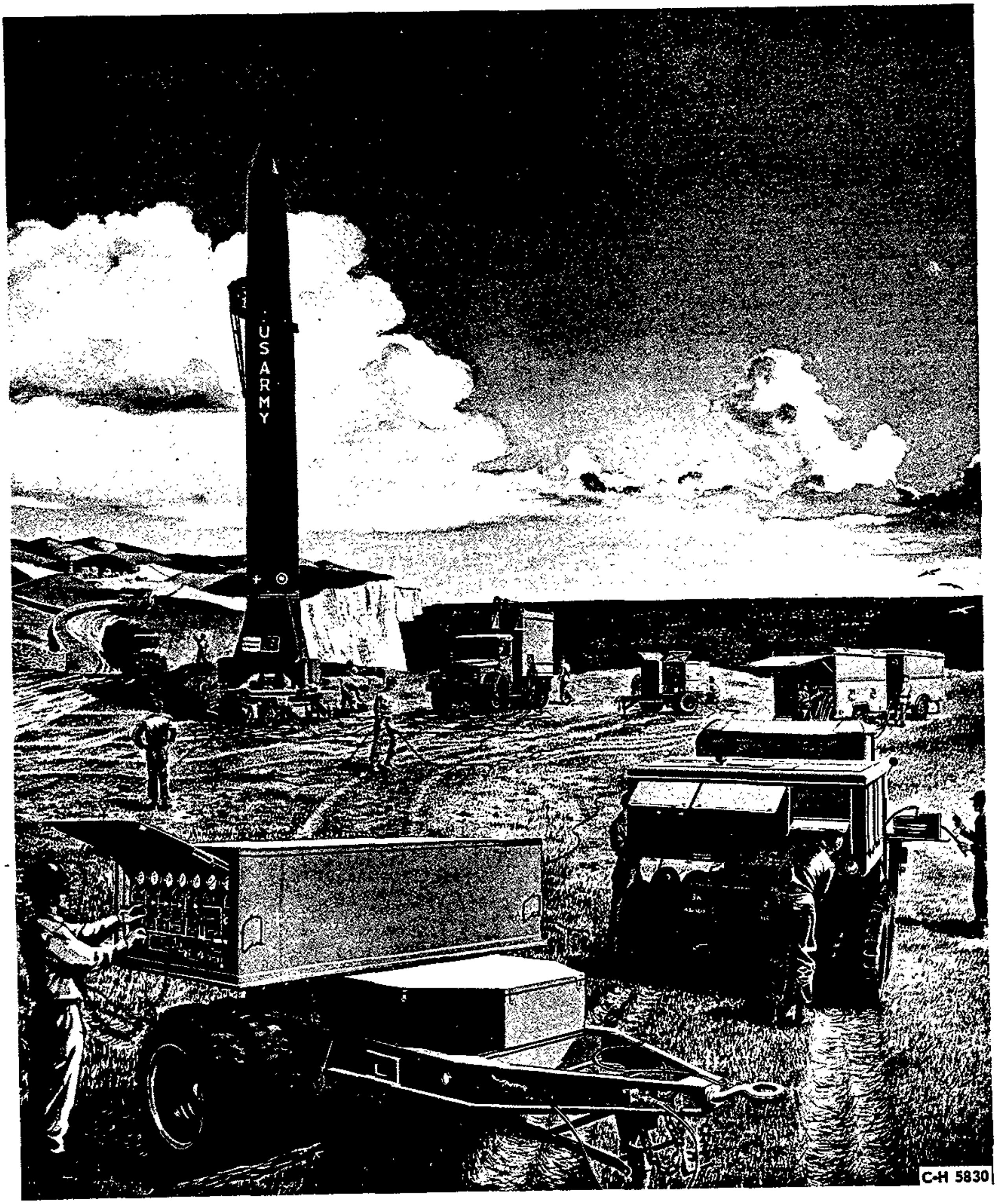


Figure 1-17. Socket Electromagnetic Lock

There were some problems during checkout of the vehicle, when remote switching might release the cables; it was then necessary for a man on the upper work platform to secure the connection while certain testing was accomplished. Also, during the final count just prior to launch, the cables sometimes released prematurely, and vehicle batteries were unable to pick up the power load necessary for a successful flight. In addition, the teeth in the socket detail became worn, causing difficulty in locking and unlocking the connection. Sometimes the worn teeth (or binding of the center pin, caused by misalinement) resulted in the cables' failing to release. There were undoubtably occasions when the cables flew with the vehicle.

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.

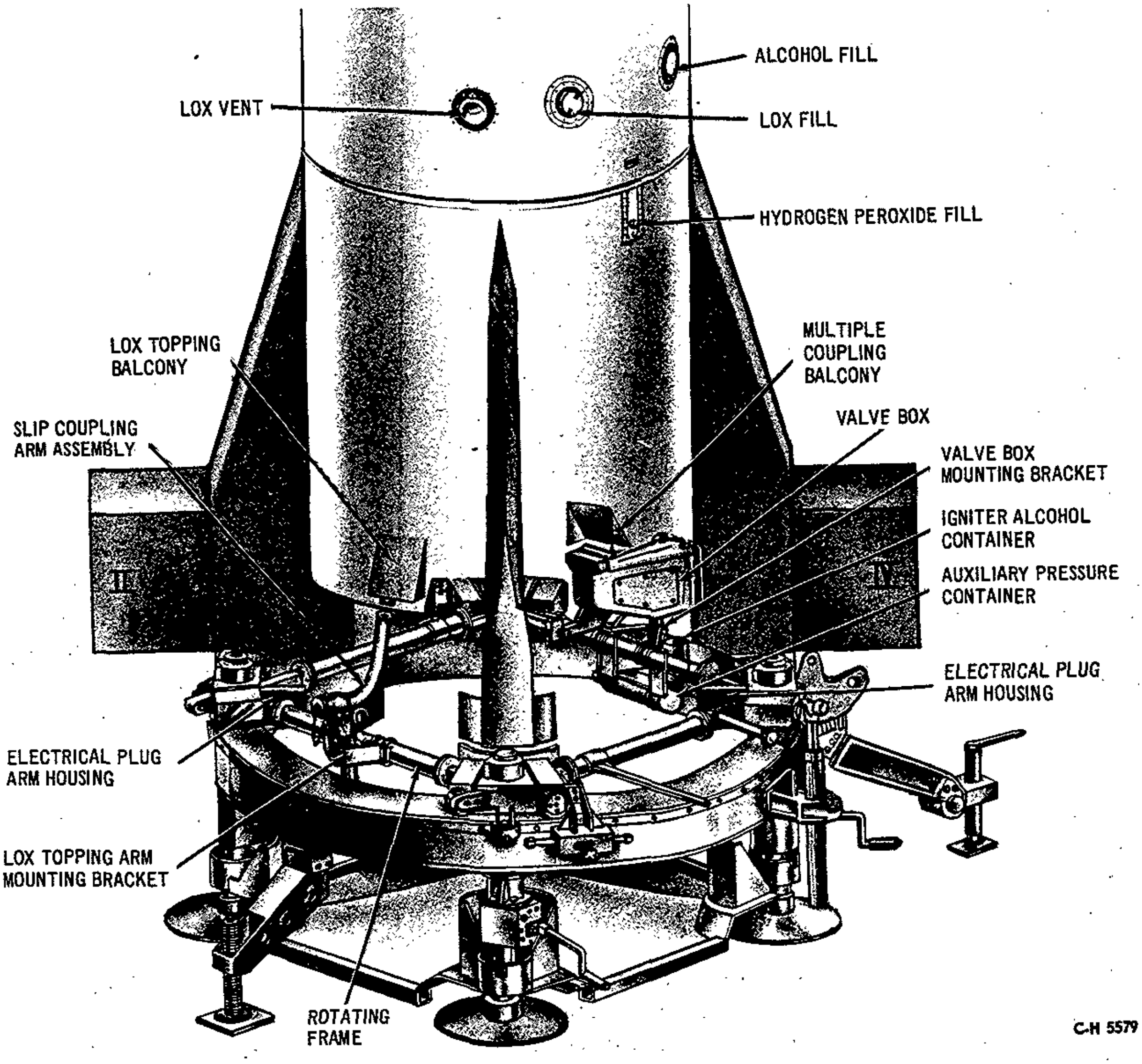


Figure 2-1. Umbilical Connections

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

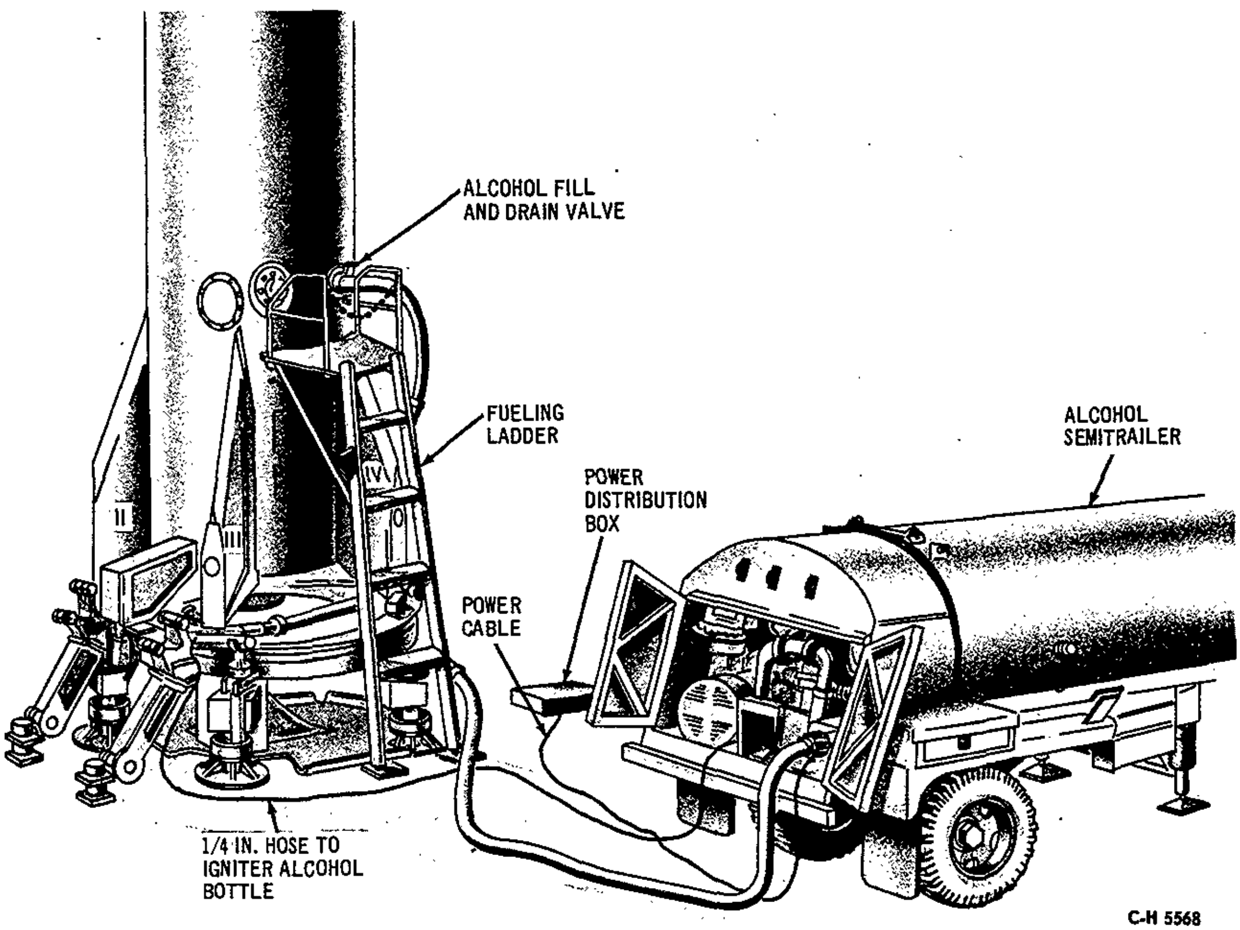


Figure 2-2. Alcohol Filling

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.

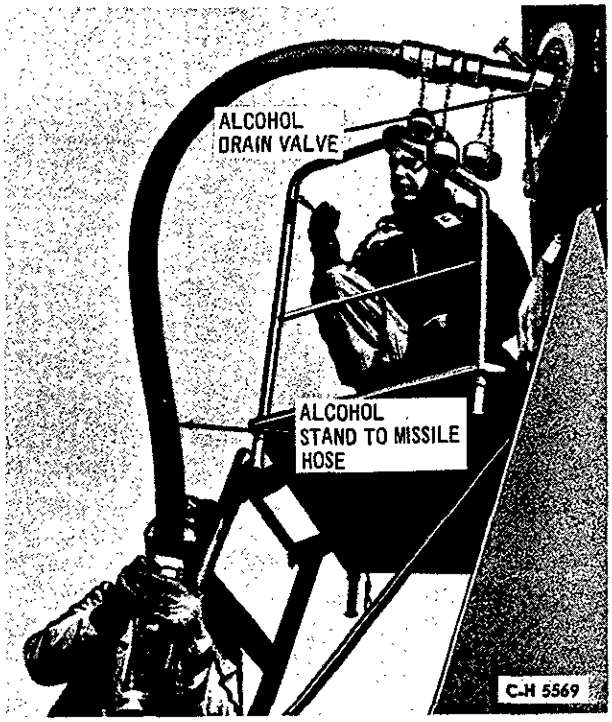


Figure 2-3. Alcohol Fill and Drain Valve

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.

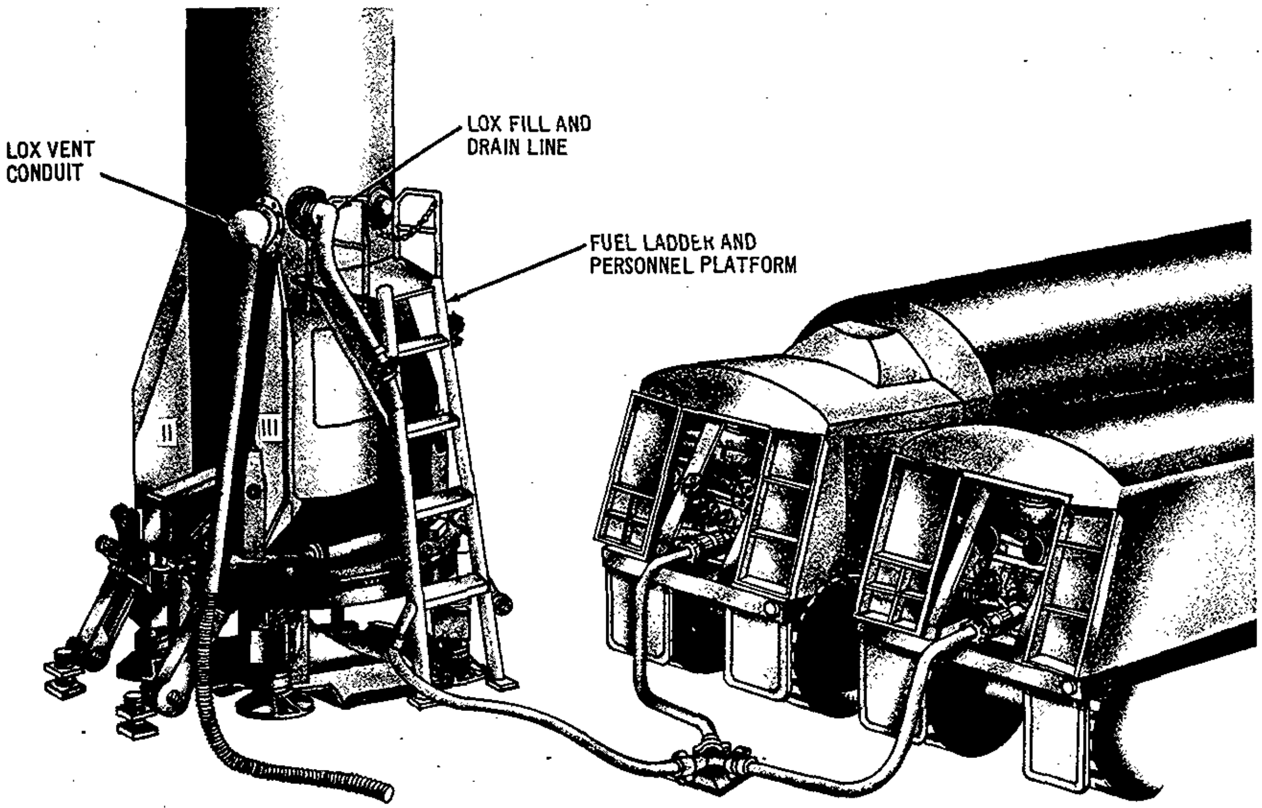


Figure 2-4. Lox Fill and Venting

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).

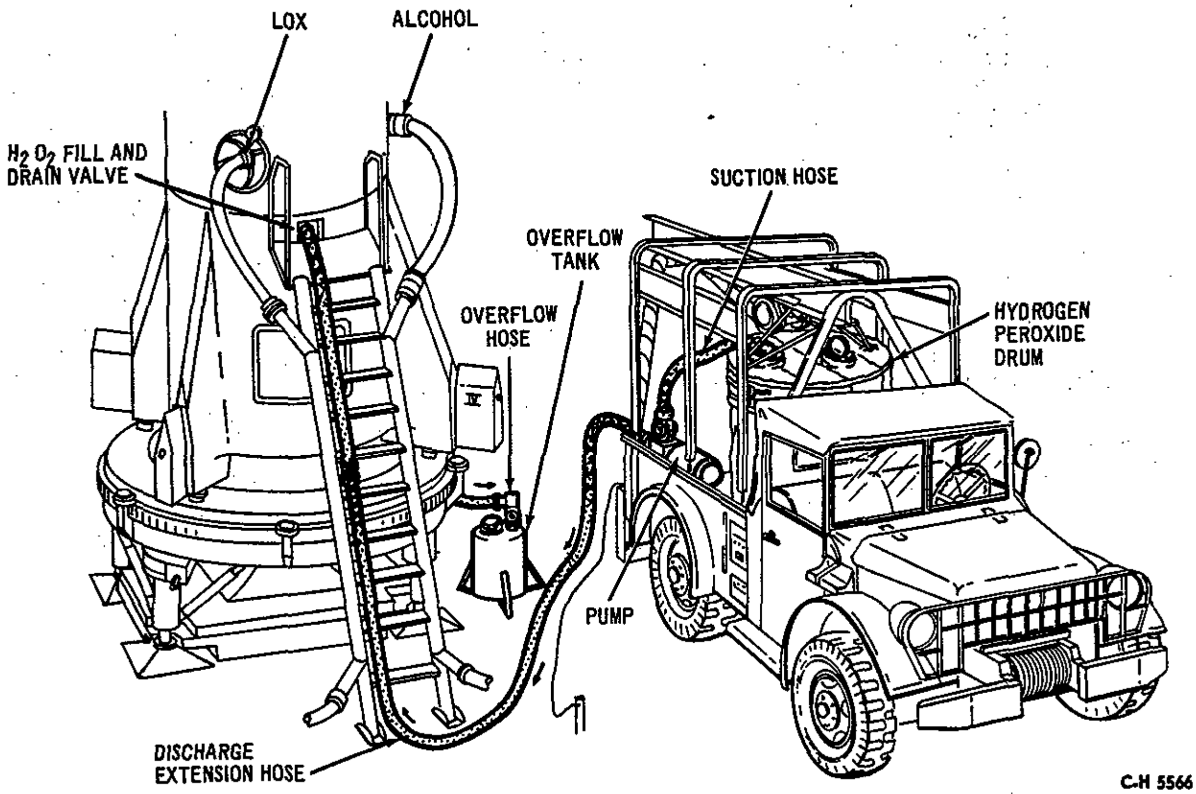


Figure 2-5. Hydrogen Peroxide Filling

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.

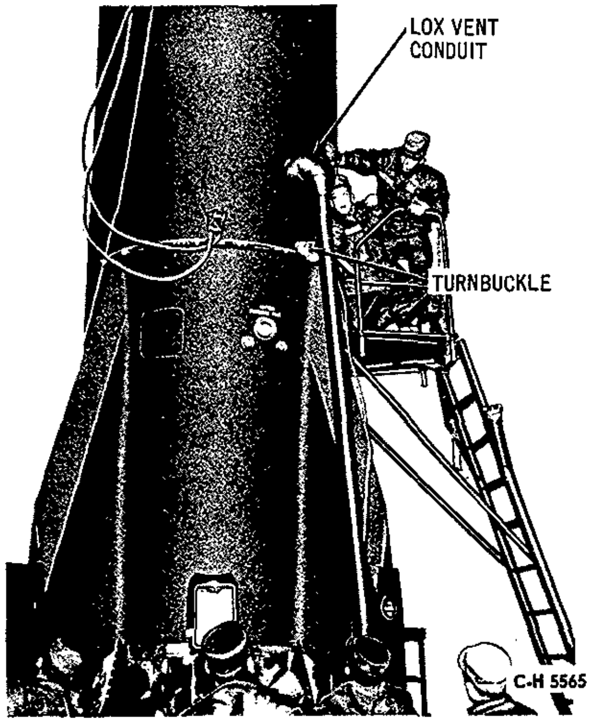


Figure 2-6. Lox Vent Conduit Installation

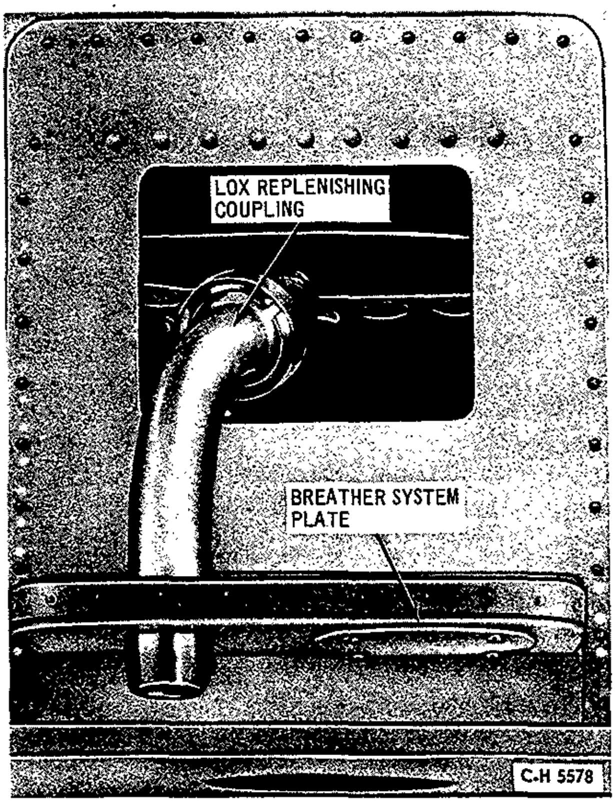


Figure 2-7. Lox Topping Balcony Assembly

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.

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.

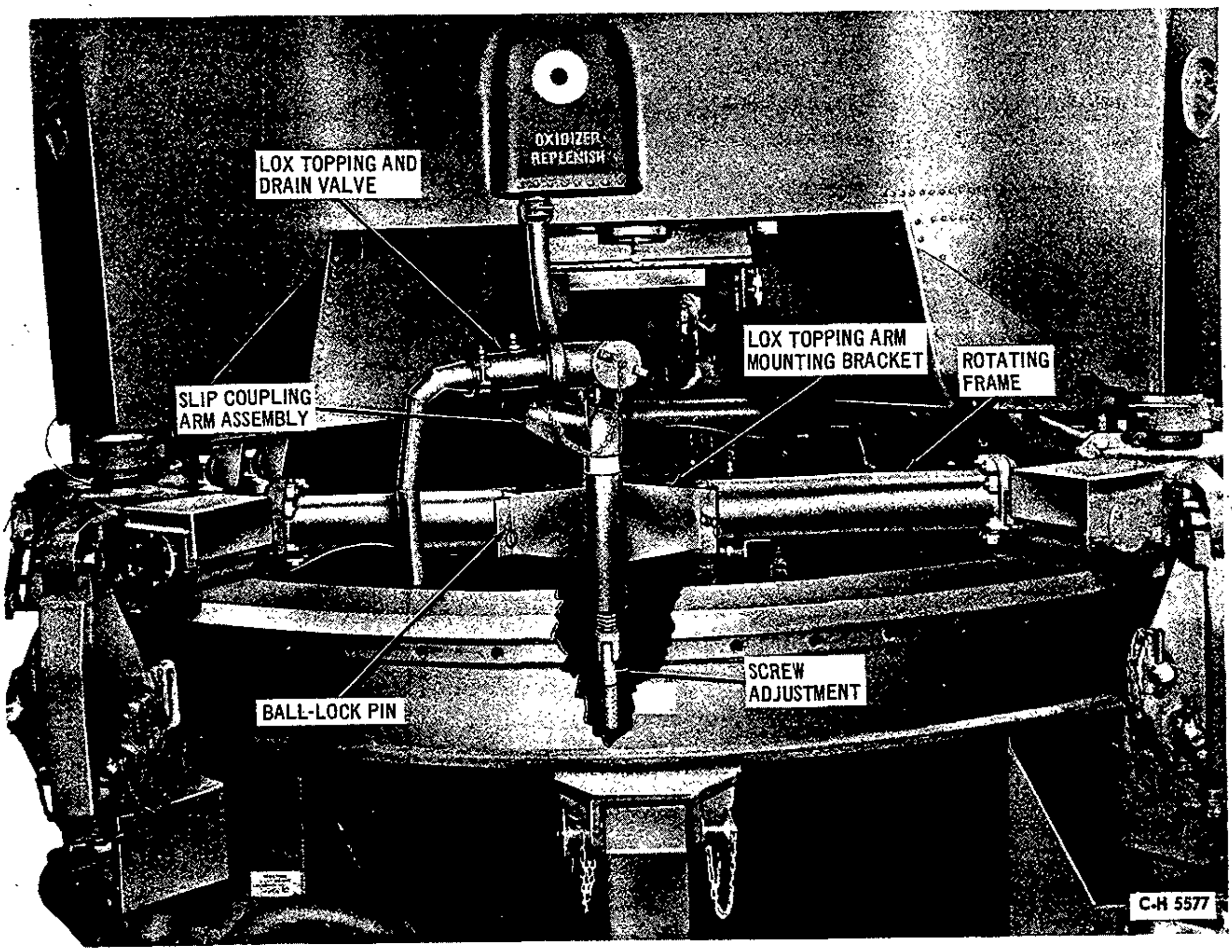


Figure 2-8. Lox Topping Assembly

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.

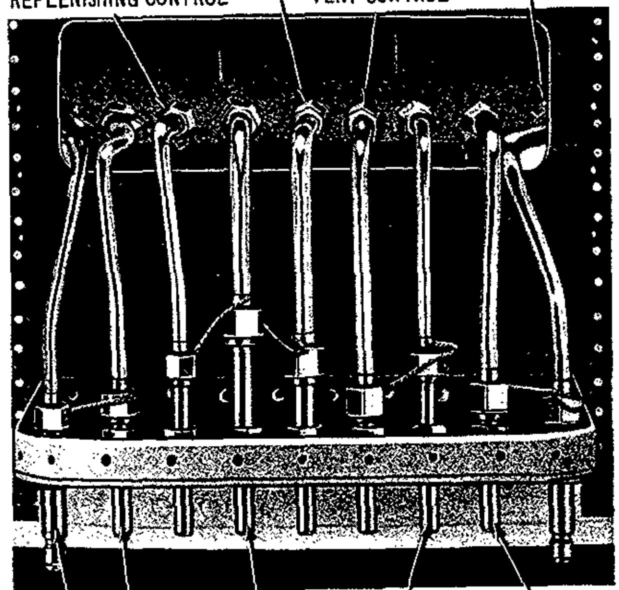


Figure 2-9. Pneumatic Couplings Balcony (Cover Removed)

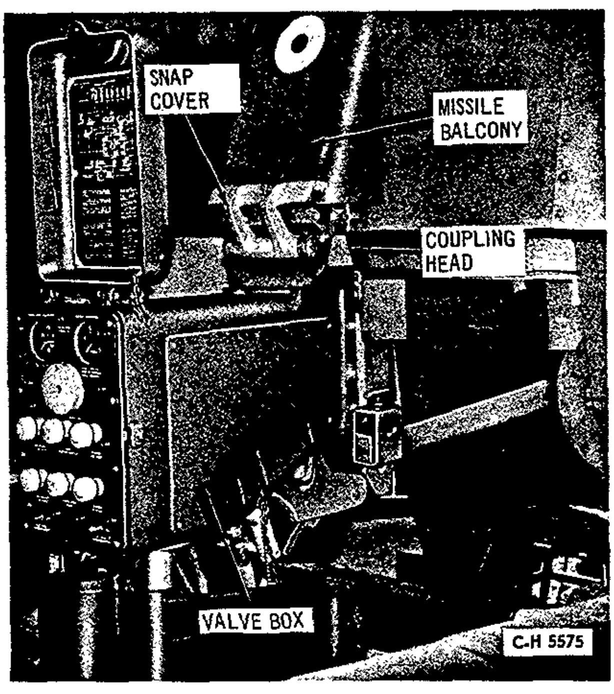


Figure 2-10. Valve Box Installed

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.

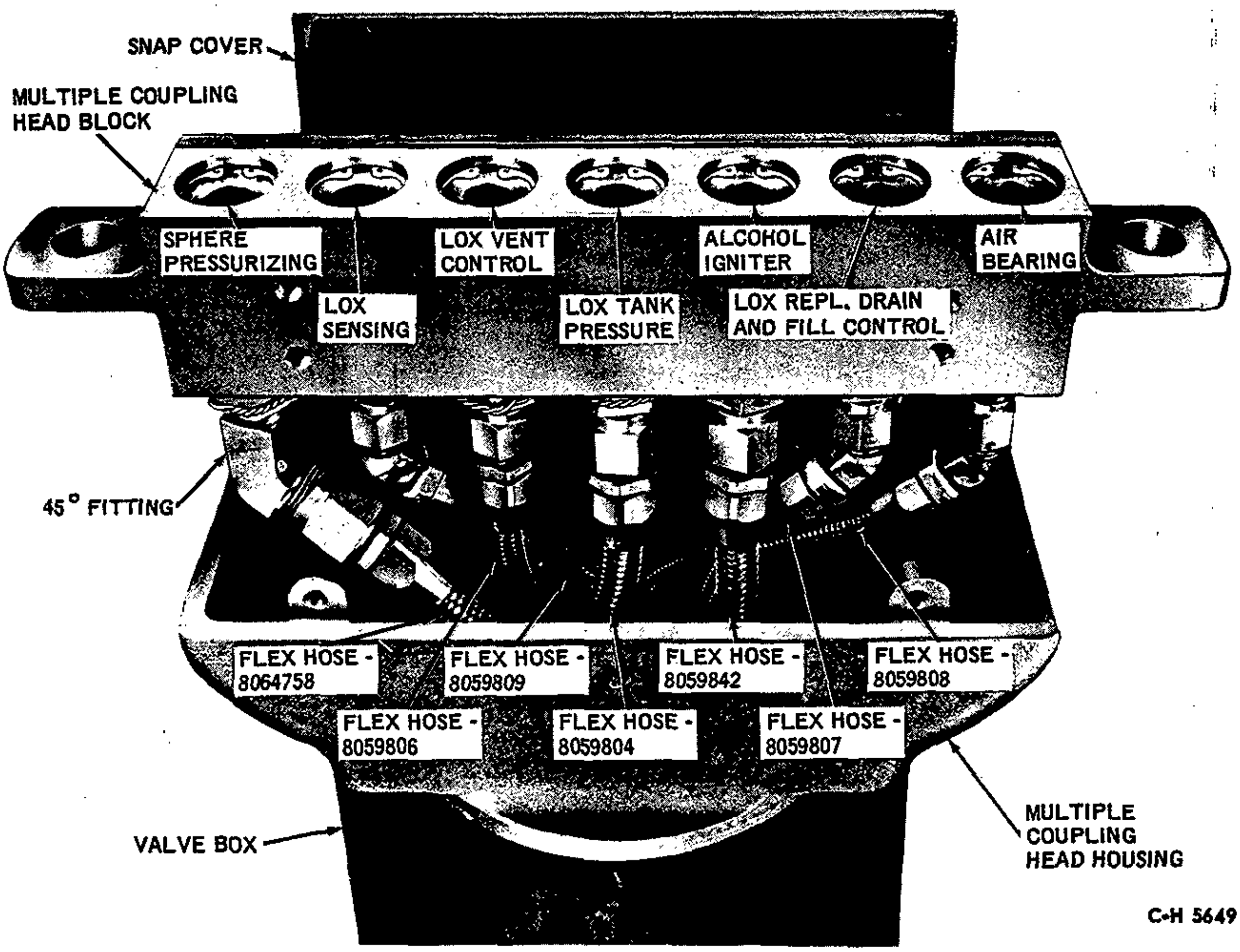


Figure 2-11. Valve Box Multiple Coupling Head

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).

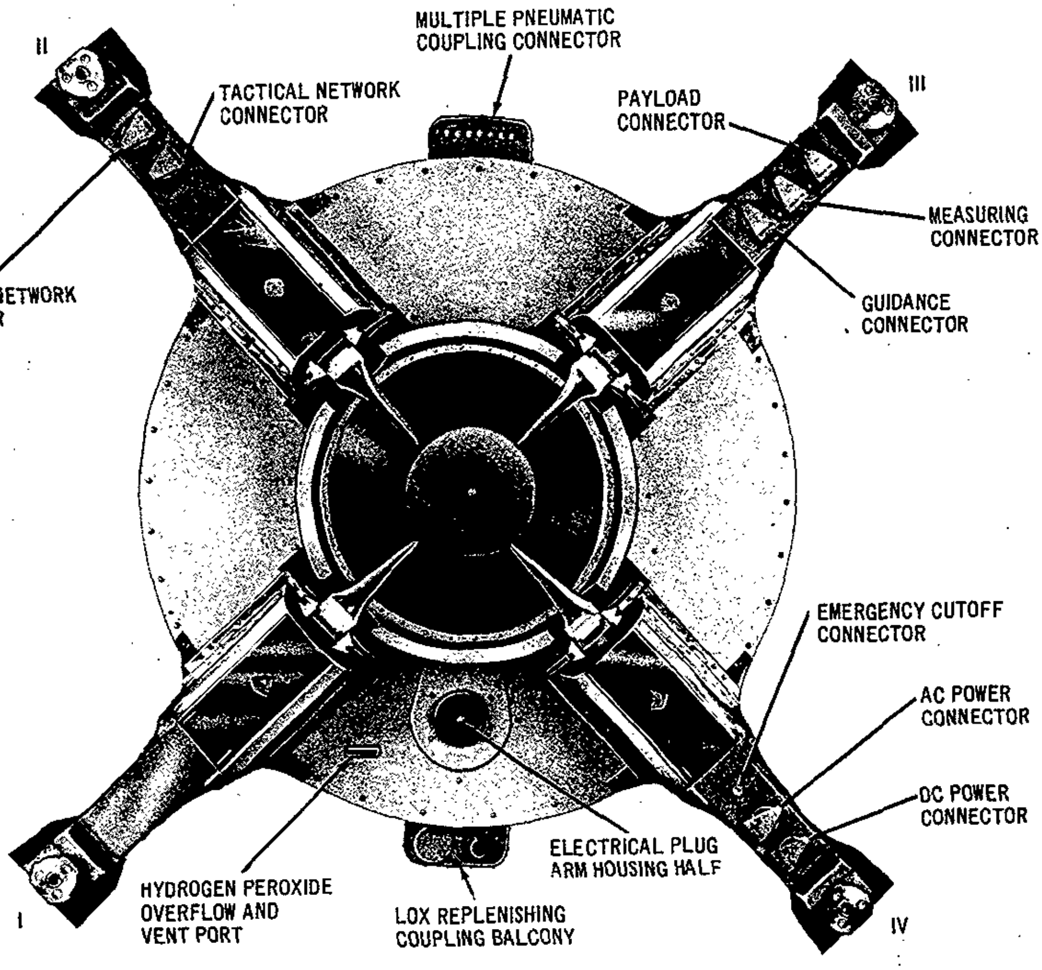


Figure 2-12. Vehicle Electrical Ground Support Connections

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.

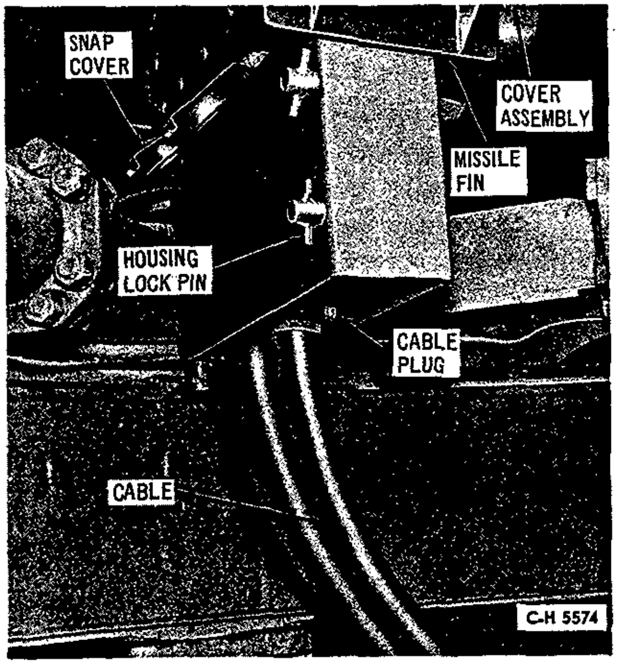


Figure 2-13. Electrical Plug Arm Housing

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).

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.

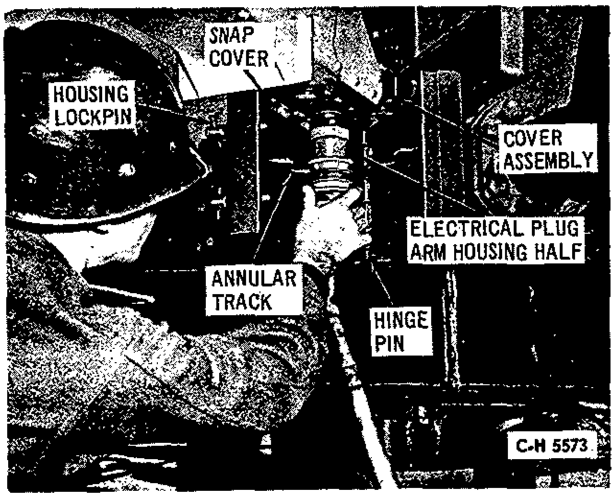


Figure 2-14. Installing Electrical Plugs

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

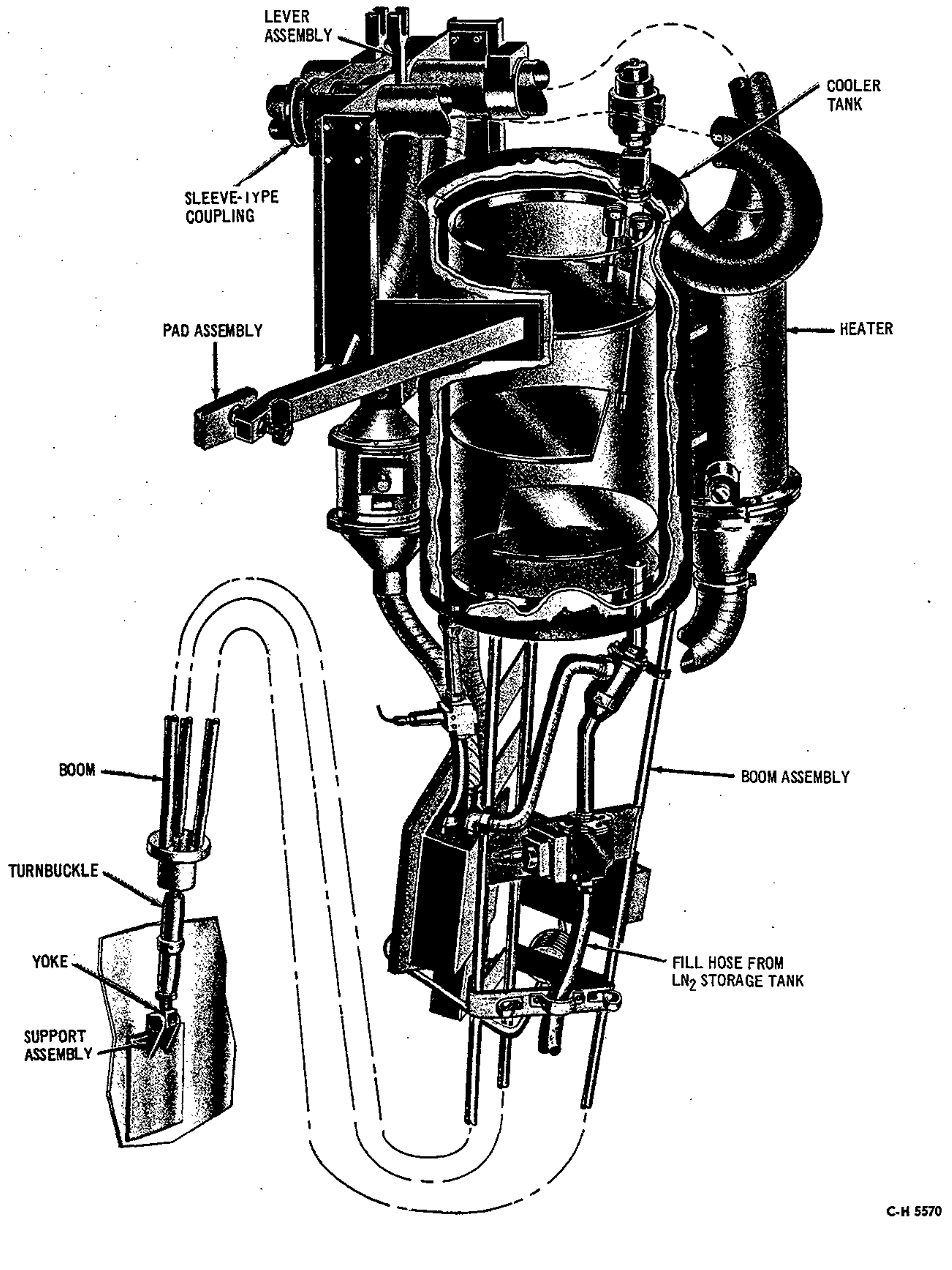


Figure 2-15. Heater-Cooler Tank Assembly

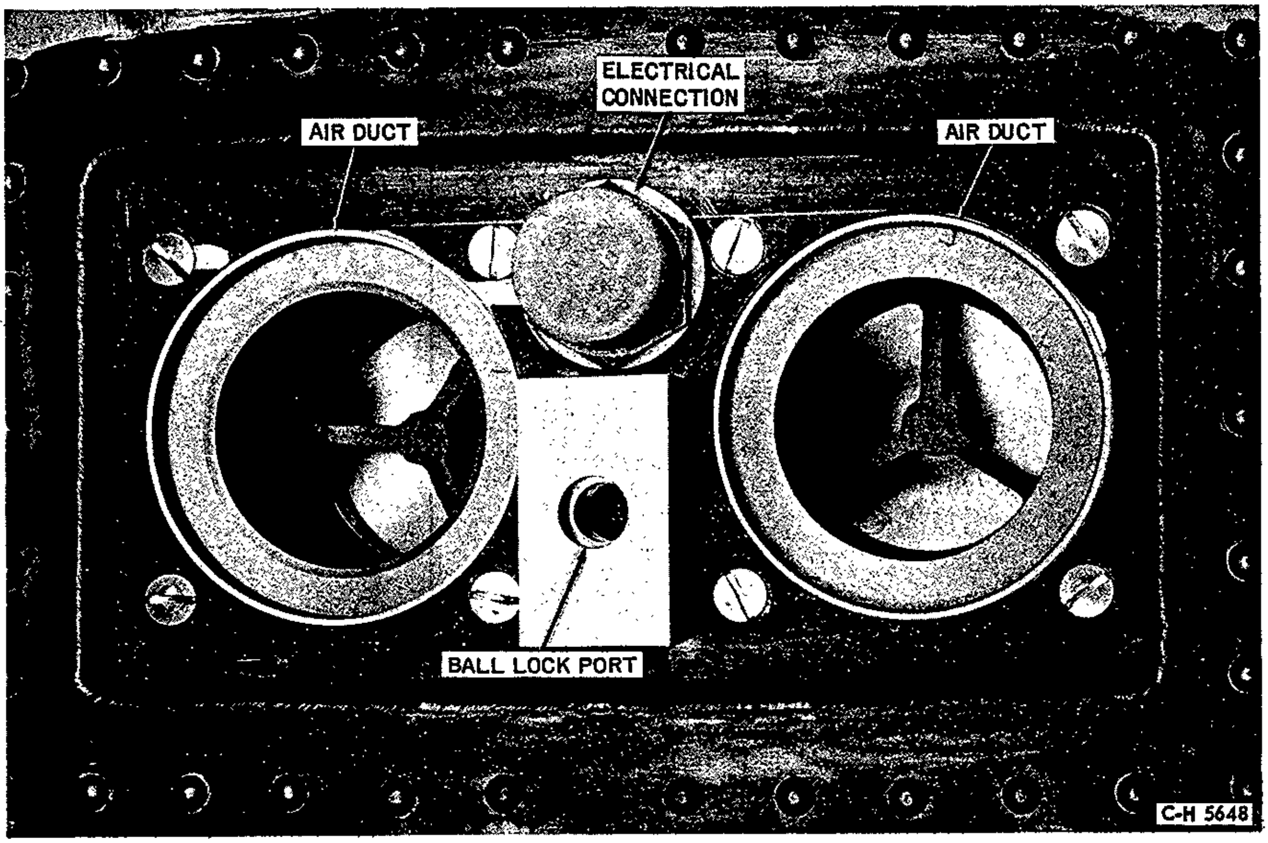


Figure 2-16. Vehicle Receiver Plate

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

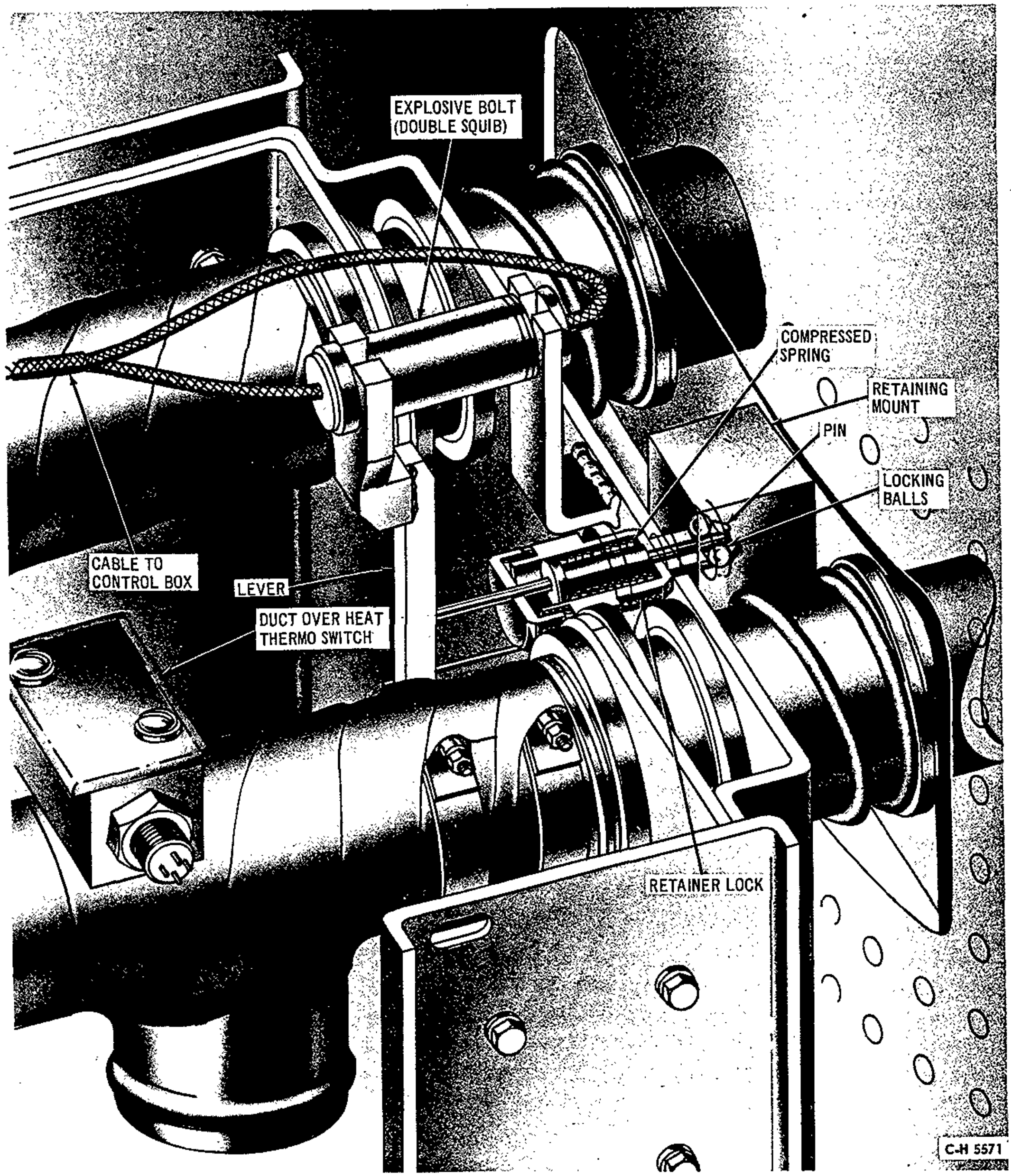


Figure 2-17. Quick-Release Mechanism Heater-Cooler Tank Assembly

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.

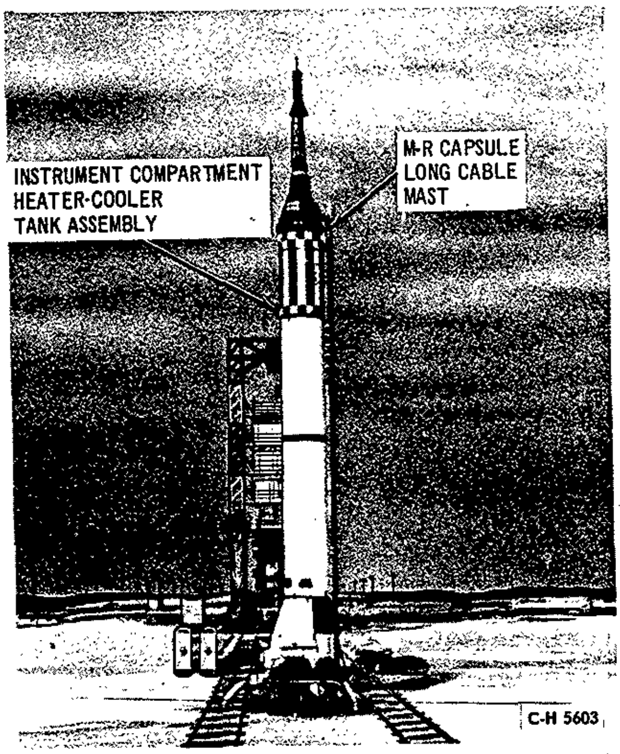


Figure 2-18. Mercury-Redstone

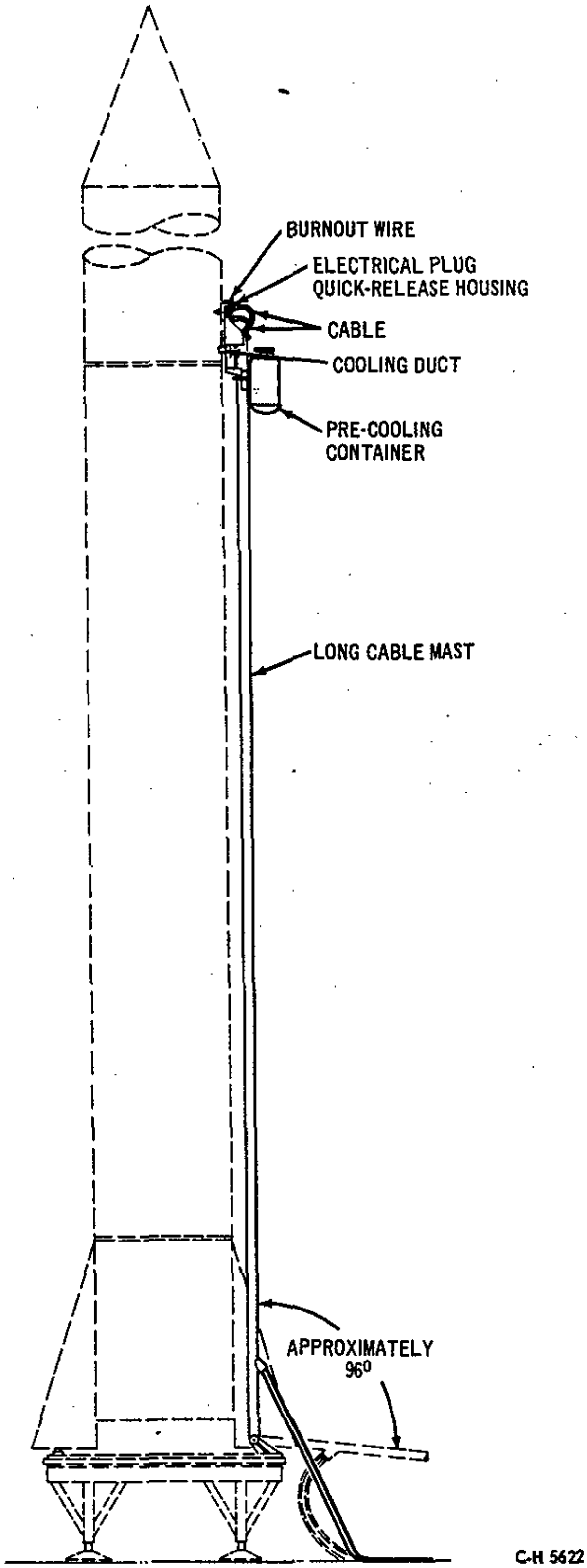


Figure 2-19. Long Cable Mast Redstone R&D Vehicle

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.

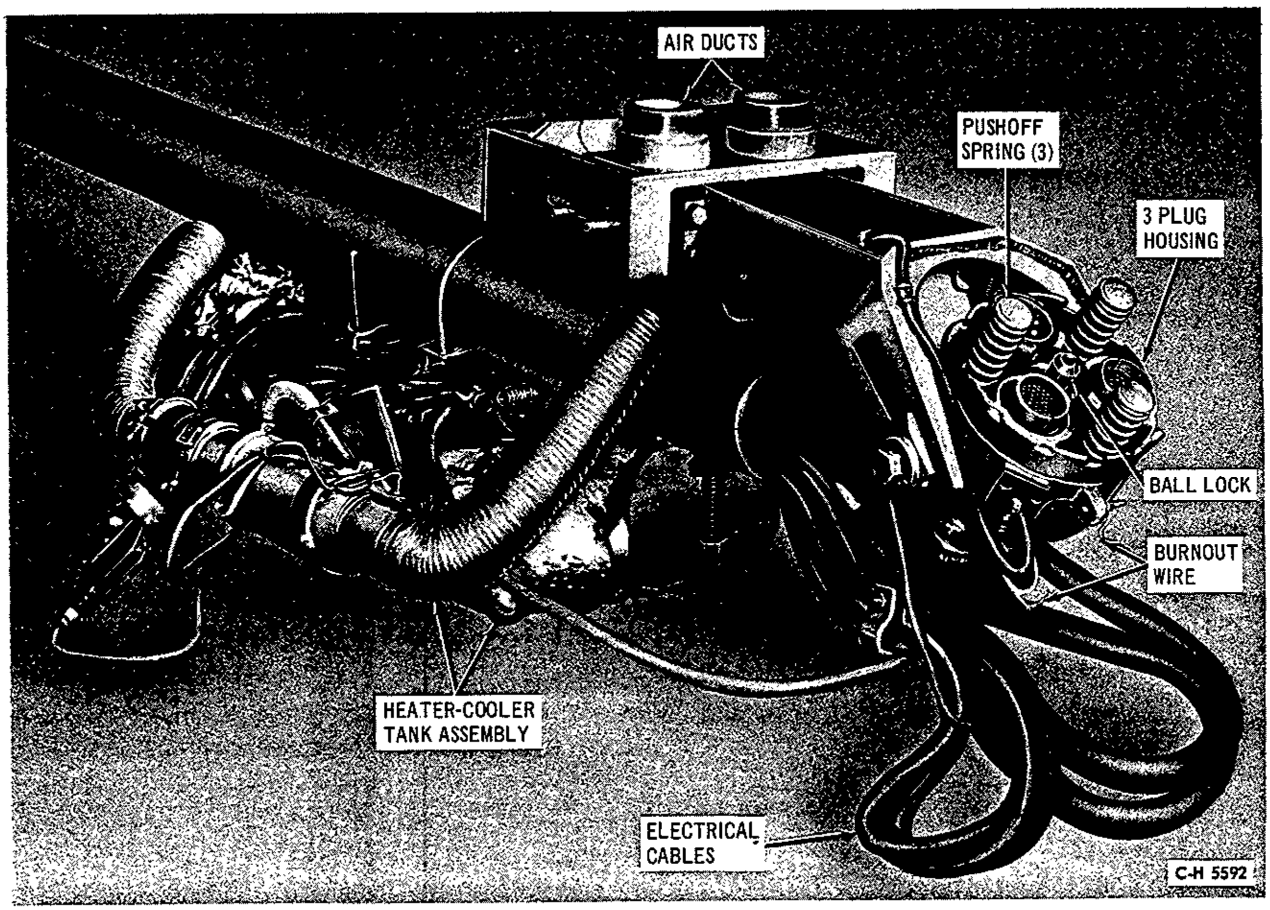
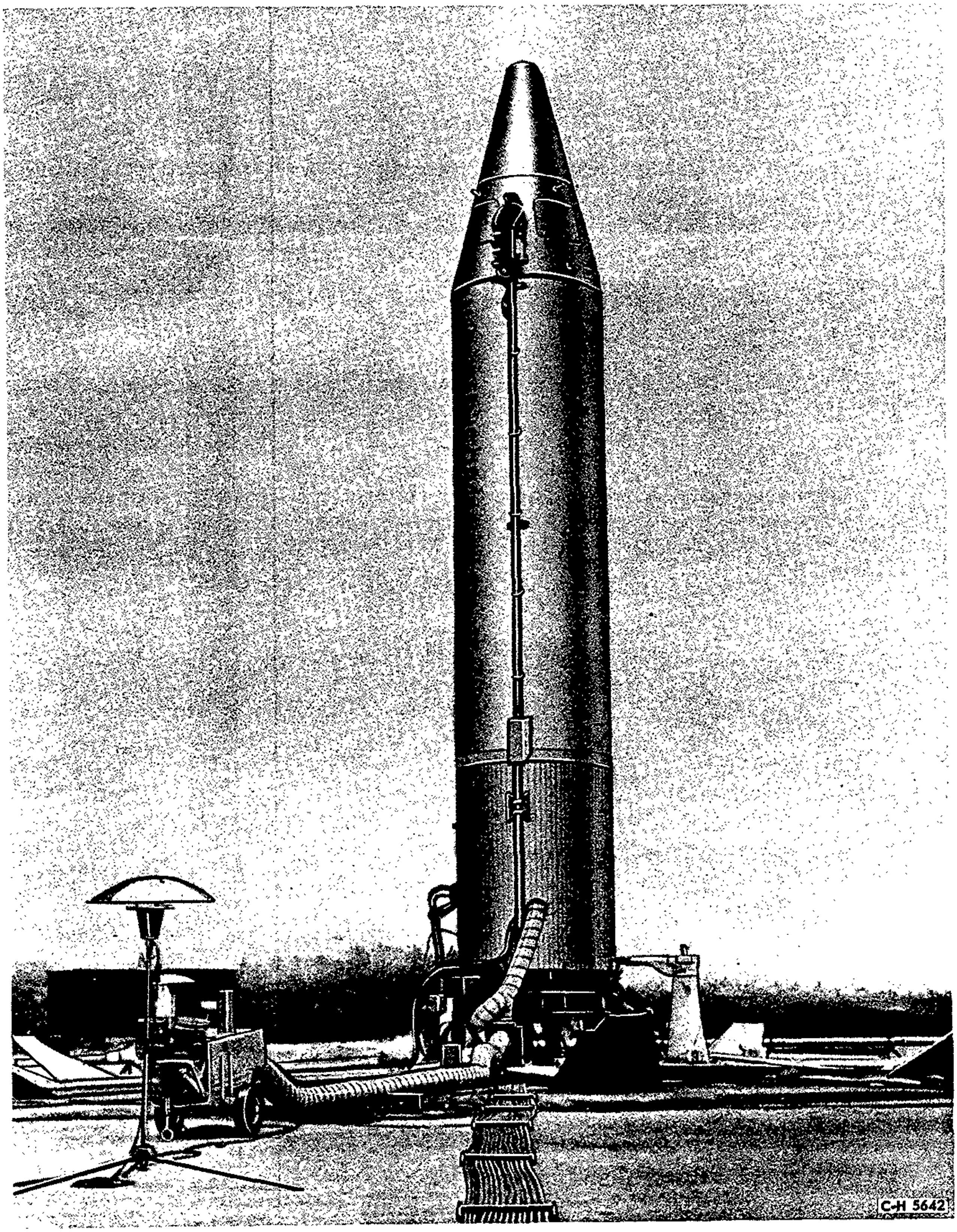


Figure 2-20. Long Cable Mast After Release

SECTION III
JUPITER


C-H 5642

SECTION III

JUPITER

INTRODUCTION

The Jupiter (USAF Model SM-78 missile) was an intermediate range ballistic missile designed to perform automatically the checkout, fueling, target alinement, ignition, and launch to the target within the specifications of the Army and later the Air Force. In order to accomplish this automatic operation, much development was done in the field of quick-release mechanisms for umbilical connections. Not all of this work was entirely successful, particularly the LOX and fuel connections

A further complication in the design of the umbilical system was imposed by the Jupiter's range and payload specifications, which made it expedient to eliminate all unnecessary weight from the vehicle. This was accomplished by reducing the amount of on-board pneumatic and electrical equipment used for prelaunch checkout and by making this equipment a part of the ground support equipment. This solution of weight reduction necessarily increased the number and functions of the electrical and pneumatic umbilical connections to the missile.

To reduce the amount of time necessary to erect and launch a vehicle at the launch emplacement, the missile arrived with a number of umbilical connections to the vehicle already made This was accomplished through the use of an auxiliary ring (figure 3-1) from which all of the umbilical connections were attached to the vehicle. The ring was attached to the vehicle at the missile assembly and maintenance area. The launcher and other ground support equipment were emplaced before receipt of the missile. After some of the auxiliary ring accessory components and the warhead were installed, the missile was erected on the launcher; the remaining auxiliary ring accessories were installed, and ground connections were made to the auxiliary ring.

The auxiliary ring assembly was a circular, hollow, welded steel construction. Six pairs of pneumatically-operated missile tail grabs, spaced equally around the circumference, secured the auxiliary ring to the missile. The ring served as a means of adapting the missile to the launcher and provided space for mounting the launching accessories. Pneumatic, hydraulic, and electrical cables, connecting various accessories, were routed through the hollow structure for protection from missile takeoff blast. Also, three liftoff switches were mounted in the ring with the actuators protruding through. Brackets and supports around the outside of the ring accommodated the valve control system assembly, fuel start system assembly, LOX start system

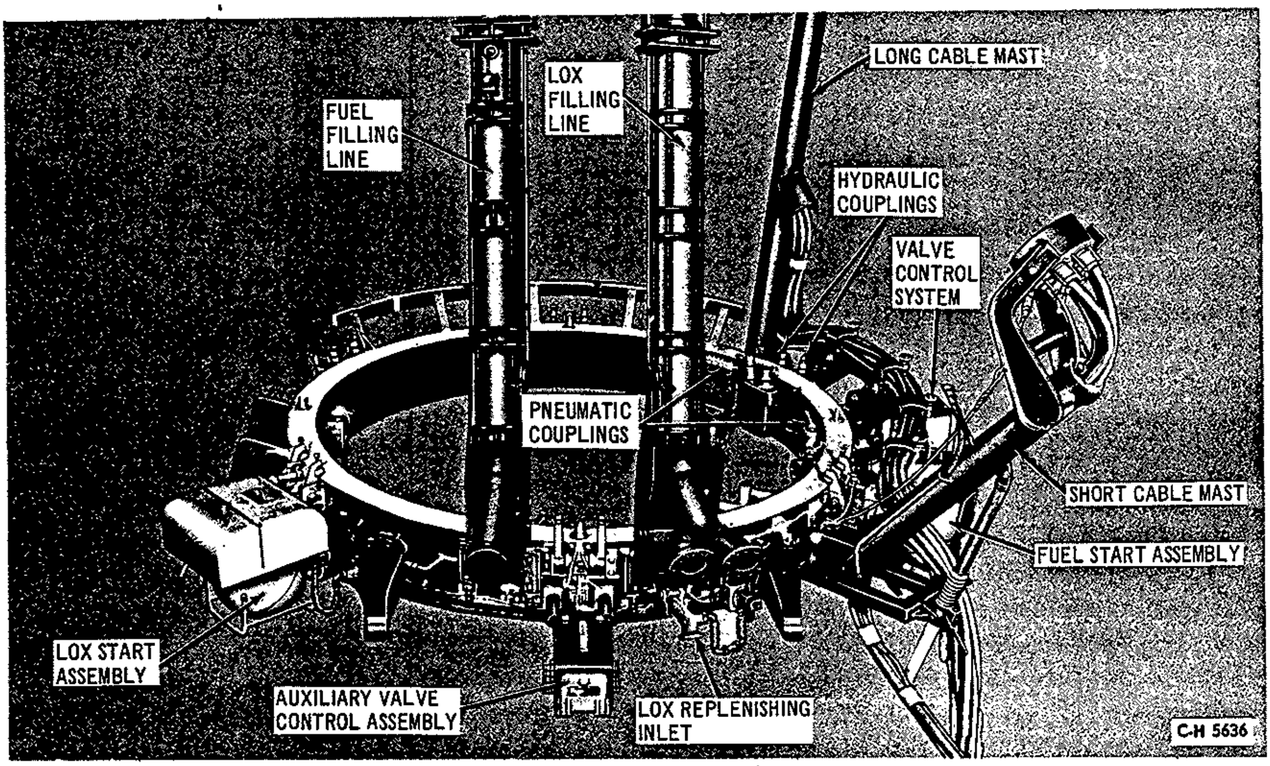


Figure 3-1. Auxiliary Ring with Umbilicals Installed

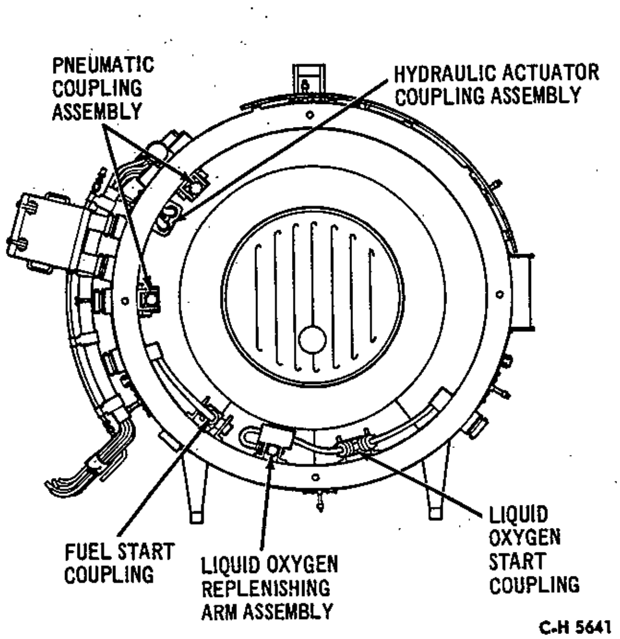


Figure 3-2. Auxiliary Ring Components Assemblies

assembly, auxiliary valve system assembly, LOX level control system assembly, the long and short cable masts, the propellant masts, and other launch accessories (including two pivot bracket arms, a snubber bracket arm, and a bracket for mounting the laying system reflector prisms). Two cable harnesses and a pneumatic supply line were also located on the ring. The inside surface of the ring provided mountings for the LOX start coupling, hydraulic actuator coupling assembly, and two pneumatic coupling assemblies (figure 3-2). These assemblies were component assemblies of the auxiliary ring.

Although the Jupiter system provided an automatic launch with automatic remote disconnect of the umbilical connections, the connections were made manually.

FUELING

RP-1 Fuel. The fuel filling assembly (figure 3-3), mounted on the auxiliary ring between fins I and IV, conducted RP-1 fuel from the fuel supply hose to the filling port on the missile tail unit. The filling assembly consisted of a 6-inch stainless steel tube approximately 142 inches in length, a masthead assembly, a lower support bracket assembly, ring supports, a hydraulic arrestor, and a pressure switch. The masthead assembly consisted of a 90-degree elbow, a locking and release mechanism, two kickoff cylinders, and two hose assemblies. The fuel filling assembly was installed at the launch emplacement after the missile was erected.

After certain adjustments had been made and the masthead had been secured to the missile filling port, the flexible fuel transfer hose was connected to the bottom of the fuel mast with a Camloc connector. The pneumatic lines to the mast release mechanism and kickoff cylinders were connected to the auxiliary valve control system assembly.

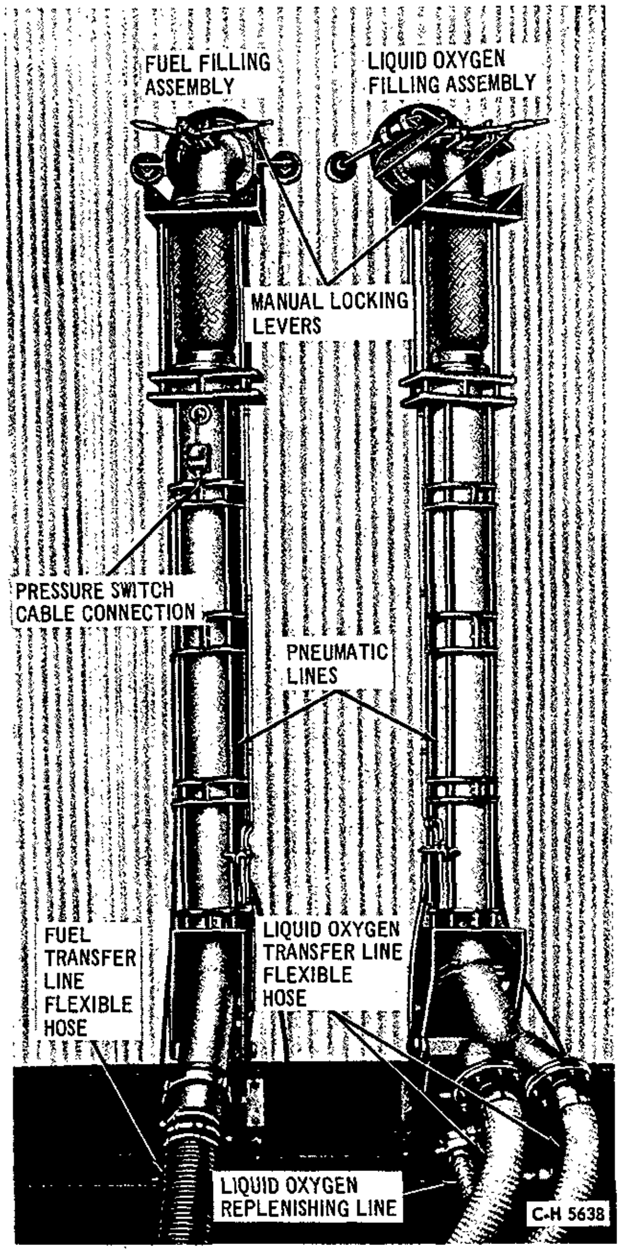


Figure 3-3. Lox and Fuel Filling Assemblies Attached

The masthead (figure 3-4) was mechanically locked to the missile filling port with a mechanical locking lever that was rotated clockwise. To aid in making this connection from the ground, a long pole was used to push the mast assembly up to the vehicle and rotate the locking mechanism (figure 3-5). Because the connection joined cylindrical mating parts, proper alinement was critical and difficult to achieve without damaging the O-ring seal of the masthead. Vertical alinement of the fuel mast assembly was accomplished by two adjusting screws in the bottom of the mounting bracket assembly. Lateral alinement was accomplished by adjusting a pin on the mounting bracket. There was no self-alinement feature built into the masthead at the connection, and first contact was made by the O-ring seal on the face of the masthead. With the critical alinement problems of the cylindrical type of coupling, frequent damage of the seal and many leakage problems with the fueling connection during the filling operation occurred. Development work was still in progress on this connection when the Jupiter program was phased out.

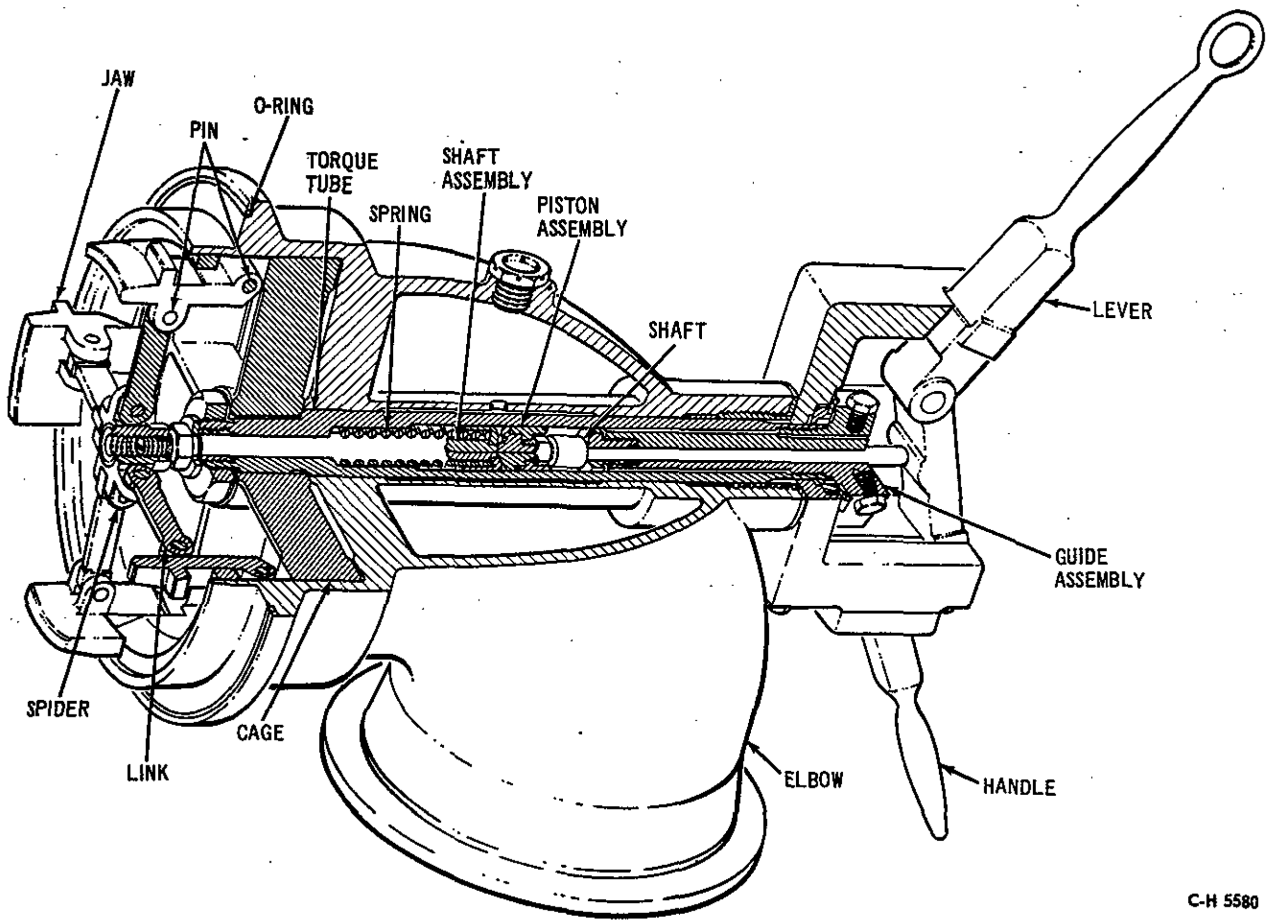


Figure 3-4. Fuel Masthead Assembly

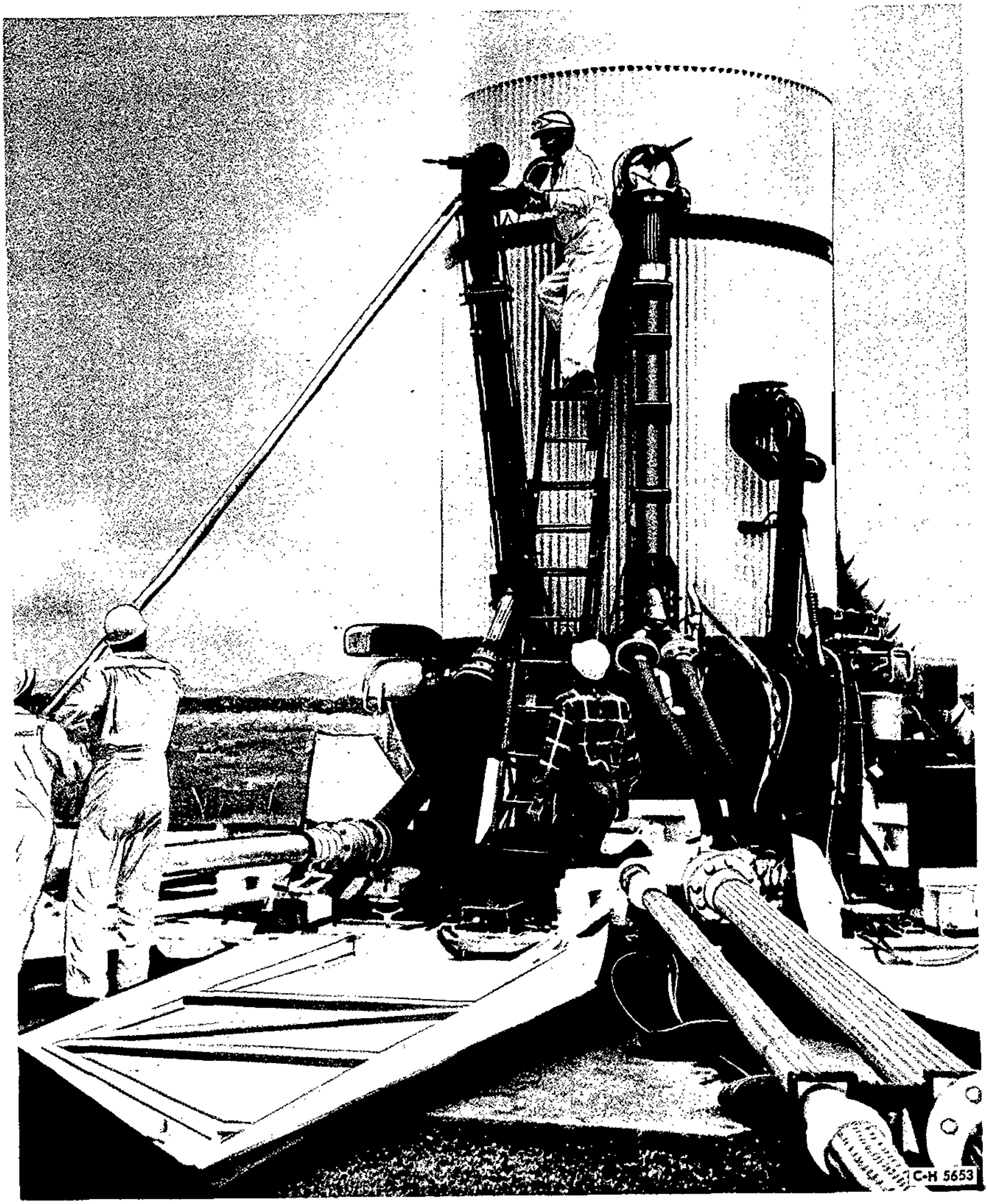


Figure 3-5. Raising Fueling Mast Assembly

Disconnect of the fueling masthead was accomplished with a 750 psig pneumatic system connected to the auxiliary valve control system assembly. Pneumatic pressure actuated the piston (figure 3-4) and moved the spider forward. Through the linkage between the spider and the jaws holding the connector to the missile, the jaws were pulled in by the forward motion of the spider, thus releasing the connection. Two pneumatic kickoff cylinders pushed the masthead clear of the missile. If the pneumatic disconnect and retract system failed, the masthead could be disconnected manually with either a lanyard or a pole attached to the lever release handle. An arresting arm checked the fall of the masthead at an angle approximately 35 degrees from the vertical.

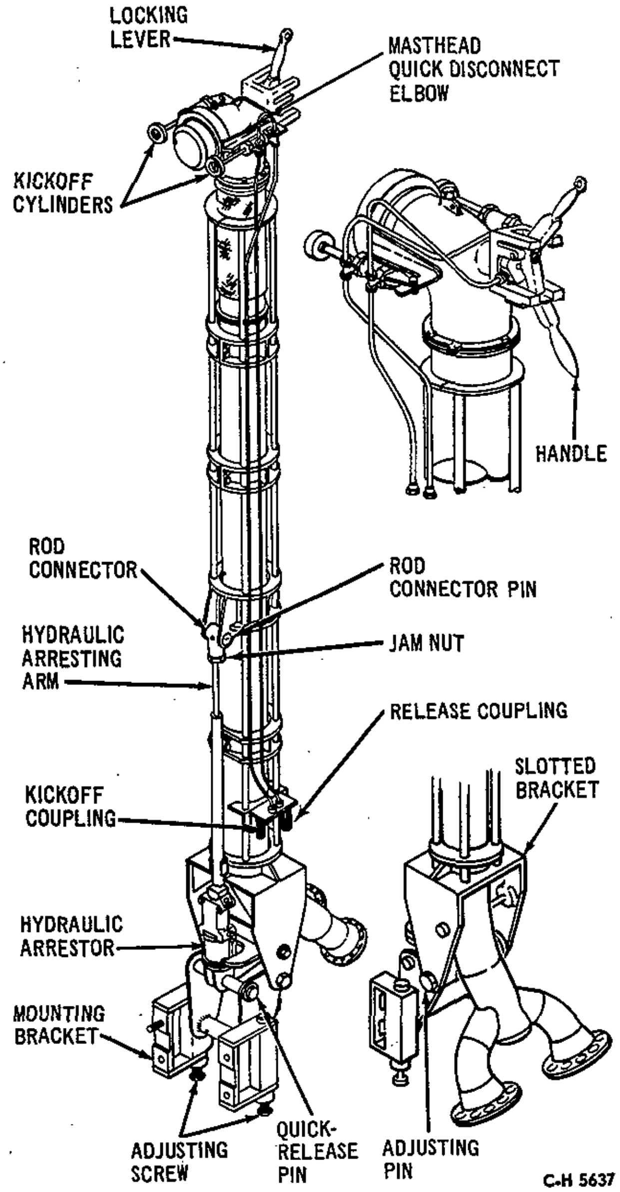


Figure 3-6. Lox Filling Assembly

<u>Liquid Oxygen (LOX).</u> The LOX filling assembly, mounted on the auxiliary ring between fins I and II (figure 3-6), conducted LOX from two supply hoses to the LOX filling port on the missile tail unit. It also had provisions on the mounting bracket for a hose connection to the LOX replenishing system. The LOX filling assembly (figure 3-6) was identical with the RP-1 filling assembly, except for the provisions at the bottom for the connection of two supply hoses and a LOX replenishing hose. Also, the overall length of the assembly was longer. The assembly was installed at the launch emplacement after the missile was erected. The assembly connected to the ground supply hoses with flange connections, bolted together with eight bolts.

The LOX masthead assembly (figure 3-7) was alined and connected to the missile in the same manner as the fuel masthead assembly.

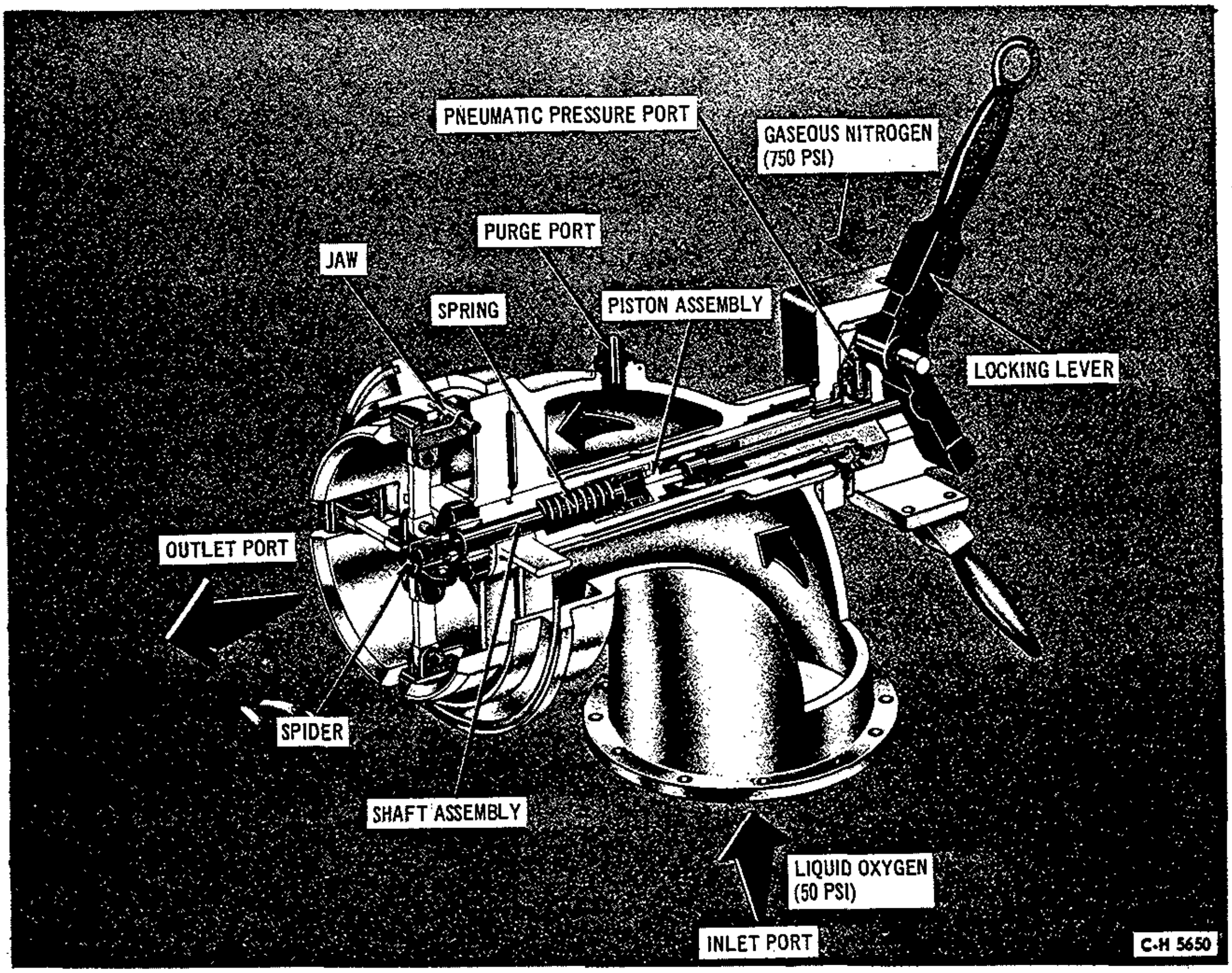


Figure 3-7. Lox Masthead Assembly

Because of the difference in expansion rates of the various materials involved in the connection between the masthead and the missile, and because only a small misalinement would cause difficulty in the release of the masthead, alinement of the LOX masthead was even more critical than that of the fuel masthead. In addition, any damage to the seal that would cause leakage could result in the masthead's freezing to the missile and failing to release.

Disconnect, release, and retract of the LOX masthead assembly was the same as the fuel masthead; however, the cryogenic problems involved with this connector were more than the design could overcome. Over one thousand Engineering Orders (E. O. 's) were issued to cover design changes, servicing, and operation of the connector in efforts to achieve its satisfactory operation during the disconnect and release cycle.

A number of design factors contributed to the failure of this connector for cryogenic use: First, the cylindrical type of connector requires nearly perfect alinement to obtain an adequate seal and to prevent binding of the mating parts. The natural arc of retraction tended to misaline the mating parts and cause binding, and the connector had no built in self-alining feature. Second, the moving parts operating in the LOX environment were subject to contraction, which caused binding of the parts and release failure. When the tolerances were opened up to reduce the binding, the parts were subject to the accumulation of condensation, which then would freeze the parts. Third, the formation of condensation during the cool-down of the head produced icing conditions on the parts and subsequent release failures.

Although the Jupiter program was phased out before the LOX connector could be completely redesigned, design work had been accomplished and the resulting connector (figure 3-8) became the prototype for the Saturn LOX and fuel filling connections. Because of further advancement in the art, this design was never used; the connector is shown here for its historical value in umbilical connector development. The connector was a manually connected type. Initial turning of the locking handle locked the ball lock in place.

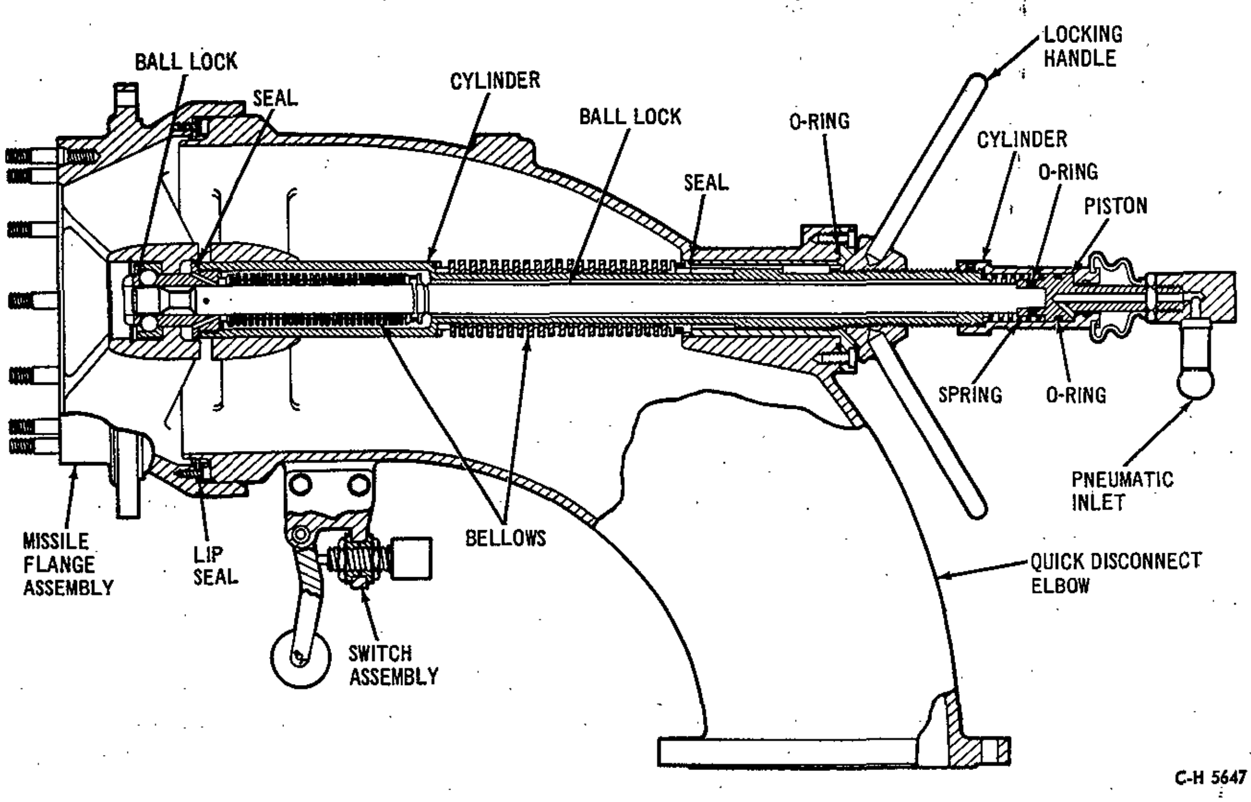


Figure 3-8. Prototype Lox Quick Disconnect Elbow with Ball Lock

Note that the ball lock first made contact with the missile counterpart and helped to aline the connection. Continued turning of the locking handle pulled the connection tight. Note that the chamfered edge of the missile counterpart and the leading edge of the connector tended further to aline the connection before the O-ring seal made contact. A bellows arrangement protected the release shaft from contact with LOX. The piston end of the release shaft was outside the connection and was not subject to cryogenic factors. 750 psig pneumatic pressure was used to move the piston forward and drop the locking balls and release the connection. Kickoff was accomplished with two pneumatic cylinders.

Figure 3-9 shows another type of LOX quick disconnect which was designed for the Jupiter, but because of the phasing out of the Jupiter Weapon System it did not progress beyond the prototype stage.

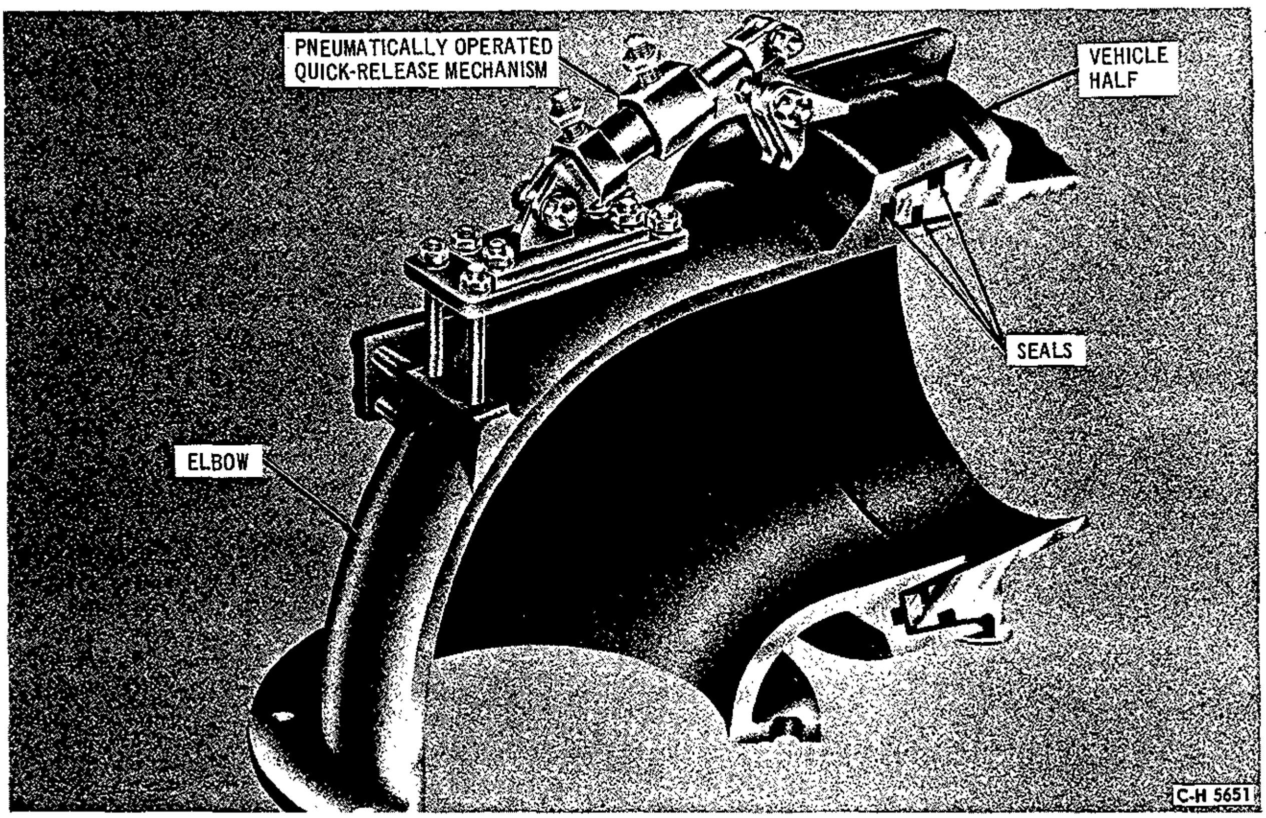


Figure 3-9. Prototype Lox Quick Disconnect Elbow

Fuel Start System. The fuel start assembly (figure 3-1) was attached to a coupling on the outside of the auxiliary ring between fins I and II. This assembly consisted of a 6.25-gallon spherical tank and its controls, the associated plumbing, a mounting boom, and a protective shroud. Nitrogen from the valve control system assembly at 3,000 psig reduced by a built-in regulator to 675 psig, was used to pressurize the tank. A control regulator, a liquid level sensor, solenoid valves, and the necessary pneumatic tubing and hoses were parts of the assembly. The assembly arrived at the launch emplacement in an aluminum container and was installed after the vehicle was raised to the vertical position.

The fuel start coupling (figure 3-10), a part of the fuel start assembly, was mounted on the inside surface of the auxiliary ring between fins I and II. It was installed at the missile assembly and maintenance area. The 1.25-inch slip-type coupling linked the fuel start assembly to the missile. The ground half of the coupling was gimbal mounted to permit movement, and a self-sealing feature prevented loss of fuel. The fuel start assembly was gravity filled

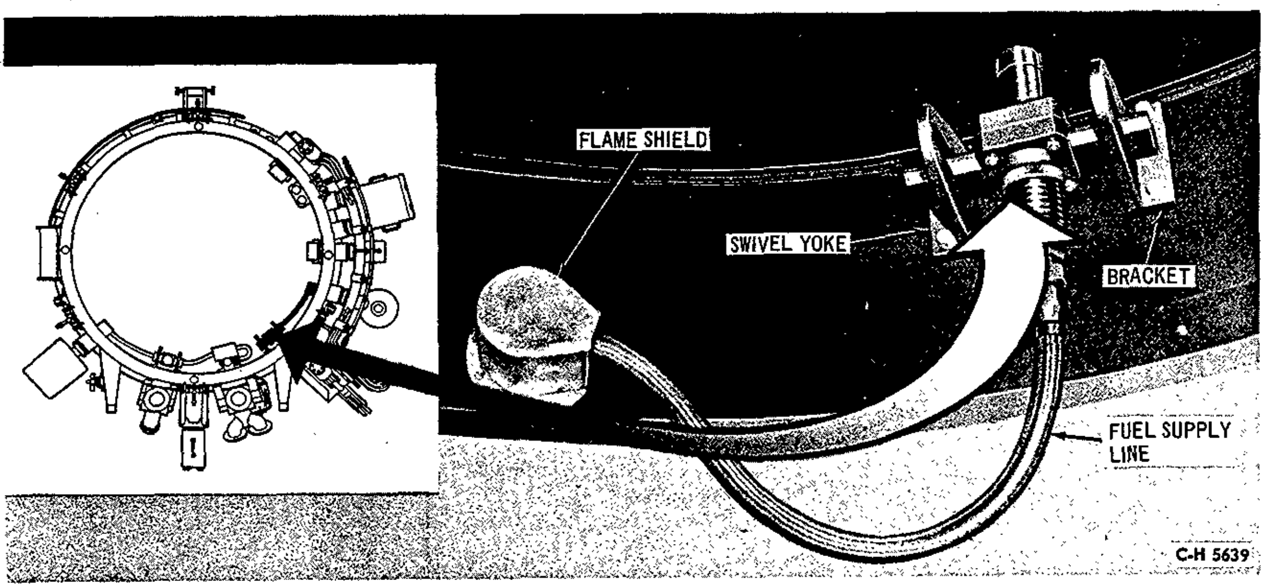


Figure 3-10. Fuel Start Coupling

through a T-fitting in the fuel duct inside the vehicle and through the fuel start coupling. A level sensor in the fuel start tank controlled the level of fuel by actuating a solenoid vent valve on the tank. Design of the fuel start coupling permitted 3 inches of missile travel with respect to the launcher before flow was discontinued. This ensured connection of the fuel start line after ignition until bootstrap occurred. The missile start line contained a check valve to prevent loss of fuel after liftoff.

LOX Start Assembly. The LOX start assembly (figure 3-1), mounted on the auxiliary ring midway between fins I and IV, supplied liquid oxygen, at a regulated pressure, to the rocket engine gas generator during the starting sequence. The assembly consisted of a 6.25-gallon spherical tank, its controls and associated plumbing, a mounting boom, and a protective shroud. 3,000 psig pneumatic pressure, from the auxiliary valve control system assembly, was reduced by a built-in regulator and provided the pressure for operating the assembly. The tank was filled through a line connected to the LOX replenishing arm via the Y-connection of the LOX start coupling. The assembly arrived at the launch emplacement in an aluminum container along with connecting tubing and hoses. The assembly was installed after the missile was erected.

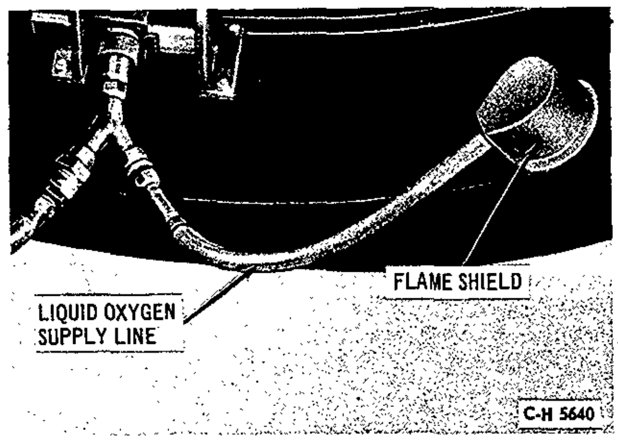


Figure 3-11. Lox Start Coupling

The LOX start coupling (figures 3-11 and 3-14) was a part of the LOX start assembly and was installed at the missile assembly and maintenance area. The LOX start coupling was mounted on the inside of the auxiliary ring near fin I and connected the ground LOX start assembly to the missile. It was a slip-type coupling that disconnected from the missile at liftoff. The launcher half of the coupling was self-sealing and was gimbal mounted to permit movement. A check valve was provided in the missile LOX start line to prevent reverse flow when the coupling was disconnected. The coupling permitted 3 inches of missile travel before the LOX flow was interrupted. This ensured connection of the LOX start line until bootstrap occurred.

HYDRAULIC

The hydraulic actuator coupling assembly (figure 3-12), mounted on the inside surface of the auxiliary ring at fin II, was a component part of the auxiliary ring. It was connected to the base of the missile. The assembly had two modified slip-type quick-disconnect couplings on a common spring-loaded mounting bracket covered by a flame shield. The coupling provided connections for supplying the missile hydraulic system with ground hydraulic pressure, during certain test procedures and during countdown, until the missile hydraulic system developed sufficient pressure. One coupling transmitted high pressure hydraulic fluid to the missile and the other returned the low pressure fluid.

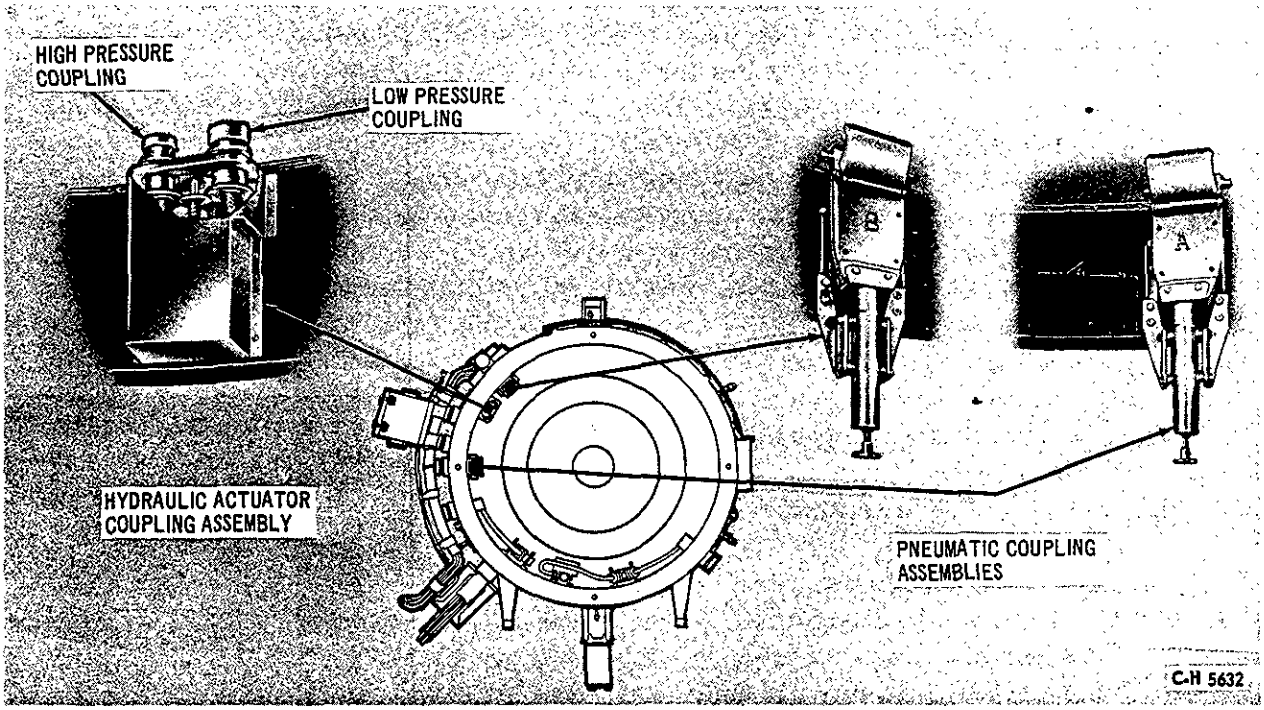


Figure 3-12. Hydraulic and Pneumatic Couplings

The high pressure coupling received its hydraulic supply through a high pressure filter mounted on one of the brackets of the long cable mast assembly (figure 3-13).

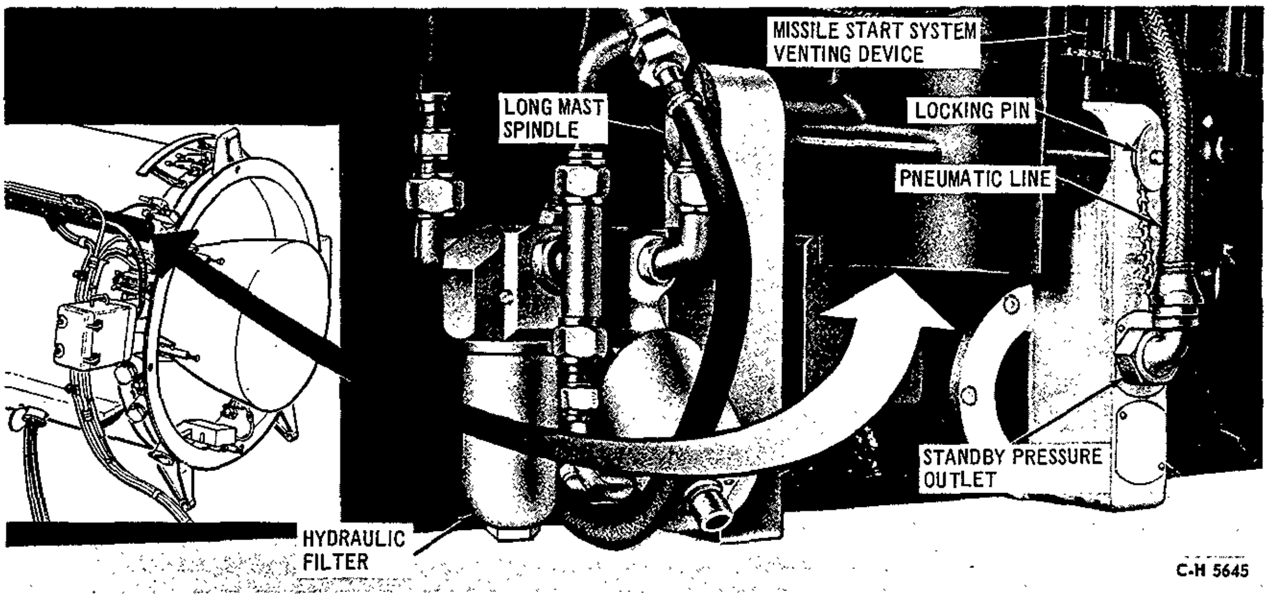


Figure 3-13. Long Cable Mast Mounting Area

LOX REPLENISHING

The LOX replenishing arm assembly (figure 3-14), mounted on the inside surface of the auxiliary ring near fin I, connected the LOX replenishing line to the missile. The LOX replenishing arm assembly was installed at the missile assembly and maintenance area. A line from the LOX replenishing arm to a connection at the base of the LOX filling mast connected the arm to the LOX transfer lines. Also, a line connected the LOX replenishing arm to the Y-connection of the LOX start coupling. A 2-inch slip-type coupling provided a means of disconnecting the LOX replenishing line from the missile at liftoff. The launcher half of the coupling had a floating mounting to permit movement and a screw adjustment to obtain seal tightness of the self-sealing feature in the coupling. The missile LOX line contained a check valve to prevent reverse flow through the missile coupling after disconnect. Design of the coupling permitted 4 inches of missile travel with respect to the launcher before the seal was broken, preventing loss of pressure in the ground LOX replenishing line and spillage of LOX from the missile LOX replenishing line before liftoff.

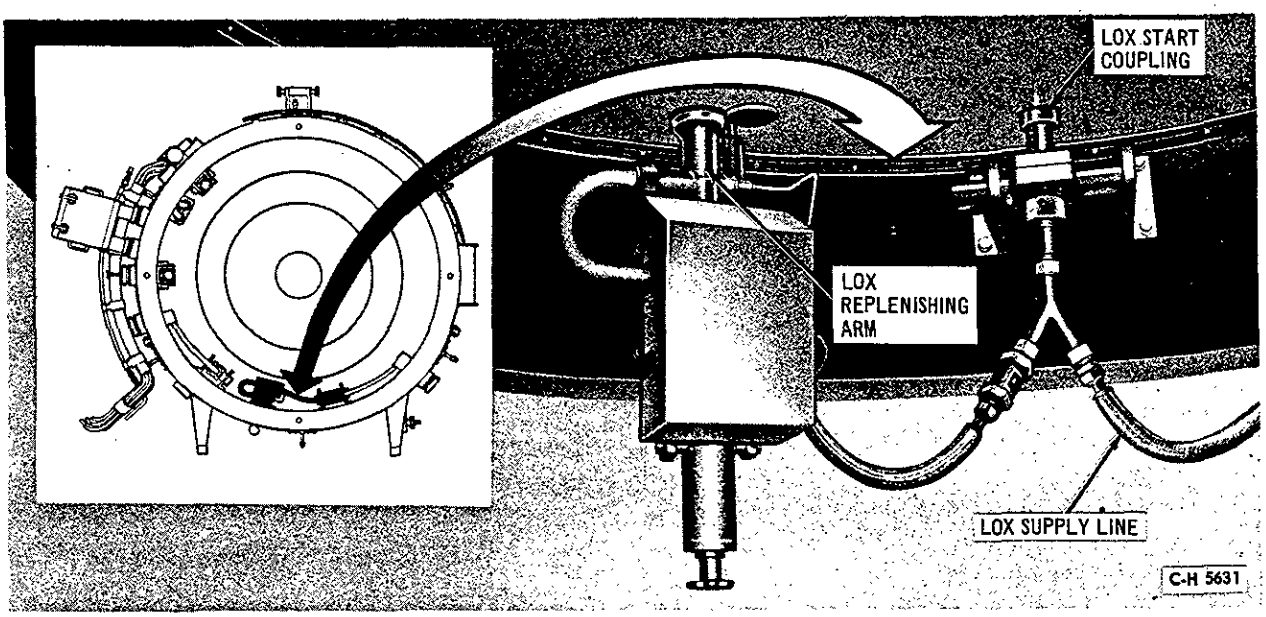


Figure 3-14. Lox Replenishing Arm Assembly

A pneumatically operated LOX replenishing line vent valve was a part of the LOX replenishing system. The valve was installed on the LOX filling mast mounting bracket, with pneumatic lines connected to the auxiliary valve control system assembly (figure 3-15).

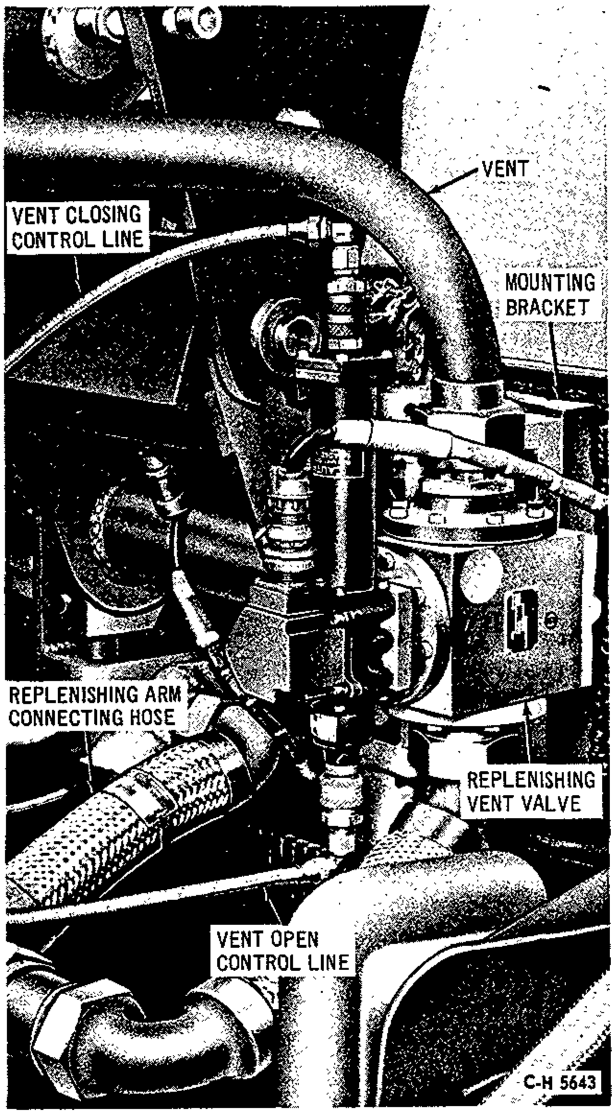


Figure 3-15. Lox Replenishing Line Vent System

A LOX level control assembly was attached to the auxiliary ring at fin II. By sensing and measuring the differential pressure between the head of the LOX tank and the vapor pressure of the tank, the level control assembly computed the head of liquid in the tank. The control assembly then relayed the signal to an electropneumatic converter on the LOX transfer trailer. The converter supplied a proportional pneumatic signal to the LOX replenishing throttling valve that controlled the LOX level filling, topping, and replenishing.

PNEUMATIC

Two pneumatic coupling assemblies (figure 3-16) were attached to the inside surface of the auxiliary ring between fins II and III and provided two sets of multiple slip-type quick disconnect couplings between the missile and the valve control system assembly. Each pneumatic coupling assembly had six quick disconnect connections to the missile, and a snap cover that closed as the couplings disconnected and protected the ground half from rocket blast. An adjusting screw permitted extension or retraction of each assembly to obtain a proper seal.

The pneumatic coupling assemblies were component parts of the auxiliary ring. Pneumatic lines were routed from each coupling assembly through the auxiliary ring to two socket plate assemblies mounted on the outer surface of the auxiliary ring. The valve control assembly provided two plug plate assemblies that mated with the socket plate assemblies from the pneumatic

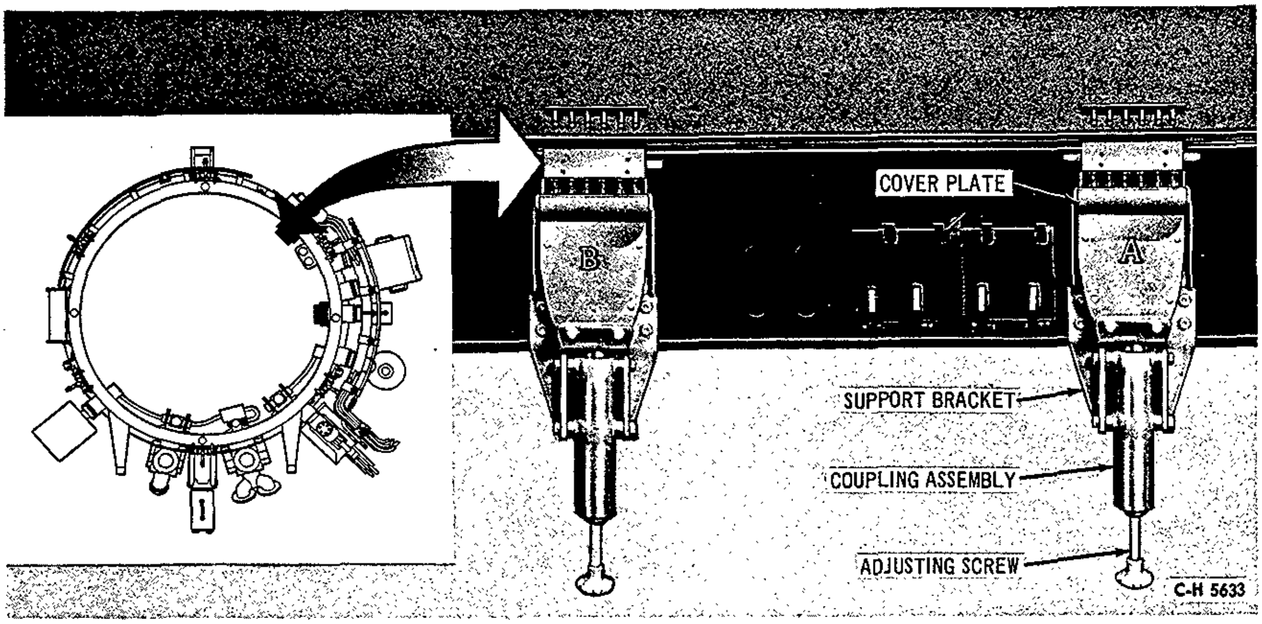


Figure 3-16. Pneumatic Coupling Assemblies

coupling assemblies, enabling the valve control assembly to be attached to the auxiliary ring. A single nitrogen line from the ground supply source provided 3,000 psig to the valve control assembly.

The valve control assembly (figure 3-1) was a group of electrically operated pneumatic valves mounted in an aluminum housing near fin II. It was installed at the launch emplacement before the missile was erected. The supporting legs and mating plugs extended through the back. Six pneumatic connectors and an electrical connector were located on the back of the assembly under the supporting legs. The valve control assembly was functionally divided into three pneumatic systems: the 3,000 psig supply and vent system, the 750 psig supply and vent system, and the missile LOX and fuel containers pressure sensing system. The valve control system assembly controlled the following missile functions: high pressure supply, fuel duct purge, 750 psig supply, fuel fill and drain, LOX fill and drain, fuel vent control, spheres vent, air bearing vent, cable mast vent, LOX sensing, ground LOX vent control, cable mast supply, air bearing supply, and fuel pressure sensing.

The auxiliary valve control system assembly (figure 3-1) was a group of electrically operated valves used in conjunction with the valve control system assembly. The valves were mounted in an aluminum housing that attached to the auxiliary ring at fin I. It was installed at the launch emplacement after the missile was erected. The auxiliary valve control system assembly obtained its 750 psig control pressure from the valve control system assembly. The housing had six pneumatic connections on each side and an electrical connector on the bottom. The auxiliary valve control system controlled the following ground pneumatic functions: LOX start tank fill (opening and closing control), LOX replenishing vent (opening and closing control), LOX mast pushoff, fuel mast pushoff, LOX mast release, fuel mast release, tail grab release, and lube tank pressurization. The auxiliary valve control system assembly also controlled the standby pressure to the missile and the ground cable distribution box.

HEATING AND COOLING (AFT UNIT)

The heating and cooling assembly (figure 3-17) was a component assembly of the long cable mast. Connection was made to the aft unit through the quick-release housing assembly of the mast. Two supply ducts carrying low pressure gaseous nitrogen (GN_2) and a high pressure liquid nitrogen (LN_2) line comprised the heating and cooling connections contained in the quick-release housing. The LN_2 coupling was a quick disconnect slip-type coupling, and the heater ducts were quick disconnect sleeve-type couplings. Ground support connection for the LN_2 was made at the LN_2 line on the cable trough mounted on the auxiliary ring. The GN_2 was connected to the instrument compartment pressurizing line from the auxiliary valve control system assembly. The heater-cooler assembly was disconnected when the long cable mast was released.

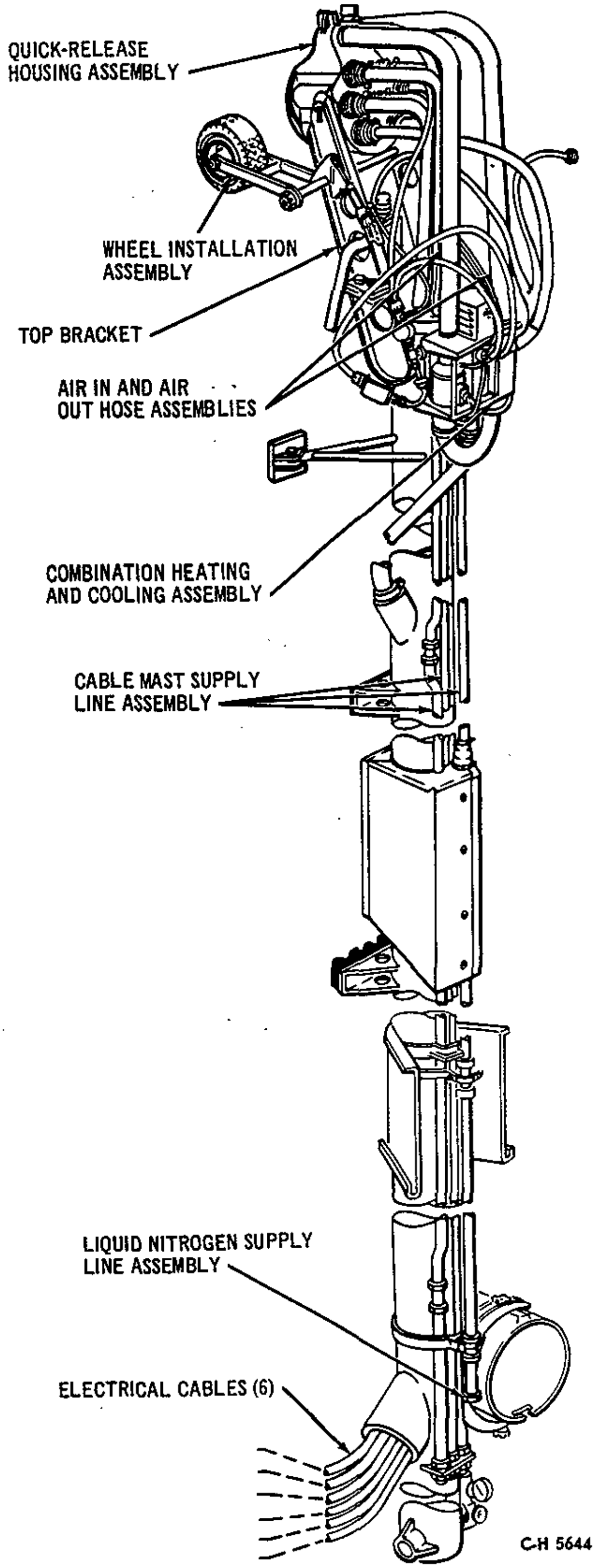


Figure 3-17. Long Cable Mast Assembly

ELECTRICAL

Vehicle Systems. The short cable mast assembly (figure 3-18) was installed on the auxiliary ring between fins I and II. It was installed at the launch emplacement while the missile was in the horizontal position. The mast assembly contained four cables that supplied electrical power and control signals to the missile tail unit and aft unit during missile vertical checkout, standby, and countdown. The ground lube tank pressurizing line was also supported on the mast and was mated to the missile 30 inches above the missile forward ring. Two wire cables, from the mast to the coupling, disconnected the coupling when the mast disconnected and fell back. Two of the four short cables connected to the electrical equipment trailer. One cable connected to the power distribution trailer and one connected to the cable distribution box.

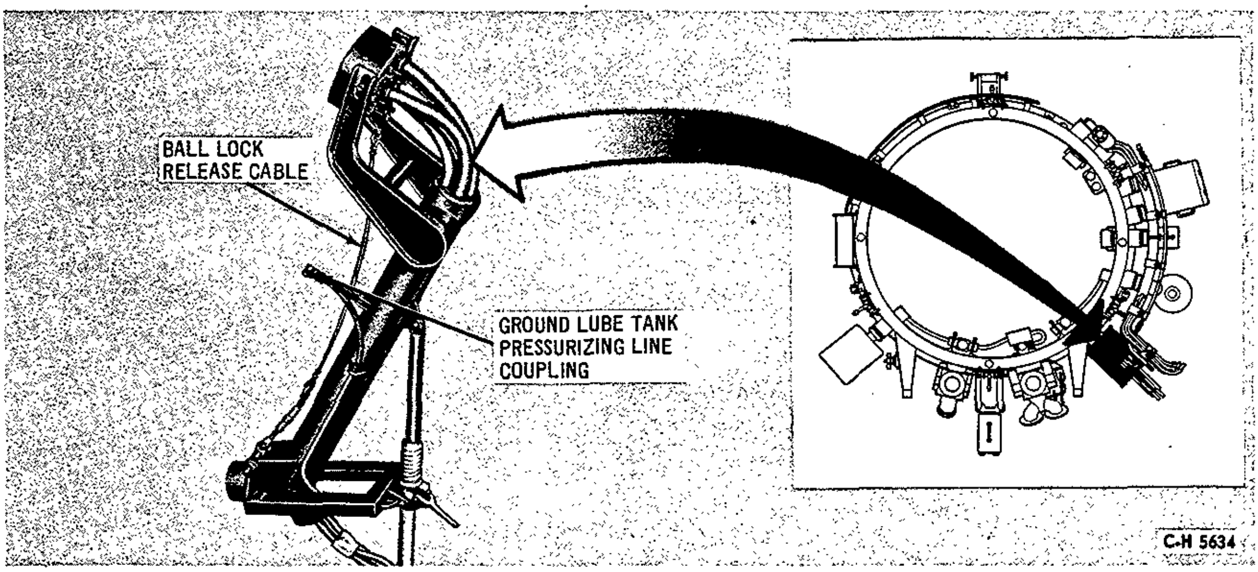


Figure 3-18. Short Cable Mast Assembly

When the tail plug assembly (figure 3-19) was mated to the missile it was secured with a ball-lock assembly. The spring-loaded lockbolt of the ball-lock mechanism was held in place with a lever that was linked to a quick-release lever by a shear pin. A quick-release cable connected the quick-release lever to the cable mast mounting bracket. The five (one inert) electrical plugs housed in the tail-plug housing assembly of the short cable mast were inserted in the housing and were mated with the sockets in the socket plate of the missile.

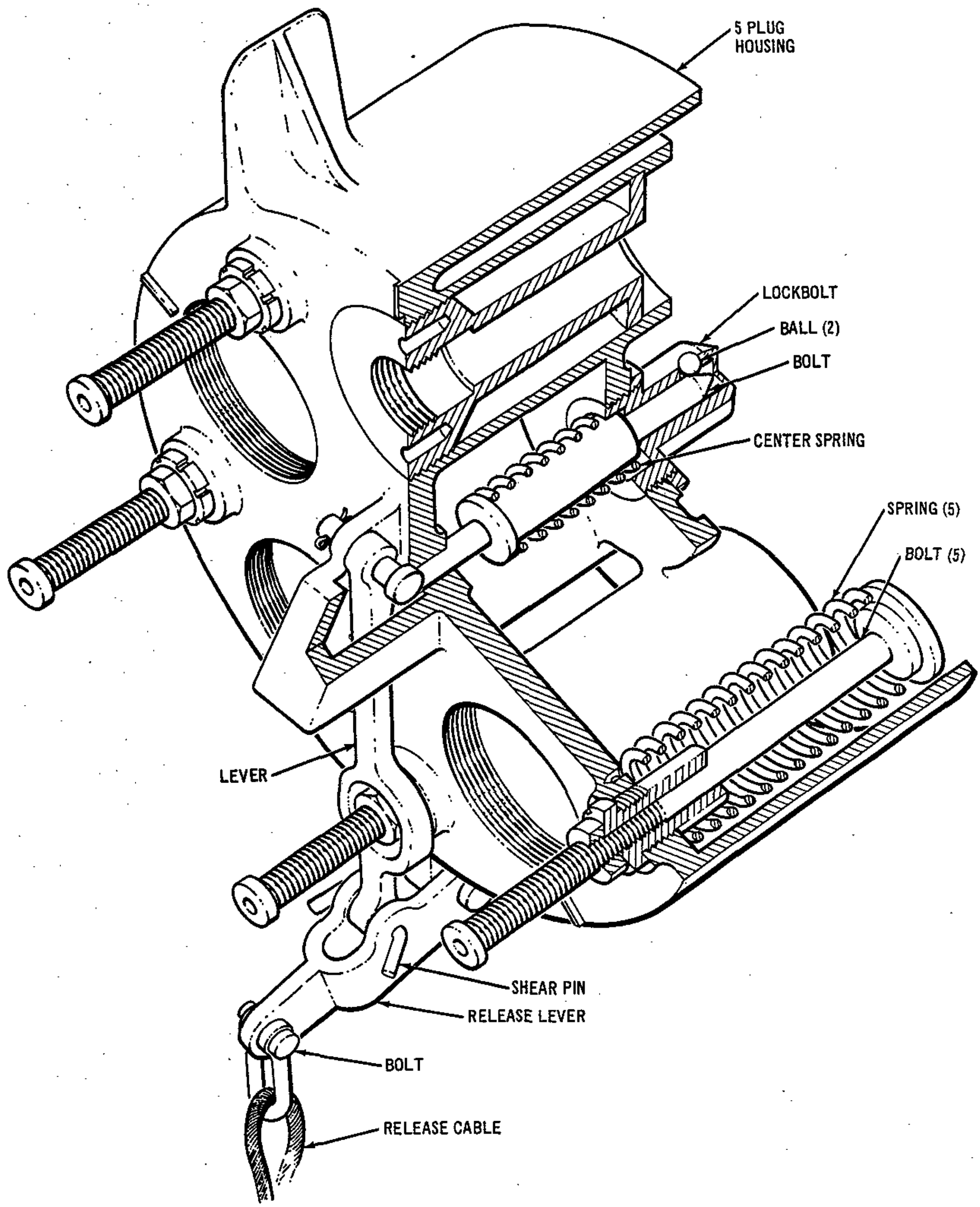


Figure 3-19. Short Cable Mast Tail Plug Housing

After the tail plug housing was secured to the missile, the five pushoff spring-bolt nuts were backed off, thus loading the pushoff springs.

Disconnect of the short cable mast was accomplished by missile travel. As the missile lifted, the quick-release cable exerted force on the quick-release lever, and sheared the pin holding the locking lever. With the release of the locking lever, the spring-loaded lockbolt moved out and released the ball lock, thus disconnecting the tail plug housing (figures 3-20 and 3-21). The five loaded pushoff springs pushed the short cable mast assembly away from the missile. As the mast fell away from the missile, cables attached to the lube pressurizing line from the cable mast disconnected the lube pressurizing line.

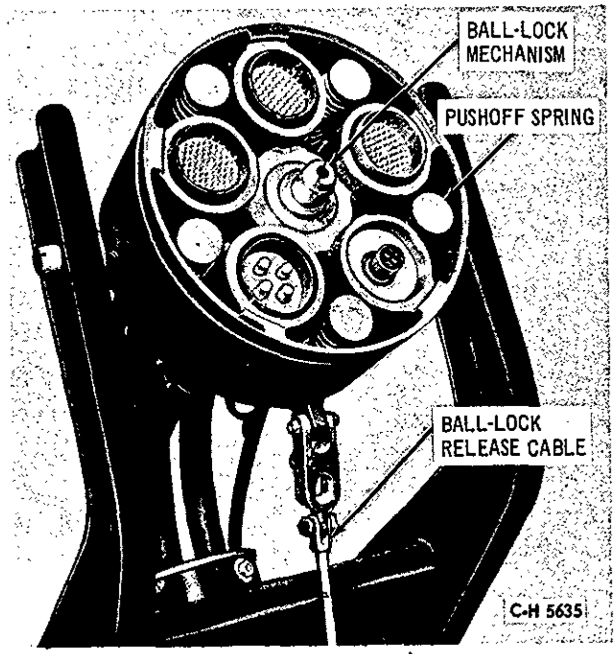


Figure 3-20. Short Cable Mast Quick-Release Housing Interface

Design of the short cable mast release mechanisms was a direct result of the development in design of the long cable mast release mechanisms for the Redstone R&D vehicles. The ball-lock connection and release had proved reliable so that the design work for the short cable mast of the Jupiter was merely a matter of adapting it to another location and function. Several experiments with release mechanisms, including the use of a slip pin, resulted in the shear pin method of release. The only questionable drawback to the release method was in the possibility that someone would forget to preload all the pushoff springs. To preclude this possibility the spring bolt heads were painted red as reminders.

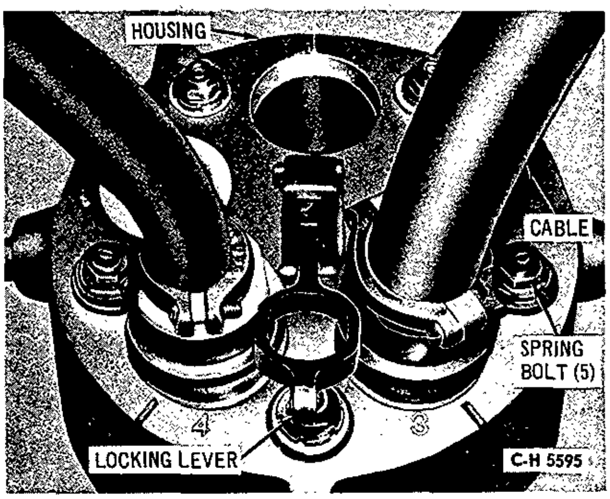


Figure 3-21. Cable Mast Quick-Release Housing

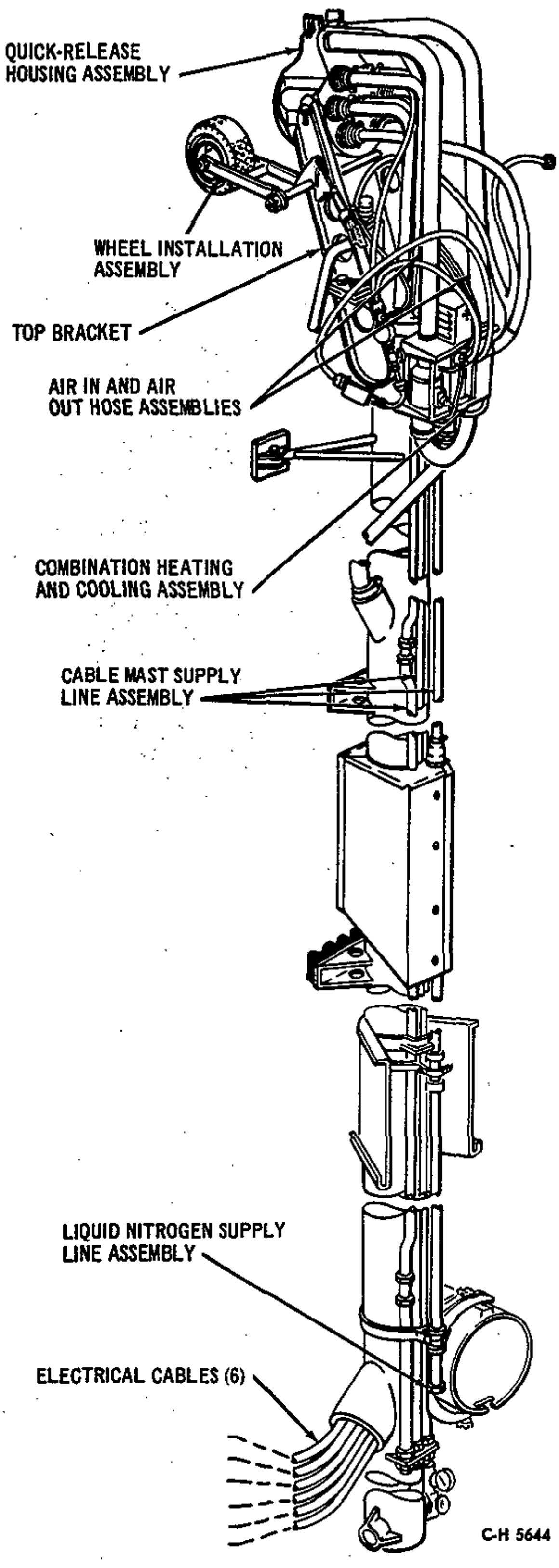


Figure 3-22. Long Cable Mast Assembly

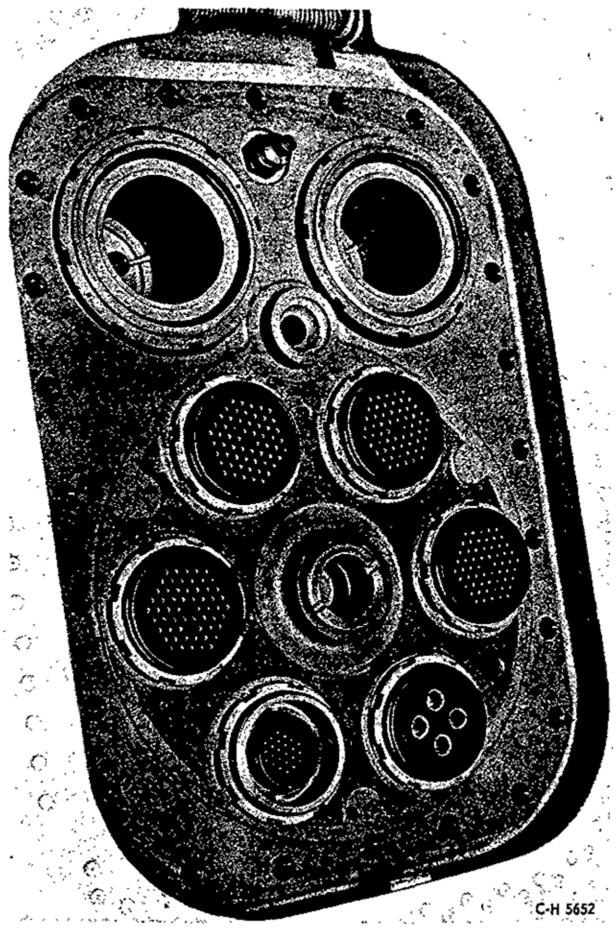


Figure 3-23. Aft Unit Service Plate

Instrumentation, Guidance, and Control Systems. The long cable mast assembly (figure 3-22) was connected to the missile and the auxiliary ring between fins II and III. It provided a means of routing, connecting, and disconnecting the electrical, pneumatic, and liquid nitrogen lines to the aft unit (figure 3-23). The lines supplied the ground electrical power for monitoring and controlling the temperatures in the instrument compartment, the pneumatic pressure for servicing the air bearing and pressurizing the instrument compartment, and the liquid nitrogen for cooling the instrument compartment.

The assembly consisted of an aluminum tube, a heating and cooling assembly, two heater hoses, three pneumatic lines, six multiple-conductor electrical cables, a liquid nitrogen supply line, a lightning rod, and a quick-release housing. It was installed on the missile at the assembly and maintenance area.

The ground service connections were made at the lower end of the long cable mast assembly. Four of the electrical cables were connected to the electrical equipment trailer, one was connected to the power distribution trailer, and one was connected to the cable distribution box. The 3, 000 psig high pressure pneumatic line was connected to the valve control system assembly via connections to the auxiliary ring; the 750 psig control pressure line was connected to the auxiliary valve control system assembly; and the low pressure instrument compartment pressurizing line was connected to the auxiliary valve control system assembly.

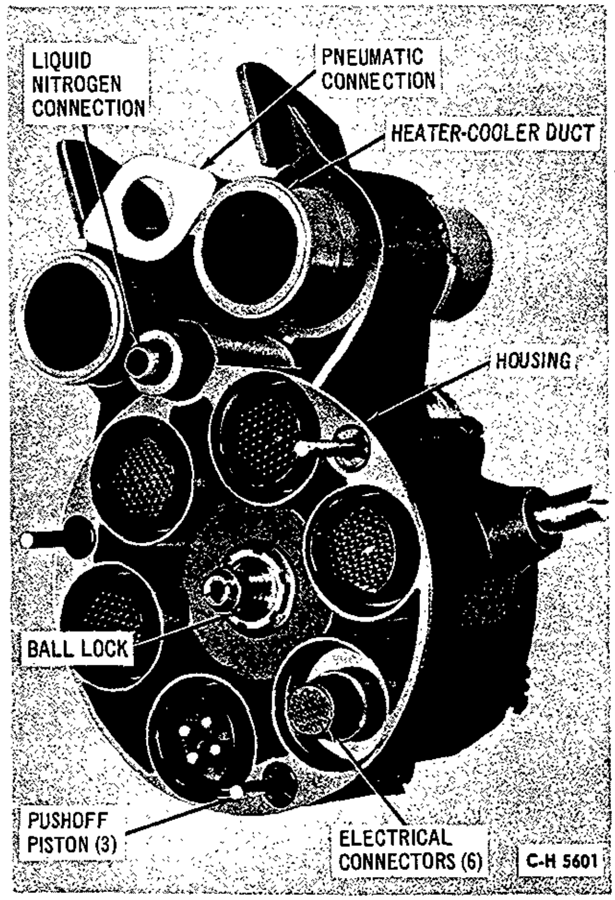


Figure 3-24. Long Cable Mast Quick-Release Housing

The quick-release housing assembly (figure 3-24) provided for connecting six electrical plugs, two air-conditioning ducts, one high pressure pneumatic line, and one liquid nitrogen line to the missile plate of the aft unit. The assembly was secured to the missile with a ball-lock quick-release mechanism.

Disconnect, release, and retract of the long cable mast assembly occurred at ignition. Pneumatic pressure actuated the release bolt of the ball lock (figure 3-24) and simultaneously thrust three pistons against the missile plate to force the mast away from the vehicle. A redundant release system was built into the wheel installation assembly. The primary function of this assembly was to keep the cable mast from blowing against the missile during high winds; however, the pneumatic pressure that actuated the quick-release mechanism of the quick-release housing also actuated the pneumatic cylinders attached to the wheels of the wheel assembly. Upon actuation of these cylinders the wheels extended toward the missile and helped push the cable mast assembly away from the missile. A cable, connected between the mast assembly and the missile, prevented the mast from swinging out more than 10 degrees until after liftoff. At liftoff a pin connecting the cable to the missile was sheared and the cable mast dropped to the ground.

So far the discussion of the quick-release housing for the long cable mast has included only the housing for the tactical Jupiter. Many prototypes for this housing were built and tested. The reliable ball-lock assembly was the heart of the quick-release mechanism, but a number of methods for release of the ball lock and pushoff of the housing assembly were tried. A governing factor for determining the method of release and pushoff of the quick-release housing was the number of connections in the housing and the subsequent amount of force needed to effect release of the housing. For example, the burnout wire used to release the original ball-lock mechanism (figure 3-25) for the three-plug housing on the R&D Redstone could not hold the spring force needed to release the six-plug housing of the tactical Jupiter; therefore, if the same method of locking and releasing the quick-release housing were to be used, a different method of holding the locking lever had to be developed.

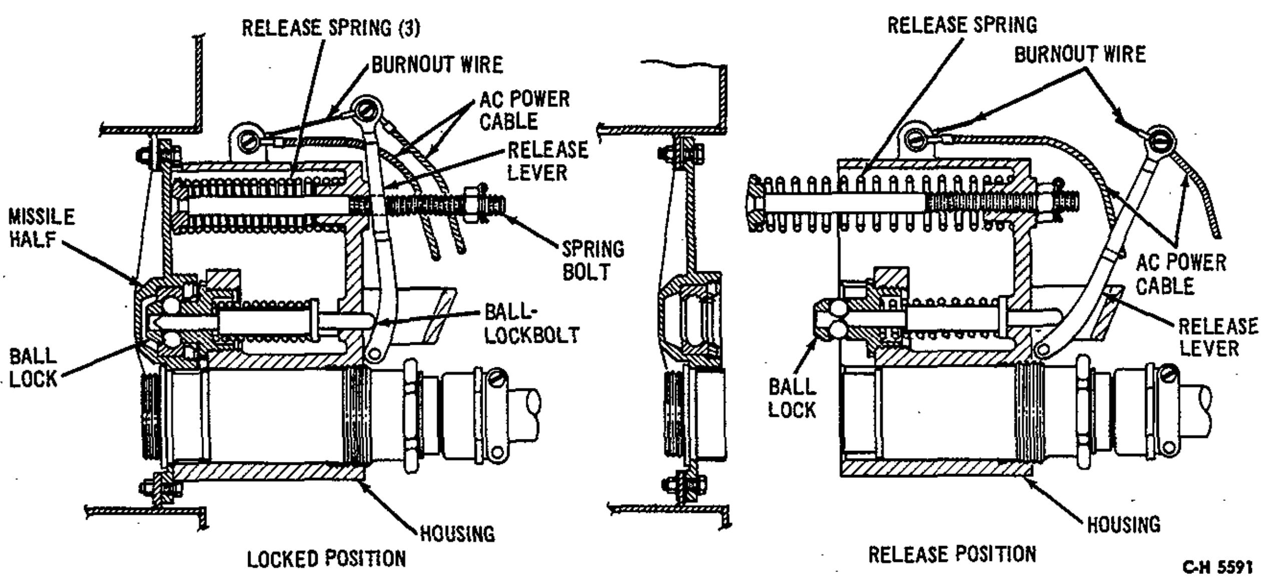


Figure 3-25. Original Ball Lock Burnout Wire Release Mechanism

On early Jupiters, 1 through 4, a five plug head (figure 3-26) using five pushoff springs and an explosive bolt to hold the release lever was tried. The method of holding and releasing the lock bolt was similar to that used for the Redstone heater-cooler assembly. The explosive bolt release operated fairly well, as evidenced by its continued use on a number of the prototype quick-release mechanisms; however, one of the disadvantages of the explosive bolt was that the explosive charge in the squib tended to deteriorate. The

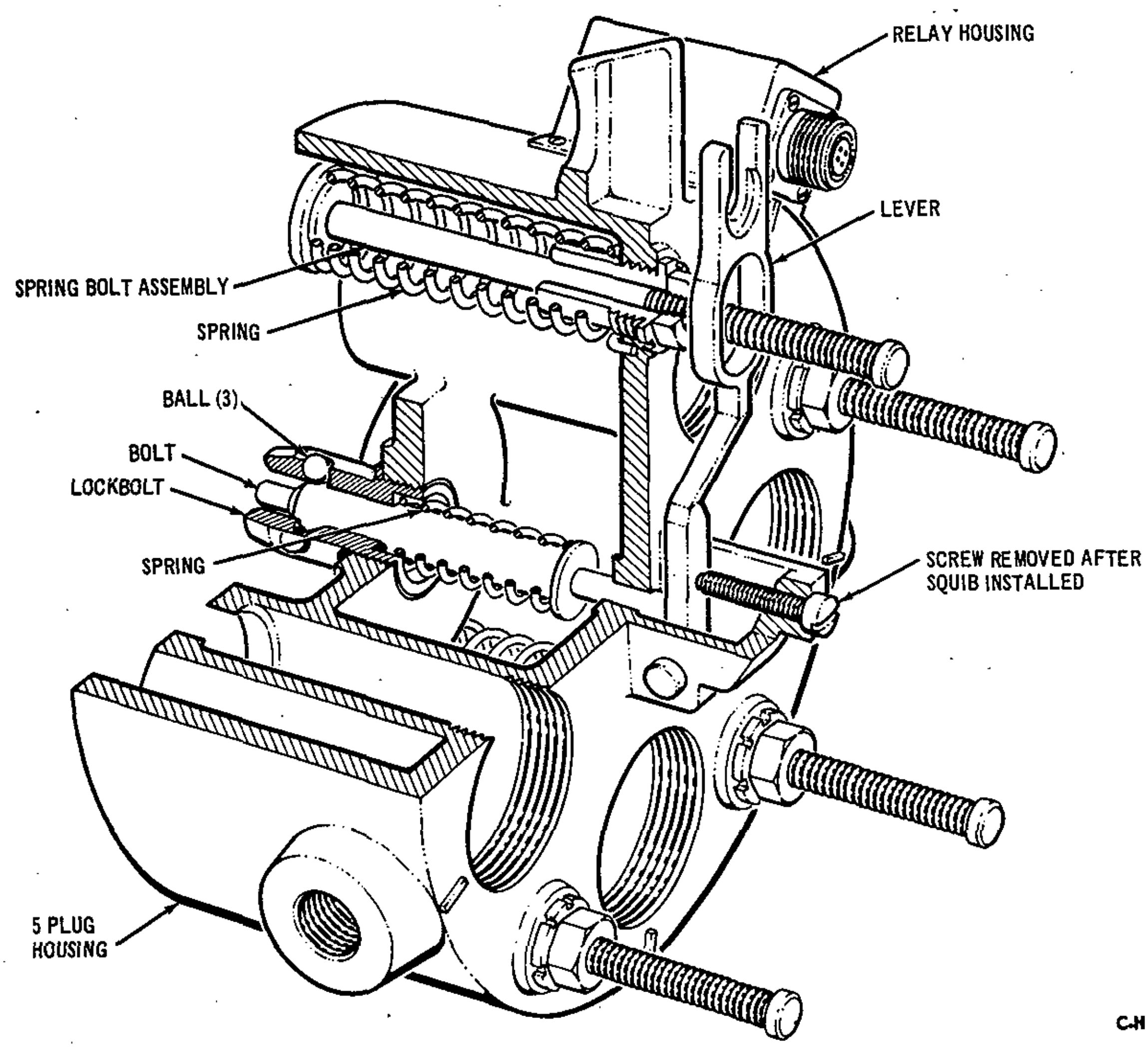


Figure 3-26. Long Cable Mast Five Plug Release Housing Prototype

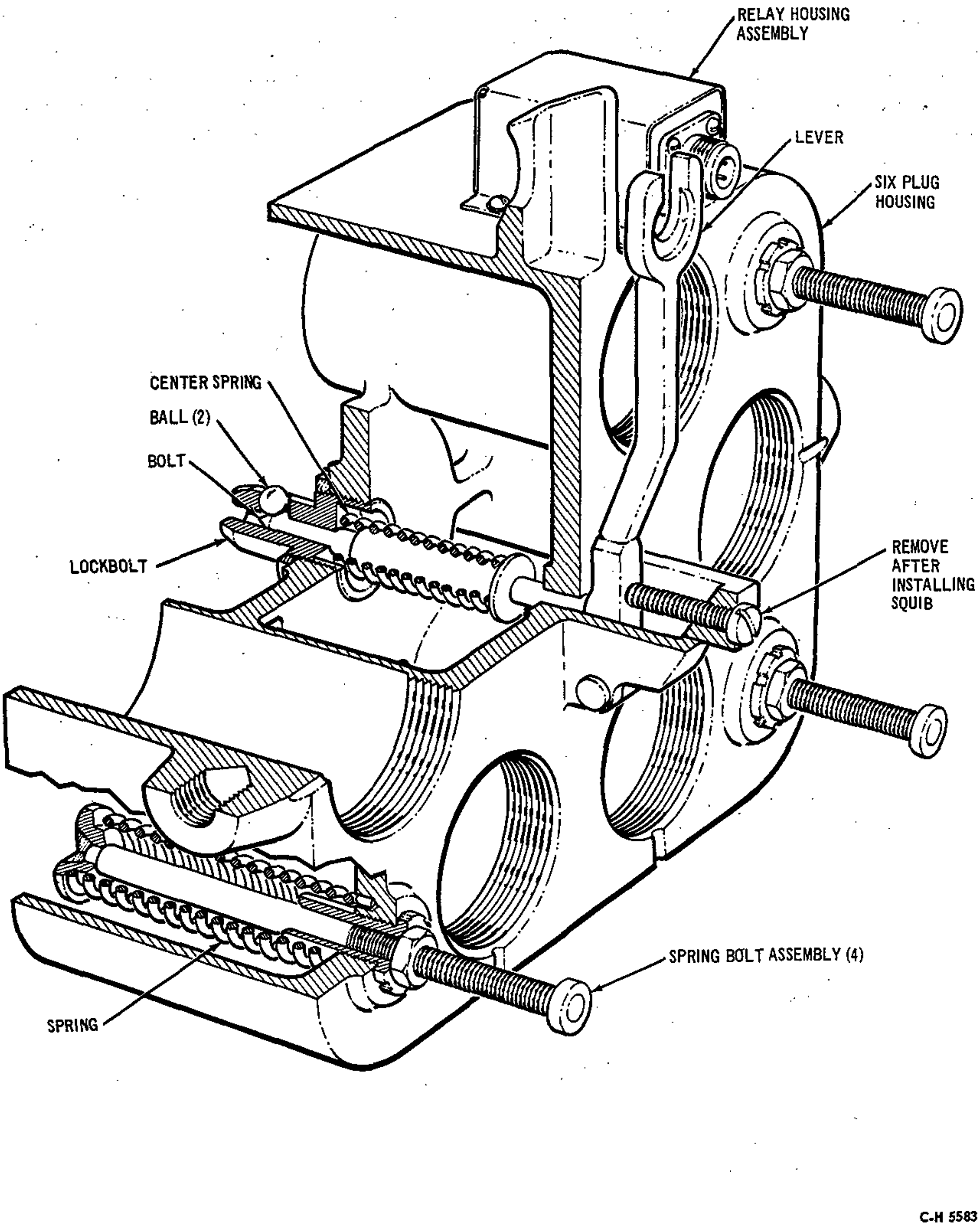


Figure 3-27. Prototype Six Plug Release Housing

deterioration of the explosive charge caused the explosive bolt to fail and consequent failure of the release mechanism.

Later experiments in trying to design a quick-release housing for six electrical plugs resulted in a rectangular design (figure 3-27). This housing used the ball lock and lever quick-release mechanism with springs for push-off. Attempts to use a burnout wire to hold the release lever were not successful, and the explosive squib shown was used to hold the quick-release lever.

Further experimenting with the rectangular housing resulted in the design of the first gas-pressure quick-release mechanism (figure 3-28). The lockbolt in this design was held in the locking position with a spring-loaded piston. Gas passages were drilled to four pushoff pistons and to the underside of the lockbolt piston. An explosive squib was installed in the housing. When the squib exploded, the expanding gases forced the lockbolt out, releasing the ball lock; simultaneously, the pushoff pistons were forced against the missile counterpart and shoved the housing assembly from the missile. There were disadvantages to this design: the passages in the housing tended to get clogged with carbon and caused release failure; it was also felt that the confined explosion could be dangerous.

Continuing experiments in design produced a five plug housing with the air-conditioning inlet and outlet connections as part of the quick-release housing. The original design of this housing (figure 3-29) used the explosive

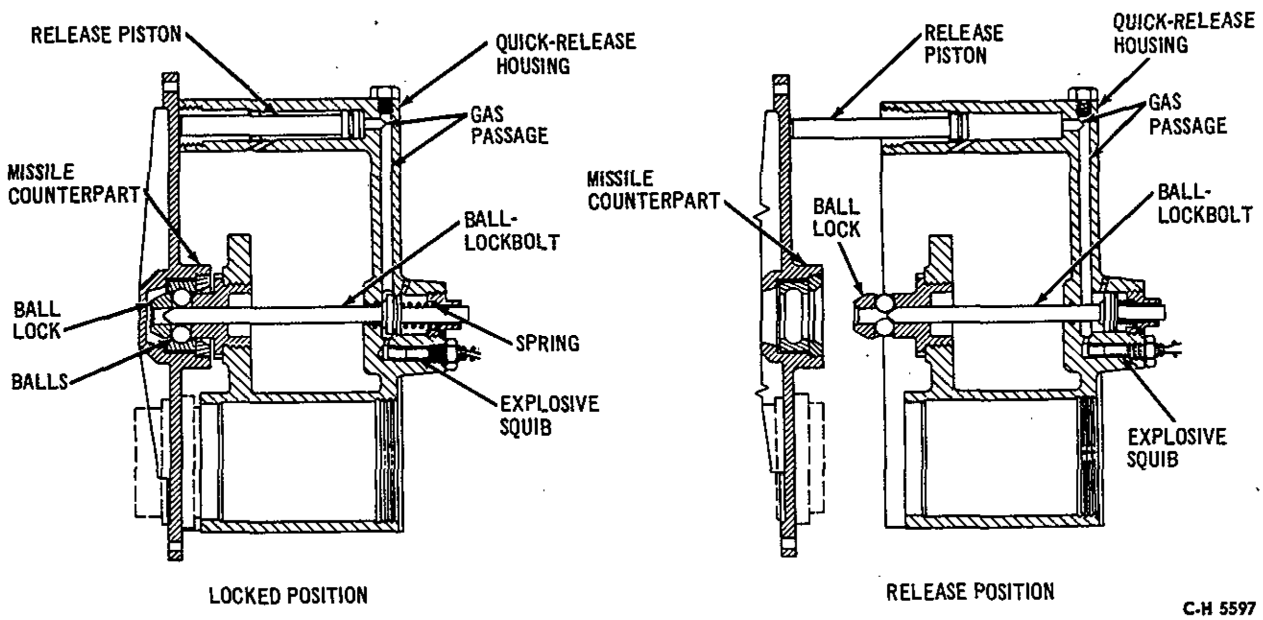


Figure 3-28. Gas Pressure Quick-Release Mechanism (R&D)

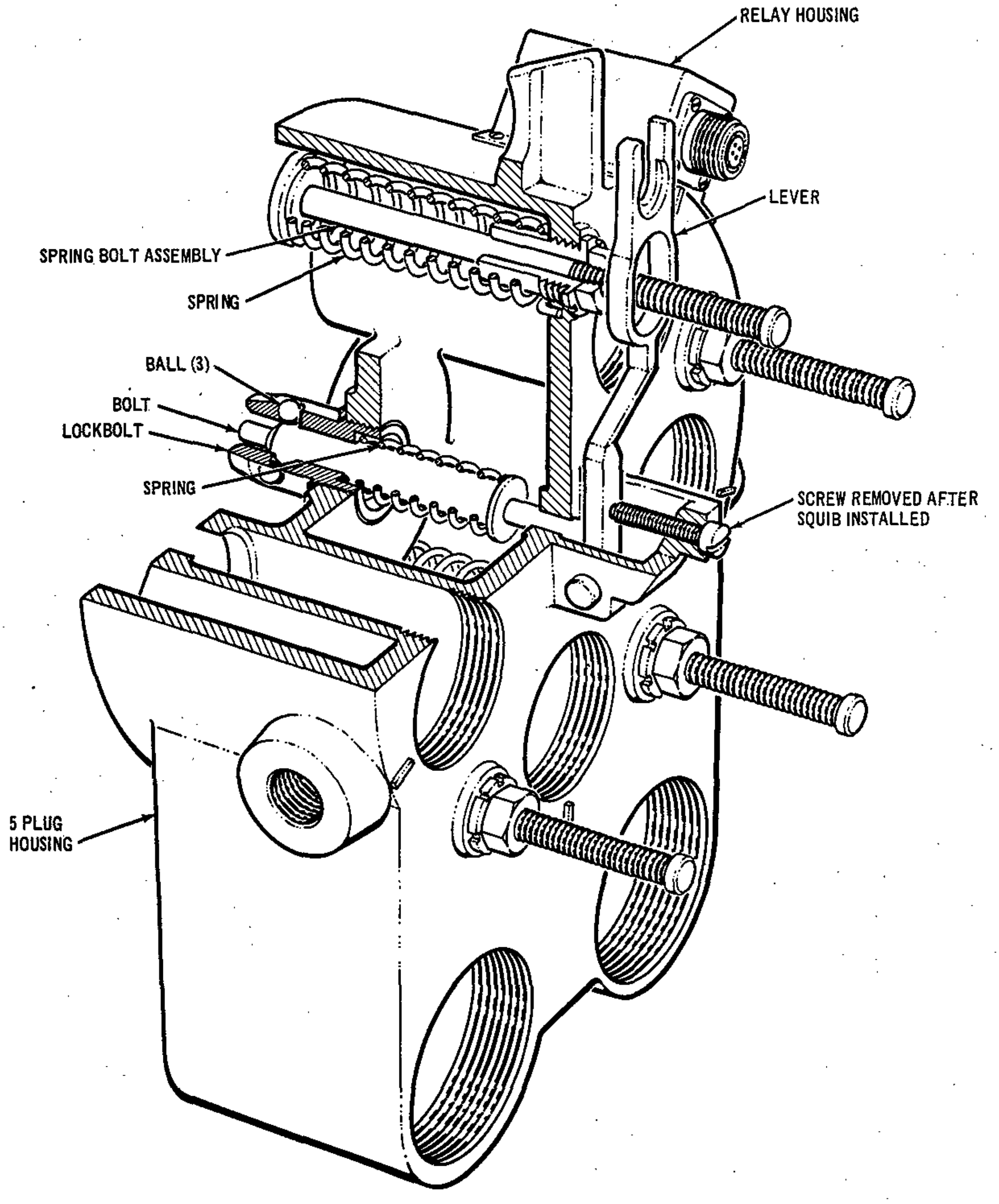


Figure 3-29. Prototype Five Plug Housing

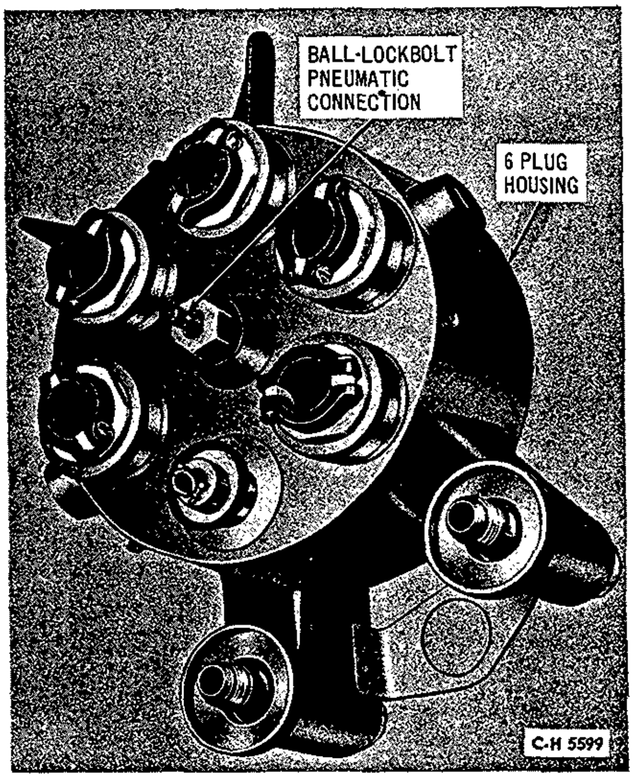


Figure 3-30. Prototype Six Plug Housing Long Cable Mast

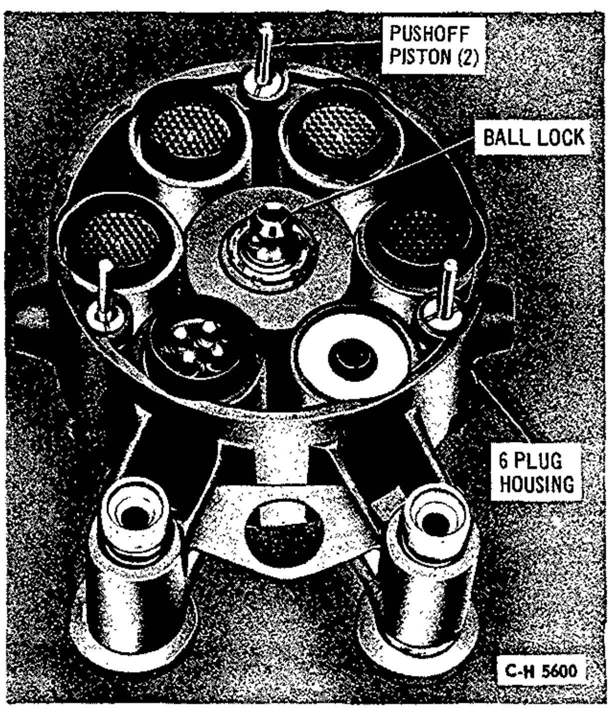


Figure 3-31. Prototype Six Plug Housing Interface

link to release the locking lever, with pushoff springs to move the housing away from the missile. In the meantime, the idea of releasing the ball lock and quick-release housing with pneumatic pressure had proven feasible with the rectangular prototype quick-release housing; therefore, the five-plug housing with the precooling ducts was modified to use pneumatic pressure for quick-release and pushoff from the missile. This housing was further modified to accommodate six electrical plugs (figures 3-30 and 3-31) and was used on Jupiter 9.

The tactical Jupiter quick disconnect housing (figure 3-32) was the

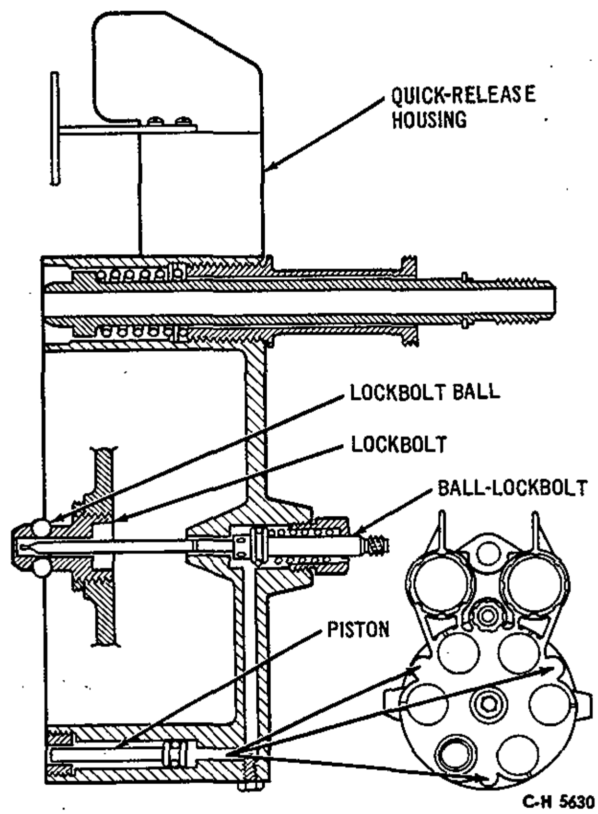


Figure 3-32. Long Cable Mast Release Mechanism

end result of the development work for the quick-release methods tested in the Jupiter program. As shown in figures 3-33 and 3-34, the housing operated satisfactorily under extreme environmental conditions. The ball lock and pneumatic release method has been successfully used on the Saturn vehicles.

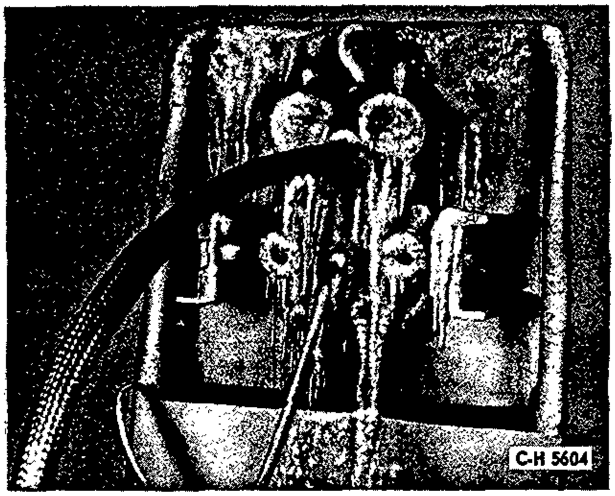


Figure 3-33. Icing Test Jupiter Quick Disconnect Housing Before Release

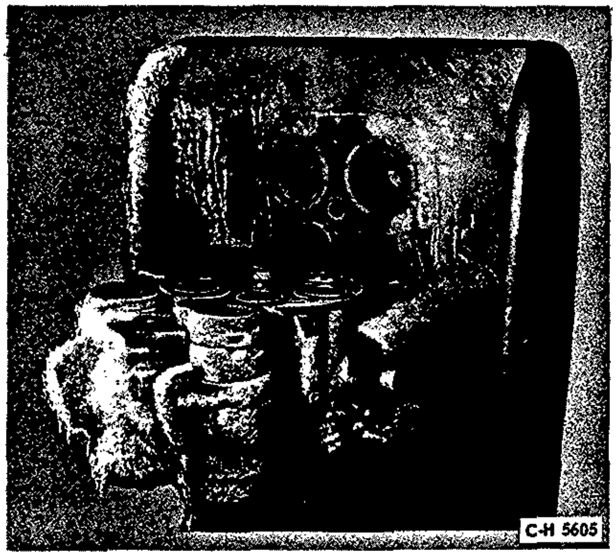
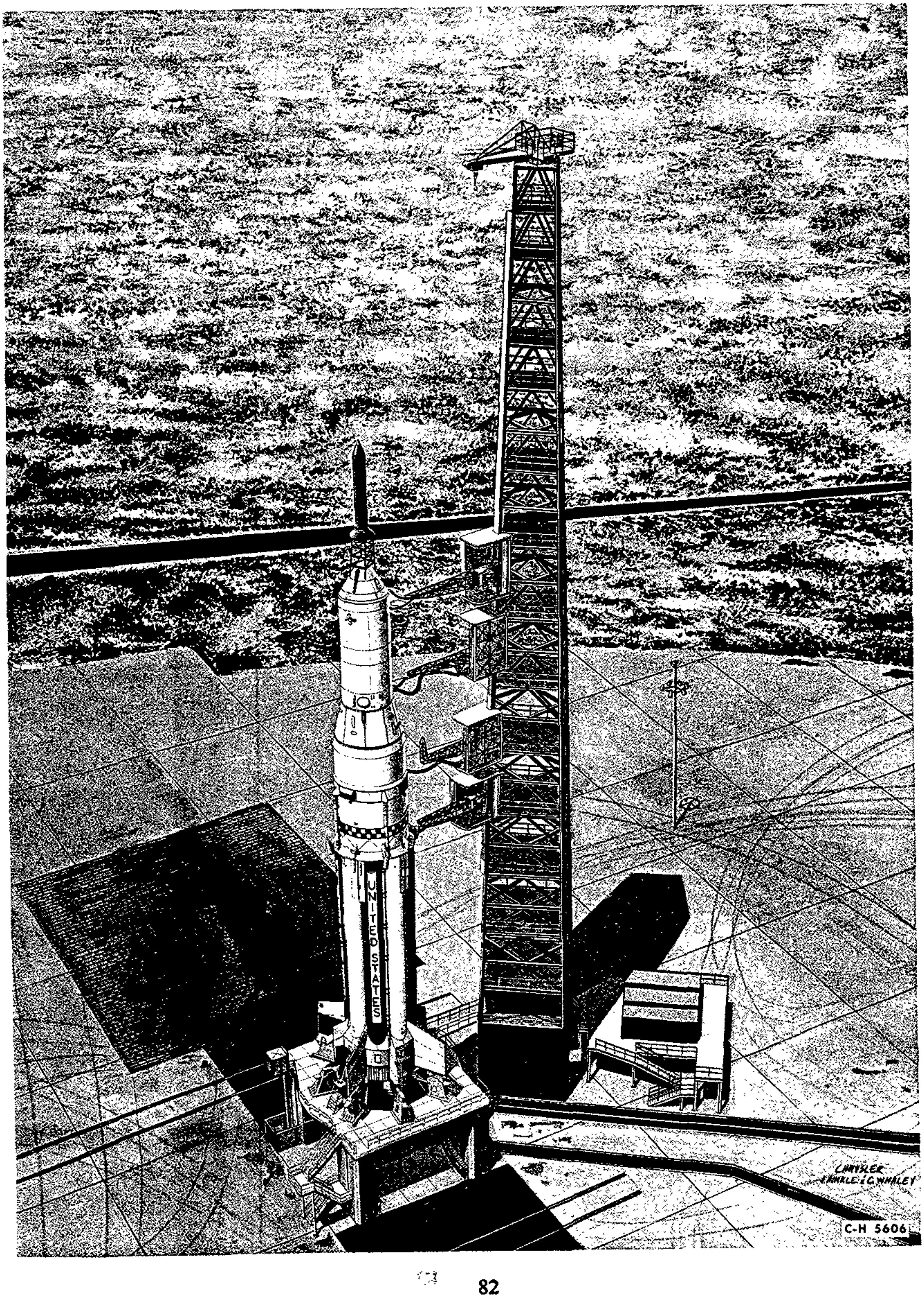


Figure 3-34. Icing Test Jupiter Quick Disconnect Housing After Release

SECTION IV
SATURN I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SECTION IV

SATURN I

INTRODUCTION

The Saturn I space vehicles have the primary mission of providing the booster capacity for earth-orbiting the three-man Apollo Spacecraft. These flight tests will provide the proven hardware and techniques prerequisite to accomplishing a manned lunar landing within this decade. The secondary missions of the Saturn I vehicles will provide additional information about space. These missions will include at least two micrometeoroid experiments to determine the destructive force of meteoroids and the hazards they present to space vehicles exposed to meteoroids for long periods.

The Saturn I vehicle consists of two booster stages S-I and S-IV, an instrument unit, and the Apollo Spacecraft. The S-I first stage is powered by eight engines fueled with LOX and RP-1 liquid propellants. The S-I stage utilizes a system of clustered and interconnected propellant containers to provide the propellant capacity. The S-IV second stage is powered by six engines fueled with LOX and liquid hydrogen (LH_2) propellants. A later version of the S-IV stage, the S-IVB, will be powered with one large engine fueled with LOX and LH_2 propellants.

The first four Saturn I (SA-1 through SA-4) firings were tests of the first stage. The vehicles were designated Block I and used engines that had 165, 000 pounds of thrust. The Block I vehicles had dummy upper stages filled with water to simulate the weight of the second stage and the payload. The Block I vehicles were fired from launch complex 34 at the Atlantic Missile Range (AMR). Beginning with the fifth first-stage of the Saturn I, SA-5, the vehicles are designated Block II. The most obvious distinguishing features of the Block II vehicles are the increased length and the addition of fins to the S-I stage. The Block II S-I stage uses engines of 188, 000 pound thrust, and there are other less obvious modifications to the stage that have resulted from information obtained from firings of the Block I vehicles. The addition of fins on the Block II vehicles necessitated a change of the holddown arms on the launcher platform. This change and the advancement of the state-of-the-art occasioned by the Block I firings resulted in some differences between the launcher firing accessories used for Block I and Block II vehicles. These differences are discussed within the appropriate paragraphs of this section.

The Block II vehicles have a live second stage; and, after several flights with a boilerplate spacecraft, the spacecraft will be live. The Saturn I vehicles are launched from three pads at AMR, complex 34, complex 37, and complex 37B. All the complexes are modified to launch the Block II vehicles. At each complex, there are provisions for servicing the aft end of the S-I stage from umbilical systems mounted on the launch platform as shown in figure 4-1. Umbilical servicing of the forward end of the S-I stage, the S-IV stage, the instrument unit, and the spacecraft is accomplished by the use of swing arms mounted on an umbilical tower through which the umbilical lines are routed from the ground supply to the vehicle.

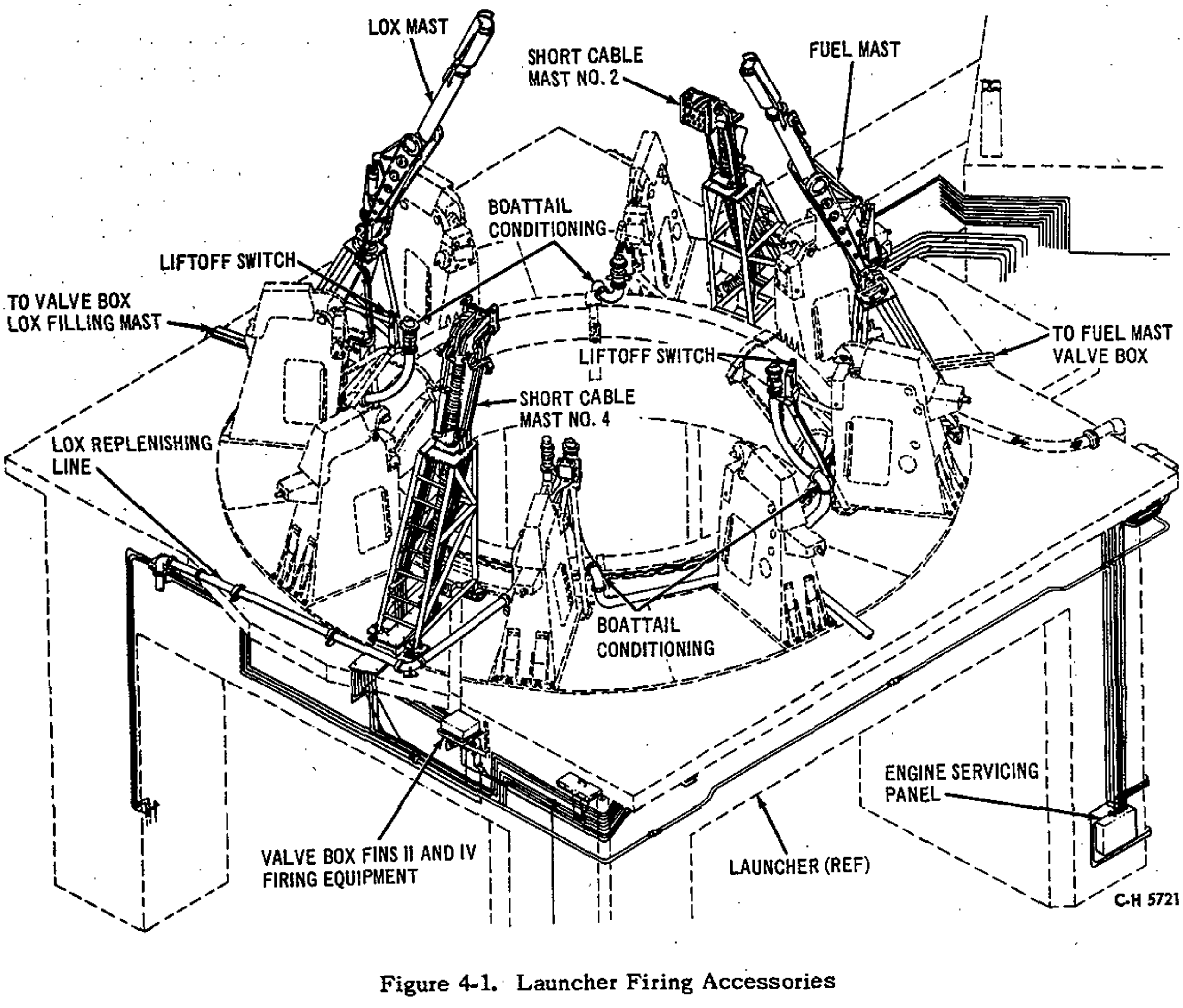

Figure 4-1. Launcher Firing Accessories

S-I STAGE

FUELING

RP-1 Fuel. The vehicle fuel nozzle (figure 4-2) is located on the aft skirt of fuel container, F-1, twenty-two and one-half degrees from fin I between fin I and fin II. Ground connection to the vehicle is made through the fuel mast installation (figure 4-1) mounted on the launch platform. The installation forms the final transfer line between the risers on the launch platform and the vehicle nozzle.

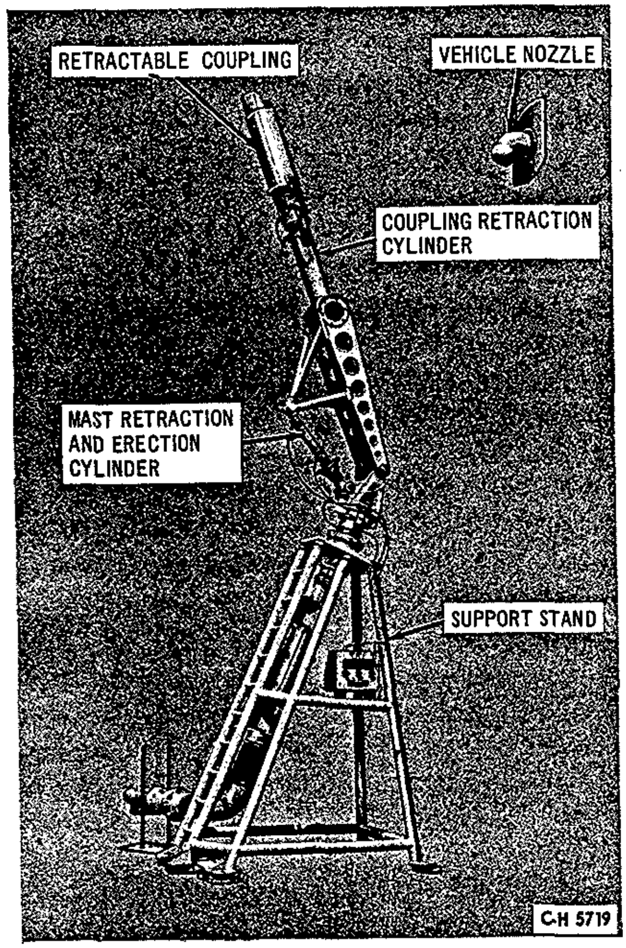

Figure 4-2. Fuel Mast Assembly Retracted

The fuel mast assembly consists of a retractable coupling assembly, two cylinder assemblies, support bracket assembly, retracting assembly, mast arrestor, mounting assembly, valve box assembly, support stand, upper and lower pipe weldments, hose assembly, and pneumatic lines. The retractable coupling assembly, the upper and lower pipe weldments, and the hose assembly provide a flow path for fuel during the tanking operation. Because of the flammable nature of fuel, the mast incorporates a vacuum breaker, purge system, and flame arrestor in the flow path. In addition, the mast assembly incorporates a turbine exhaust duct to deflect and route exhaust heat and gases away from the mast installation. The mast assembly has provision for vertical, lateral, and retracting adjustments to insure correct alinement and operation. The fuel mast installation is the same for the Block I and Block II vehicles.

Connection of the fuel mast to the vehicle is accomplished with a mechanically actuated retractable coupling as shown in figure 4-3. The mating surface of the connection is a ball and sphere with the ball surface on the vehicle nozzle, and the spherical surface with a teflon seal in the retractable coupling. The coupling assembly consists of a guide assembly and bellows assembly mounted in a shield assembly. The bellows assembly (figure 4-4) consisting of an inner pipe weldment, bellows, and an outer sleeve assembly, is mounted inside the shield assembly in a manner that permits the sleeve assembly and the outer shield assembly to

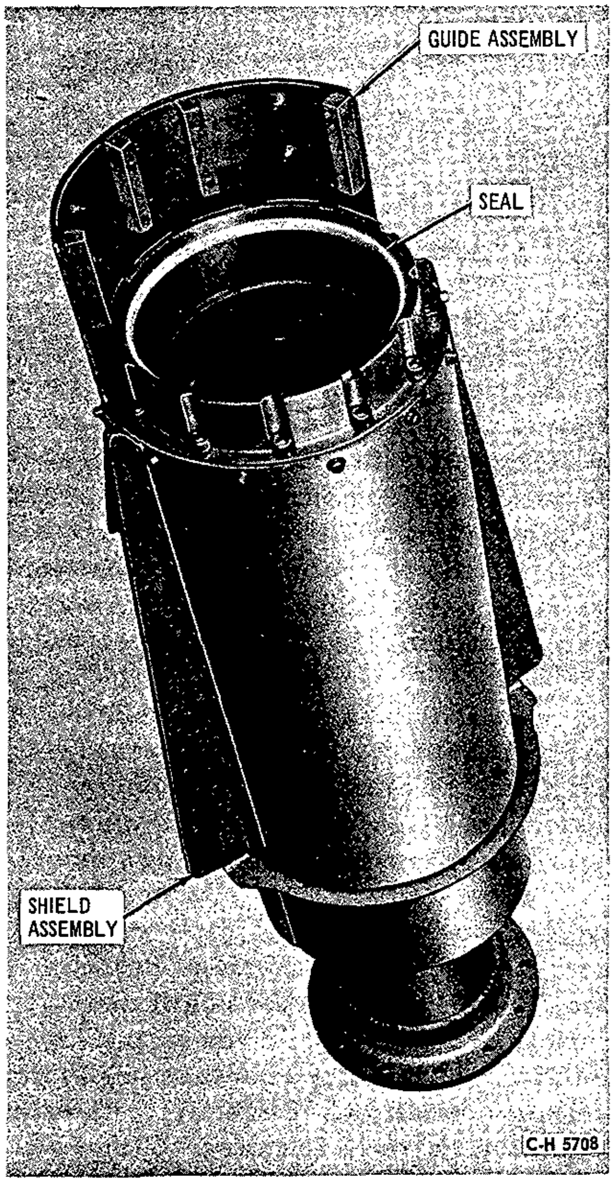

Figure 4-3. Retractable Coupling

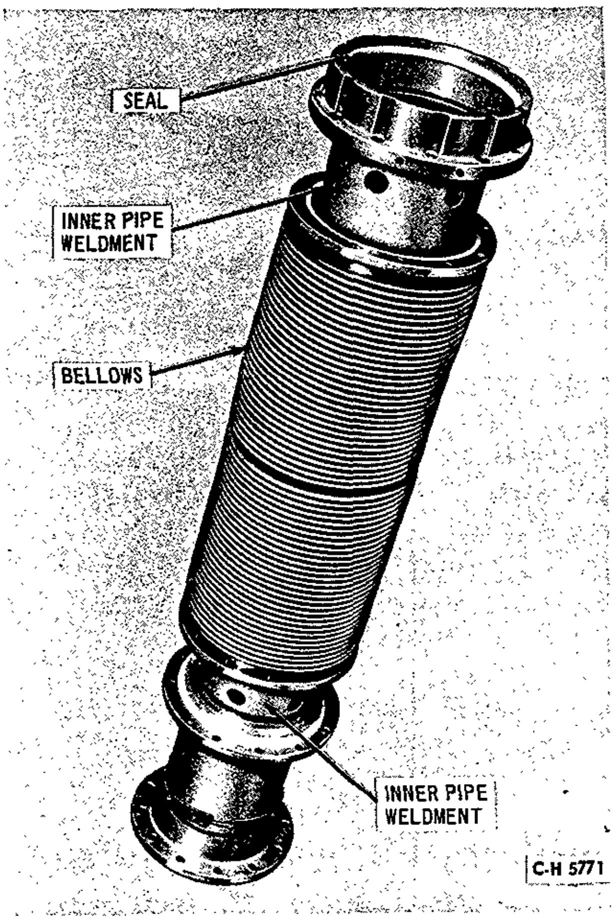

Figure 4-4. Bellows Assembly

telescope over the inner pipe weldment when an external mechanical force is applied. The bellows at the lower end is attached to the inner pipe weldment and, at the upper end, to the outer sleeve assembly. This provides a leak-free passage of fuel through the coupling Two spring-loaded pneumatic cylinders attach to the outer shield assembly and the upper pipe weldment of the fuel mast. When 750 psig pressure is applied to these cylinders, the bellows is compressed and allows the fuel mast to be erected under the vehicle nozzle. After the mast is erected, the pressure to the cylinders is vented and the bellows recoils and extends the coupling assembly to the vehicle filling nozzle. Before the filling sequence, an initial sealing force is obtained between the coupling seal and the vehicle filling nozzle by the combined recoil forces of the bellows and the springs in the pneumatic cylinders. During the filling sequence, an additional sealing force is exerted by the expansion of the bellows caused by the pressure of the fuel. There are several advantages to this coupling: the centerlines of the mating surfaces do not have to be in perfect alinement to obtain a seal; the sealing force increases with an increase of internal pressure; and the flexibility of the coupling prevents damage to the mast assembly as the vehicle settles and rises during launching.

Mast retraction at vehicle liftoff is an automatic function tied to the firing circuits for proper sequencing. The retracting assembly (figure 4-2) is in essence an adjustable pneumatic cylinder that functions to pivot the upper portion of the mast into position to or away from the vehicle filling nozzle. The application of pneumatic pressure to the upper part of the cylinder forces the cylinder piston down and pivots the mast to its retracted position. An arrestor mechanism prevents the mast from bouncing back into the vehicle. Application of pneumatic pressure to the lower part of the cylinder, together with venting of pressure above the piston, pivots the mast into its erected position. Manual control for erecting and testing the fuel mast is provided through a pneumatic valve box mounted on the mast support stand. An advantage of the fuel mast installation is its ability to automatically connect, disconnect, and reconnect to the vehicle. In addition, if at liftoff the automatic retract feature has failed, the vehicle will merely fly away from its umbilical connection.

Liquid Oxygen (LOX). The vehicle LOX filling nozzle is located in the aft skirt of LOX container L3, twenty-two and one-half degrees from fin III between fin III and fin II. Ground connection to the vehicle is made through the LOX mast installation (figure 4-5) mounted on the launch platform.

The LOX mast assembly is similar to the fuel mast assembly in operation, physical characteristics, and function; but basic differences exist in the type of installation. The LOX mast does not have the fire prevention features of the fuel mast, but it does provide expansion joints and pipe guides to compensate for LOX line length variation and longitudinal movement resulting from the extreme operating temperature variations.

The retractable coupling assembly of the LOX and fuel masts, with the sphere and ball mating surfaces, is particularly effective for cryogenic use.

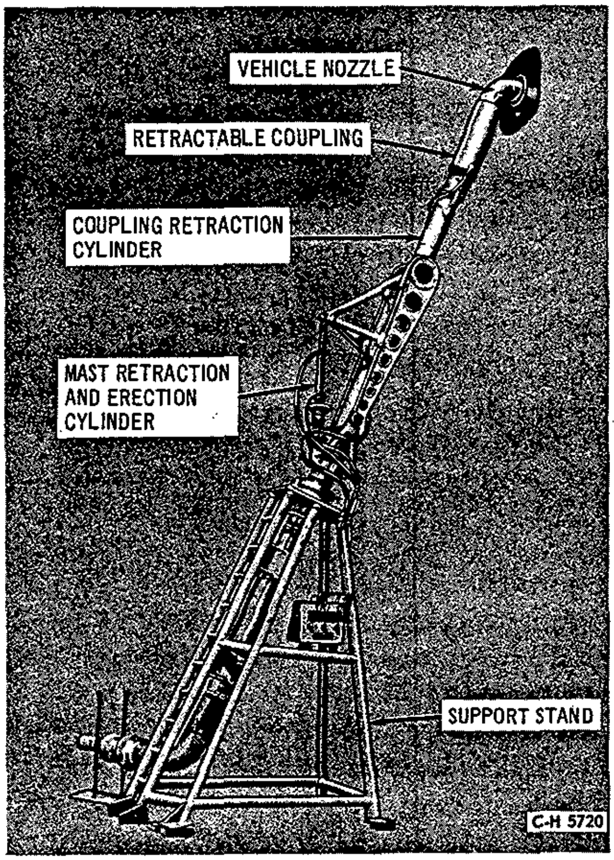

Figure 4-5. Lox Mast Assembly Connection

Figure 4-6 shows the connection at disconnect. Note that the frost has not interfered with obtaining an adequate seal or disconnect. This coupling has been so successful that adaptations of the coupling are being used for other Saturn I stages and for the Saturn V, where sealing and disconnect problems are encountered with transfer lines carrying cryogenic materials.

Although there have been no problems with disconnecting the LOX mast coupling, failure of the mast to fully retract has been encountered during firings of the Block I vehicles. These failures resulted in the destruction of the LOX mast by missile blast. It can be assumed that the cause of the failures has been corrected.

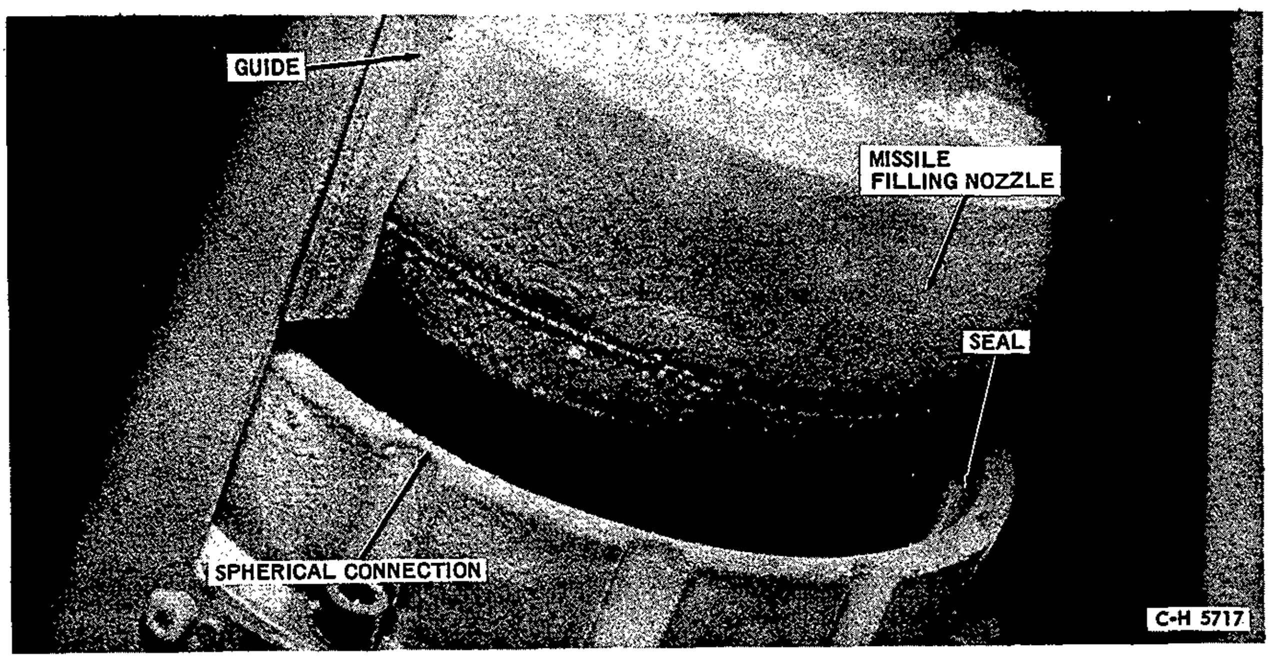

Figure 4-6. Ball and Sphere Type Coupling at Disconnect

LOX REPLENISHING

The LOX replenishing coupling is located differently on Block I and Block II vehicles. On Block I vehicles, the coupling is located at the base of the tail unit at fin line III and at the periphery of the vehicle. On Block II vehicles, the coupling is located at the base of the tail unit at fin line IV, slightly inboard of the vehicle periphery. The difference between location of the connection on Block I and Block II vehicles is the result of the difference in configuration and the method of holddown.

The LOX replenishing coupler assembly is mounted on holddown arm number III for Block I vehicles, and it is mounted on the water quench support bracket at holddown arm number IV for the Block II vehicles. The coupling installation is basically the same for both Block I and Block II vehicles. It consists of a mounting bracket, a keeper, a bellows assembly, a coupling, and an adjustment unit (figures 4-7 and 4-8), and connects the vehicle nozzle to the LOX replenishing line on the launch platform. A screw adjustment unit on the lower end of the coupling provides for general alinement of the coupling and adjusts the preflow tension on the bellows.

The bellows assembly (figure 4-9) provides a positive seal between the coupling and the vehicle nozzle, and also provides flexibility necessary to prevent damage to the coupler assembly during rising and settling of the vehicle at liftoff. The mating surfaces of the connection are ball and sphere, and a positive seal is maintained by the preflow tension maintained on the ring seal by the bellows.

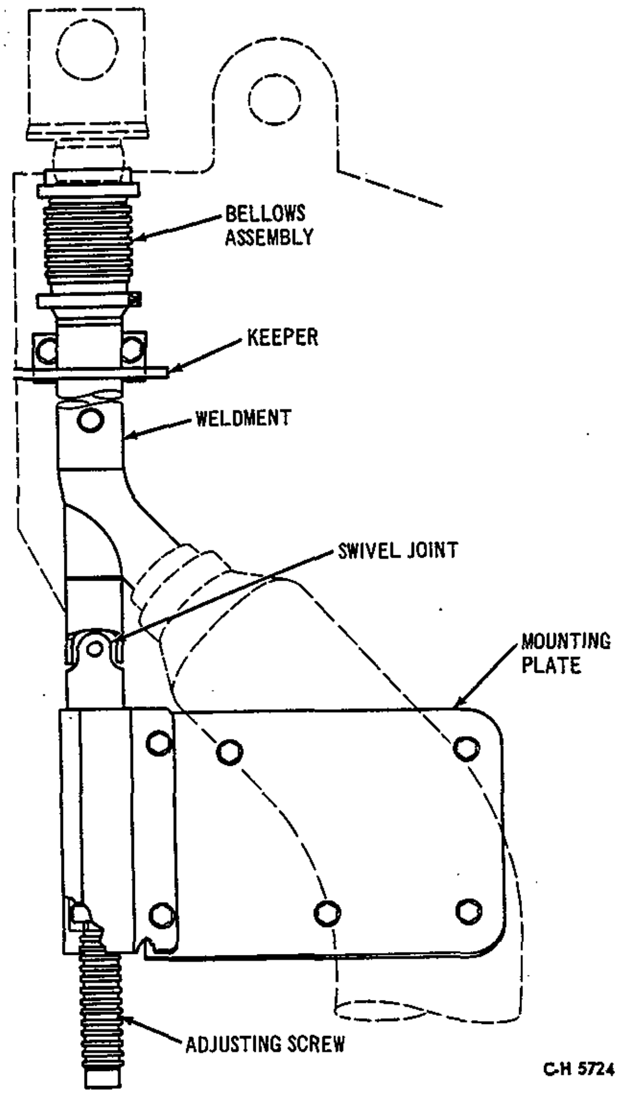

Figure 4-7. Lox Replenishing and Boattail Heater and Conditioning Coupling Assembly (Block I)

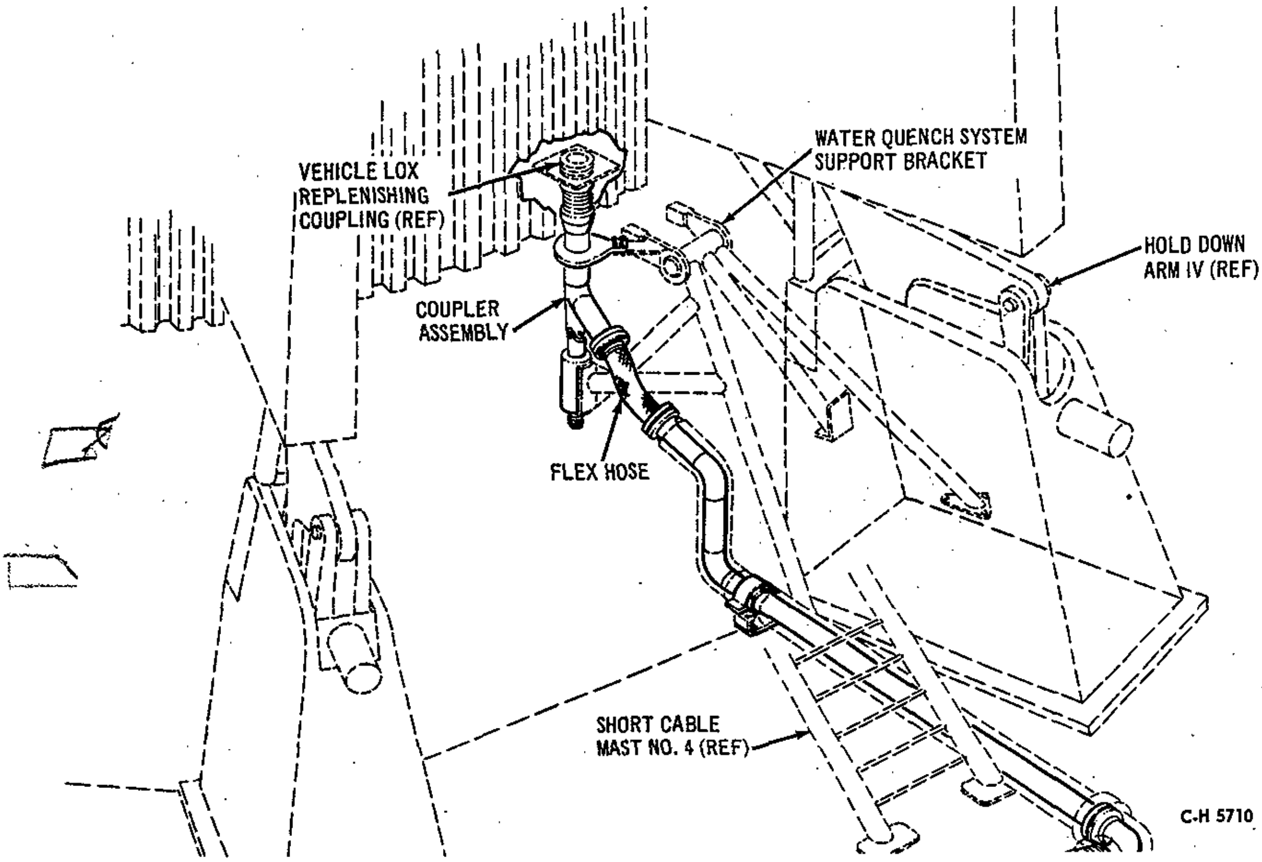

Figure 4-8. Lox Replenishing Coupler Assembly Installation (Block II)

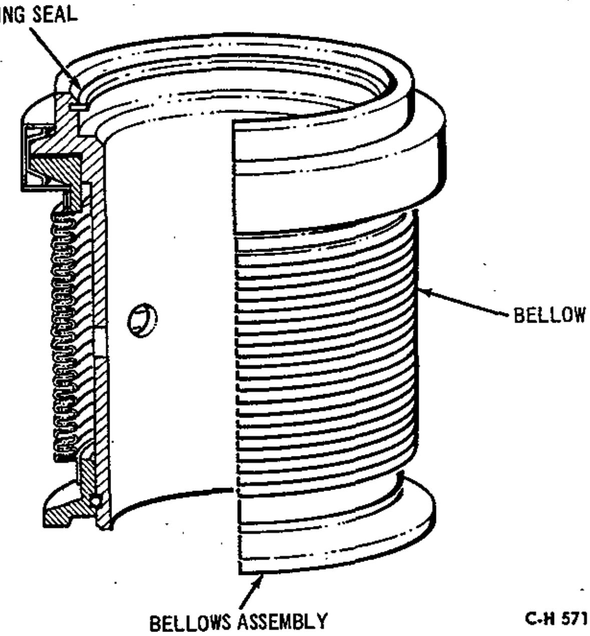

Figure 4-9. Lox Coupling Bellows Assembly

During replenishing, additional force is exerted on the ring seal as the bellows expands with the operating pressure.

There is no positive lock of the LOX replenishing connection, and disconnect is accomplished as the vehicle lifts off the ground half.

LOX VENTING

The LOX venting connections (figure 4-10) are located at the forward end of the vehicle. The 7-inch vent line connects to LOX container L1 at a point above the service structure's first service platform. The two 4-inch vent lines connect to the vent valves on LOX containers L3 and L4 in the same general location as the 7-inch LOX vent assembly.

Each vent line is 50 feet long and serves to direct the venting LOX away from the workmen working on the tower at this level.

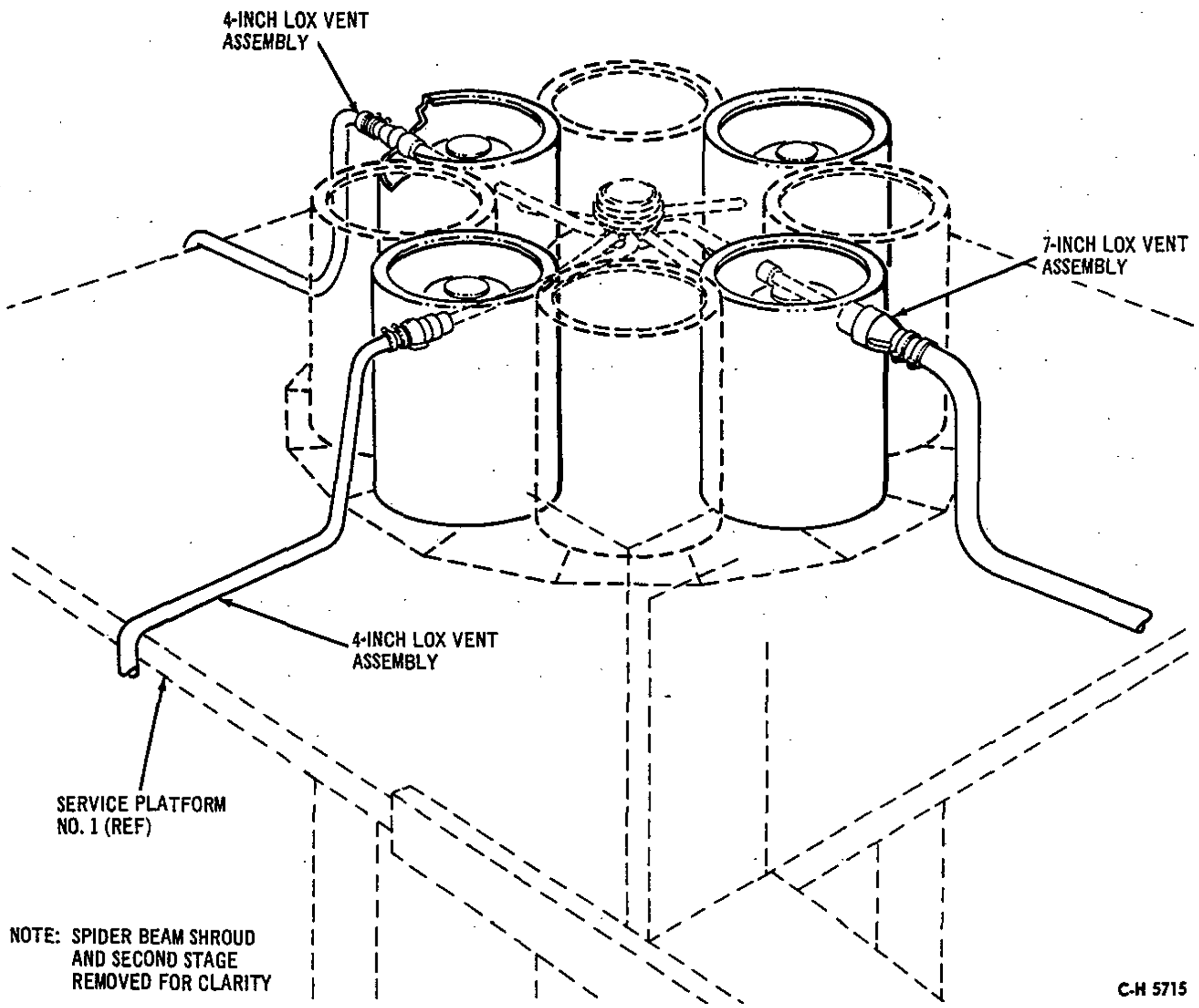

Figure 4-10. Lox Venting Connections

Connection to the vehicle is made manually with a slip-type coupling that slips into the LOX vent in the tank. When the workmen are through with prelaunch preparations at this level, the LOX vent lines are manually removed from the vehicle.

BOATTAIL CONDITIONING AND WATER QUENCH SYSTEM

The boattail conditioning and water quench system (figure 4-1) is a fire protection system that transfers water to the boattail area for combating fires that may occur before vehicle liftoff. In addition, the installation is used in conjunction with the environmental control system and deluge purge system to provide a controlled atmosphere in the boattail area for personnel safety and vehicle protection during various phases of prelaunch preparation while the vehicle is on the launch platform.

On Block I vehicles it was originally intended that the boattail conditioning and water quench systems would be separate systems with separate connections to the vehicle; however, the noise produced in the boattail heater conditioning connection, by the volume of conditioning air going through it, suggested that the desired volume of air could be obtained by routing it through the water quench system as well as the boattail heater conditioning system. This resulted in having five boattail conditioning and water quench connections to the vehicle. On Block II vehicles the boattail heater connection has been eliminated.

The boattail conditioning and water quench installation is essentially four installations located at the fin lines at the base of the vehicle. Between Block I and Block II vehicles there are differences in the location of the boattail conditioning and water quench system installation. On Block I vehicles the vehicle connections were located at the base of the tail unit on the vehicle skin next to the fin lines. The four installations were mounted on the sides of the holddown arms. On Block II vehicles, the vehicle connections are located at the heat shield on the base of the vehicle and on the centerlines of the fins. The four installations are mounted on the inboard sides of the holddown arms.

The boattail heater and conditioning system connection incorporated in the Block I vehicles was located at the heat shield at the aft end of the tail unit at fin line II. The coupling assembly (figure 4-7) was identical to the LOX replenishing coupling and was mounted on the side of holddown arm II. Disconnect was accomplished at missile liftoff.

The water quench mast assemblies (figure 4-11) of Block I vehicles consisted of a bellows assembly, an adapter, a pipe assembly, a collar assembly, and a swivel assembly. The vertical adjustment and gimbal joint of the swivel assembly facilitated the alinement of the mast to the vehicle nozzle. The rotating arm of the swivel assembly manually raised the mast assembly to mate the mast with the vehicle nozzle and provided a preflow seal of the ball and sphere mating surfaces. A collar assembly was used for the attachment of linkage that opened and retained open the spring-loaded valve in the vehicle nozzle until after liftoff. Disconnect of the connection at liftoff was accomplished by the vehicle merely moving away from the mast assembly.

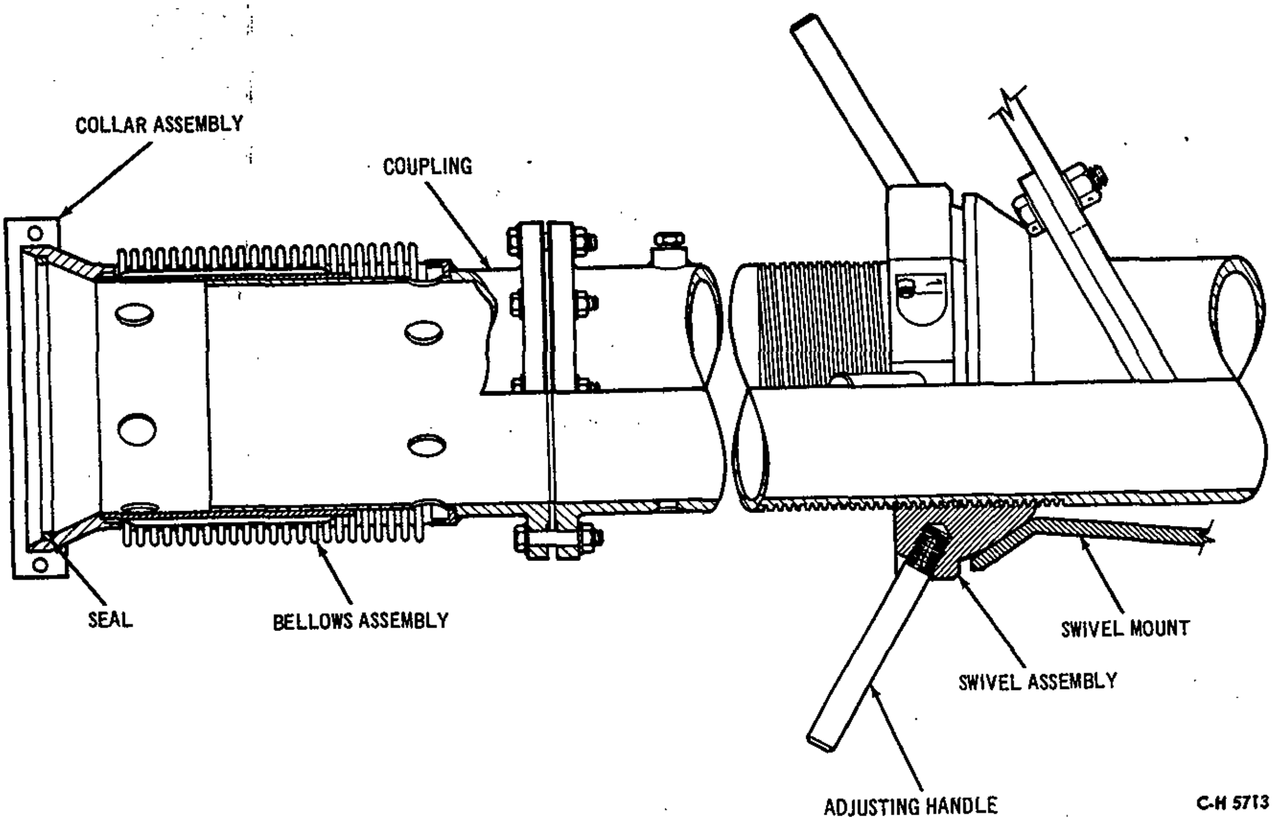

Figure 4-11. Water Quench Mast Assembly (Block I)

The boattail conditioning and water quench system installation (figure 4-12) on Block II vehicles consists of a support bracket, disconnect coupling, flexible hose assembly, valve assembly, elbow assembly, and the installing hardware. The four installations are similar with the exception of the support at fin IV, which has a modification for the installation of the LOX replenishing coupler assembly.

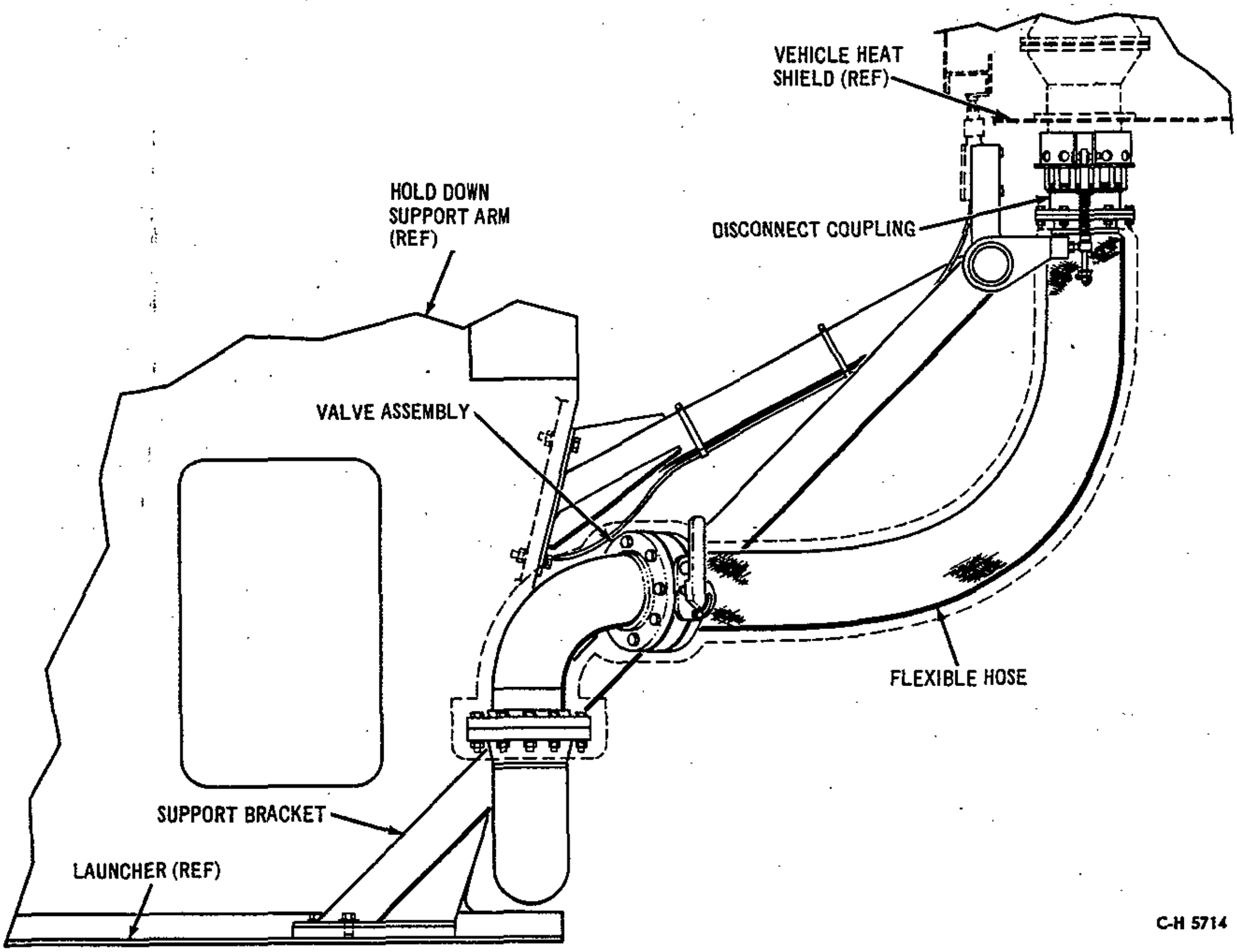

Figure 4-12. Boattail Conditioning and Water Quench Installation (Typical)

The disconnect coupling assembly (figure 4-13) consists basically of a spider secured to a coupling socket by three screws. A pin on the spider engages the poppet on the vehicle valve assembly and forces the valve assembly to the open position when the coupling is installed. The coupling socket consists of a collar and several spring fingers which lock together the disconnect coupling and valve assembly. Connection of the coupling to the vehicle is made manually and requires a force of 50 pounds.

The coupling is disconnected as the vehicle lifts away from the coupling assembly. Approximately 500 pounds is required to separate the disconnect coupling from the vehicle at liftoff. The poppet in the vehicle valve assembly is spring-loaded and automatically closes the valve assembly at liftoff.

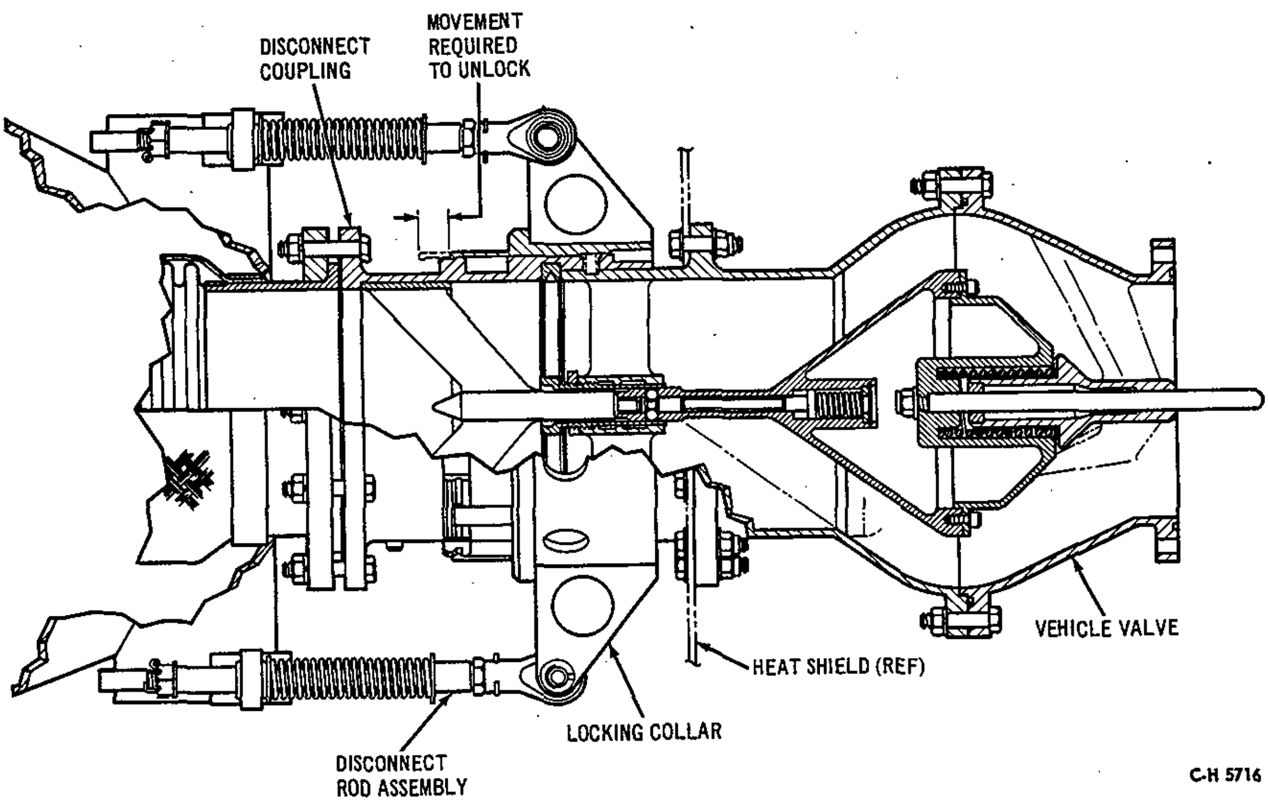

Figure 4-13. Boattail Conditioning and Water Quench Disconnect Coupling

PNEUMATIC, ELECTRICAL, AND COOLING

Short Cable Mast. The vehicle quick-release plates (figure 4-14) for the pneumatic and electrical ground service connection of the two short cable masts are located on the skin at the forward end of the tail unit next to fins II and IV respectively.

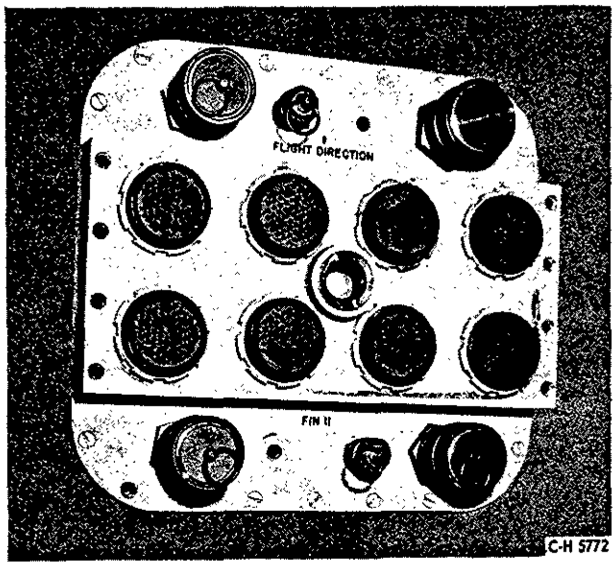

Figure 4-14. Vehicle Quick-Release Plate, Short Cable Mast

The short cable mast (figure 4-15) provides the connecting link, structural support, and disconnect capability for electrical cables and pneumatic service lines required for ground checkout and operation of vehicle engine components before launch. There are differences between the short cable masts used on Block I vehicles and those used on Block II vehicles; however, for each Block the masts used at fin II and fin IV are similarly constructed, with the most significant difference being the type, size, quantity, and routing of cables and pneumatic lines required at each fin.

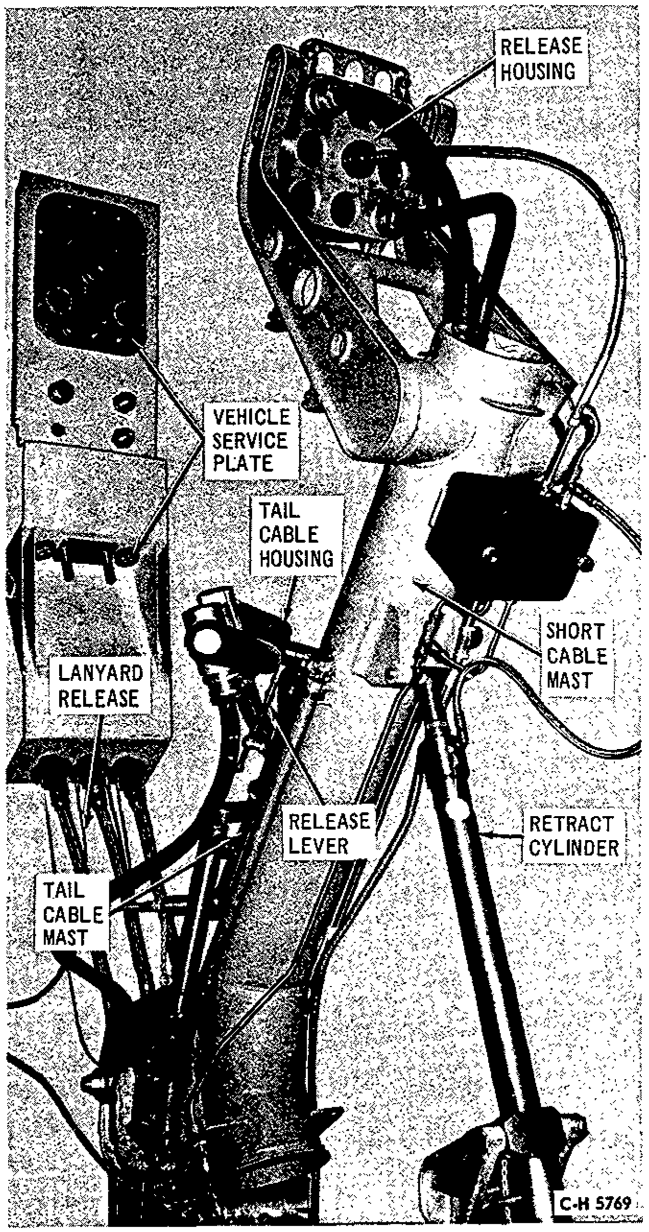

Figure 4-15. Short Cable Mast (Block I)

The Block I short cable mast shown in figure 4-16 provided for up to eight electrical connections and six pneumatic connections in the quick-release housing. The housing (figures 4-17 and 4-18) was locked to the vehicle with a ball lock. Release of the housing was accomplished pneumatically when 750 psig applied pressure released the ball-lock pin and simultaneously forced the pushoff piston against the vehicle service plate. A pneumatic cylinder retracted the mast and also acted as a snubber to prevent the mast from rebounding into the vehicle. As the mast retracted, lanyard cables attached to three additional pneumatic couplings pulled the couplings from the vehicle. There was no redundant release and retraction of the short cable masts for the Block I vehicles. In the event

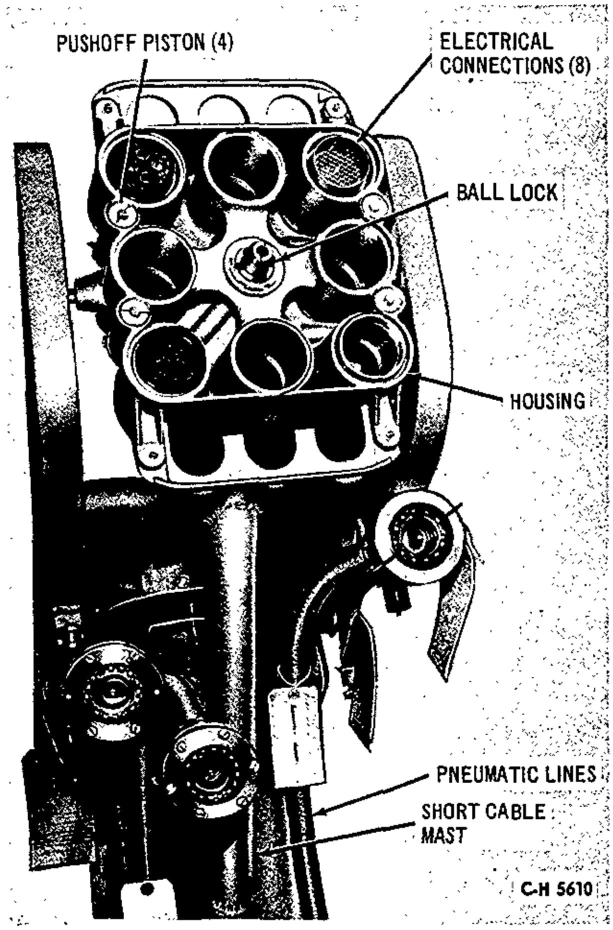

Figure 4-16. Short Cable Mast Connections

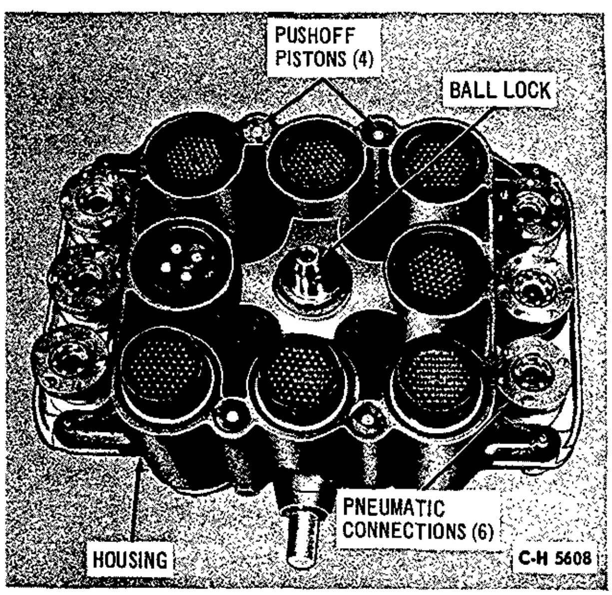

Figure 4-17. Short Cable Mast Quick-Release Housing Interface

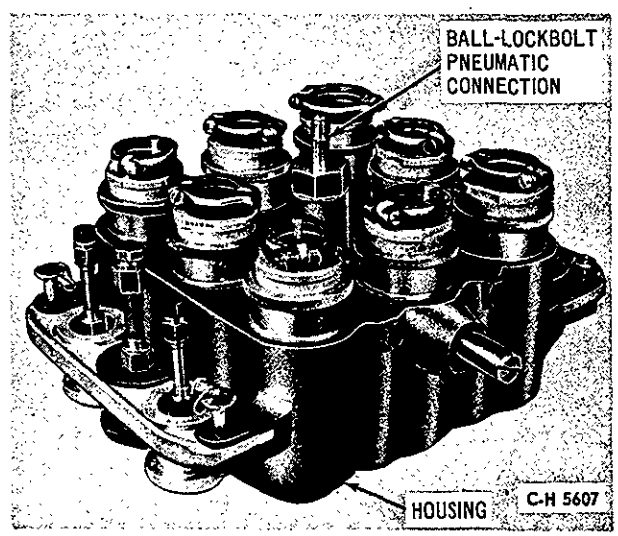

Figure 4-18. Short Cable Mast Quick-Release Housing

of a pneumatic failure of the release mechanism, the normal automatic sequence of firing was interrupted, and ignition and holddown release could not occur until the pneumatic failure was corrected and the normal sequence resumed. Fortunately this eventuality did not occur during the four successful launchings of the Block I vehicles.

Further development of the Saturn I program indicated that it would be desirable to have certain electrical and pneumatic connections remain attached to the vehicle until "bootstrap" occurred. On Block I vehicles, a tail cable mast with three electrical cable connections supplemented the short cable mast assembly as shown in figure 4-19. Also appropriate pneumatic lines were incorporated with the tail mast assembly. The connection and release of this mast was such that connection to the vehicle was maintained for a few inches of vehicle flight before disconnect occurred.

The tail cable mast was attached to the vehicle after the short cable mast was secured to the vehicle. This sequence of installation was followed because it eliminated having to overcome the tension of the tail cable mast retract cylinder springs that operated in conjunction with the retraction of the short cable mast. The tail cable housing was locked to the missile with two ball-lock pins (figure 4-19). The release lever that held in the lock pins was secured with two shear pins. A rod from the release lever extended through a stop weldment on the inner support of the tail cable mast; a stop nut was on the end of the rod.

Release of the tail cable mast housing was accomplished as the housing and mast upper support moved upward with the missile at liftoff. The stop nut, on the end of the rod that attached to the release lever, stopped at the stop weldment on the mast inner support. As the mast housing continued to move upward, the pins holding the release lever were sheared. The release

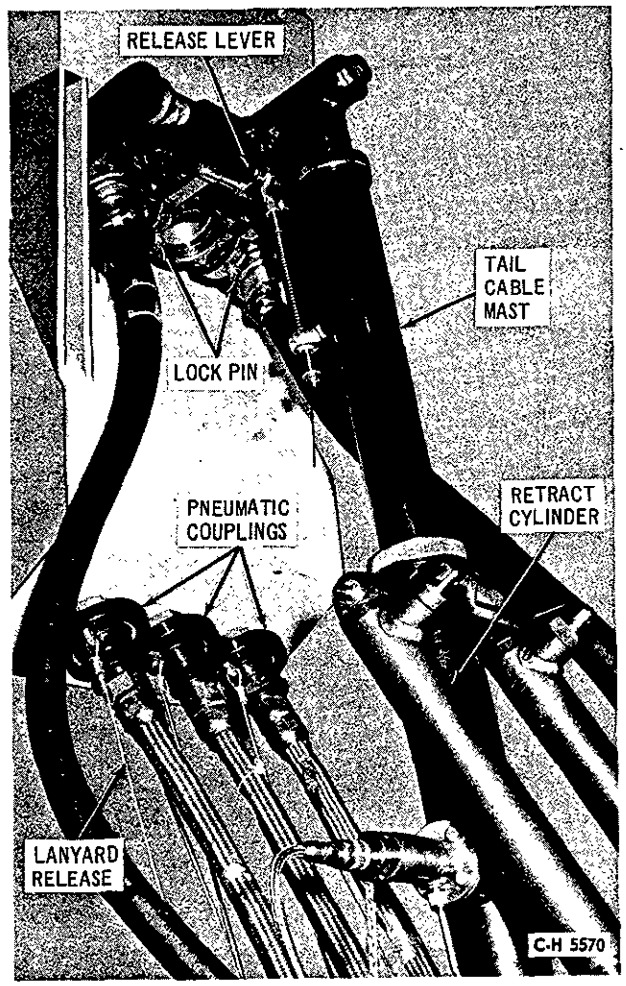

Figure 4-19. Tail Cable Mast Assembly (Block I)

lever pulled the ball lockpins, and released the housing from the vehicle. Prior retraction of the short cable mast had applied spring tension to the tail mast retract cylinder so that, as the tail mast housing was released from the vehicle, the tail mast retracted. A latch prevented the mast from rebounding into the vehicle. Lanyard cables from the tail mast to pneumatic couplings on the missile pulled these couplings from the vehicle also as the vehicle moved upward.

Development work on the short cable masts has produced, for the Block II vehicles, a quick-release housing and retract mechanism that is controlled by missile motion only, thus eliminating a need for and possible failure of pneumatic lines, valves, switches, etc. The two short cable masts for the Block II vehicles are shown in figure 4-20. Each mast assembly basically

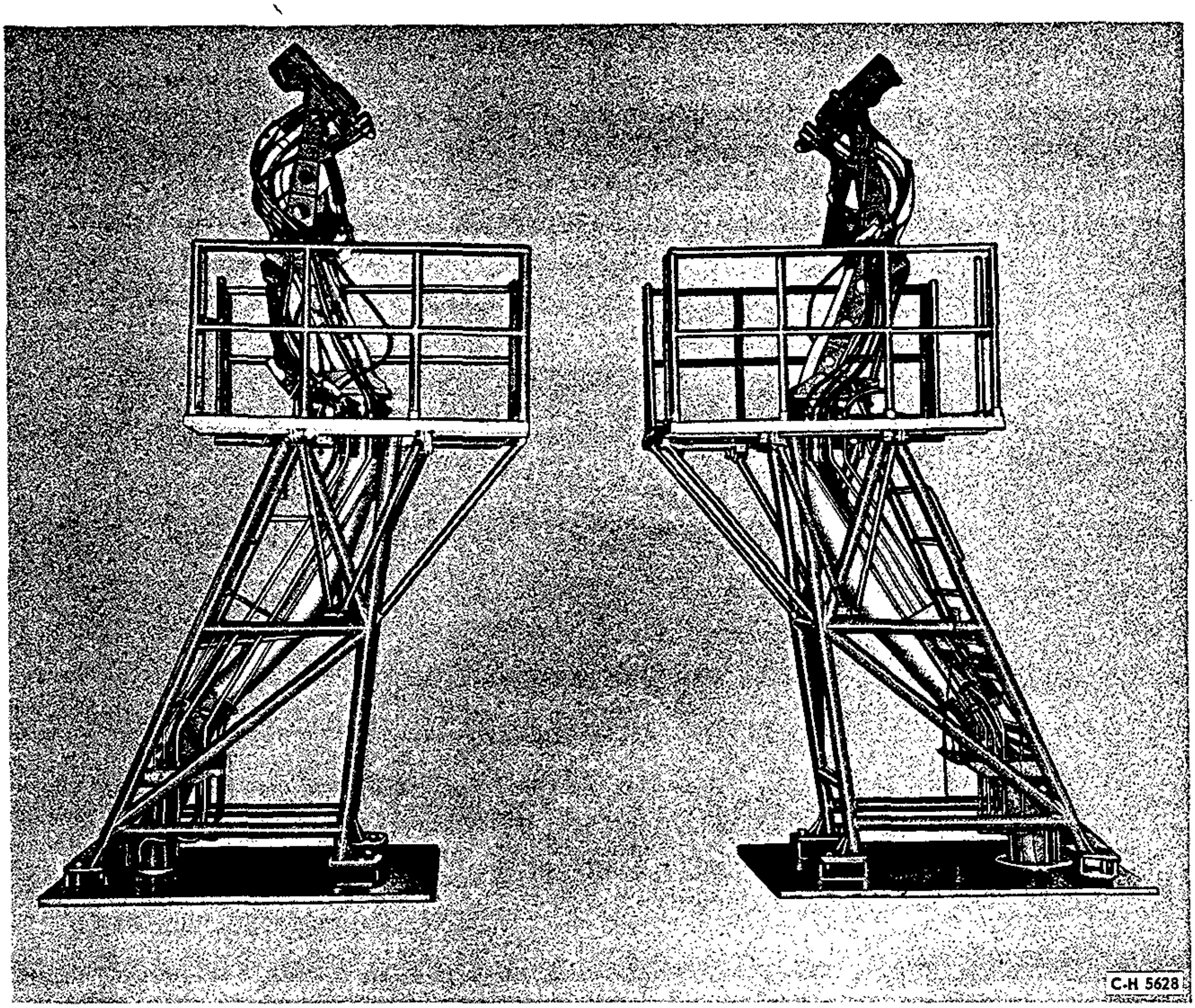

Figure 4-20. Short Cable Masts (Block II)

consists of a support platform, a mast weldment, two kickoff cylinders, a retract cylinder, a quick-release housing, a latch-back mechanism, electrical cables, pneumatic service lines, and supporting hardware.

The design of the quick-release housing and mast incorporates all the pneumatic umbilical connections in the quick-release housing, thereby eliminating the extraneous pneumatic couplings that, on Block I vehicles, required lanyard release cables attached to the cable mast. In addition, because the design of the housing and release mechanism permits several inches of vehicle travel before release, the need for a tail cable mast and its related extraneous pneumatic couplings has been eliminated.

The quick-release housing is attached to the vehicle with the familiar ball lock. For prelaunch checkout of the quick-release and retract mechanisms, the housing is provided with four pneumatically operated pushoff pistons. Normal locking and release of the housing is accomplished with a cam-operated release arm that attaches to the ball-release pin. The roller on the end of the release arm fits into the cam of the mast arm and guides the release arm to either the lock or release position. After the housing is attached to the vehicle, the two spring-loaded kickoff cylinders are extended into position on the vehicle support brackets. Figure 4-21 shows the short cable mast attached to the vehicle.

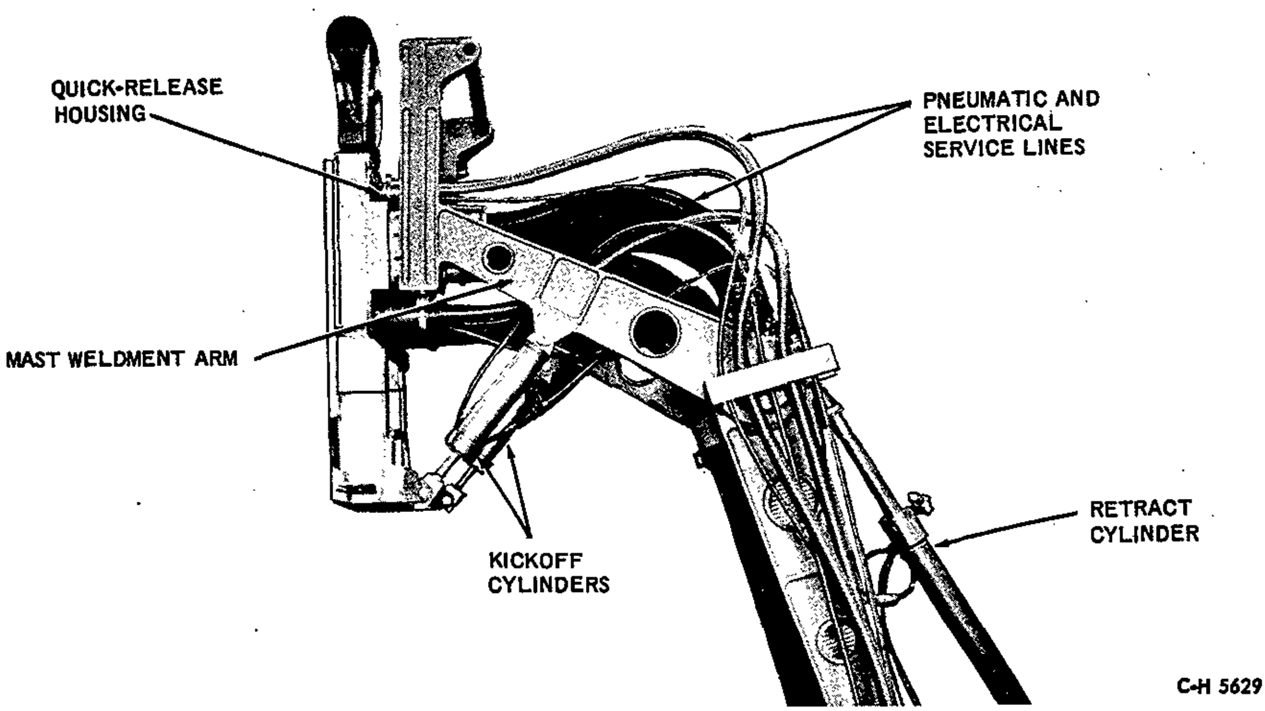

Figure 4-21. Short Cable Mast Attached to Vehicle (Block II)

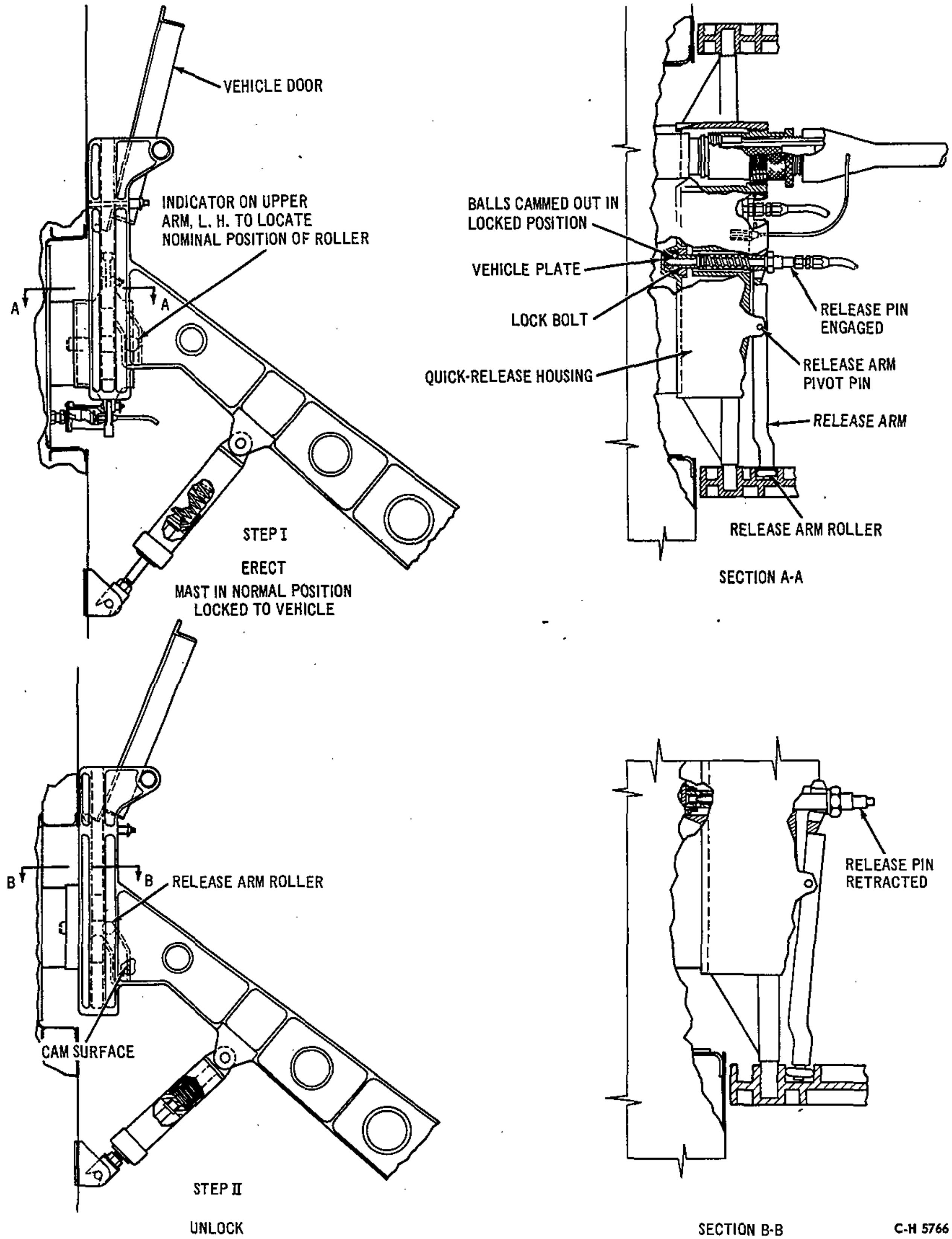

Figure 4-22. Short Cable Mast Release and Retract Sequence (Block II)

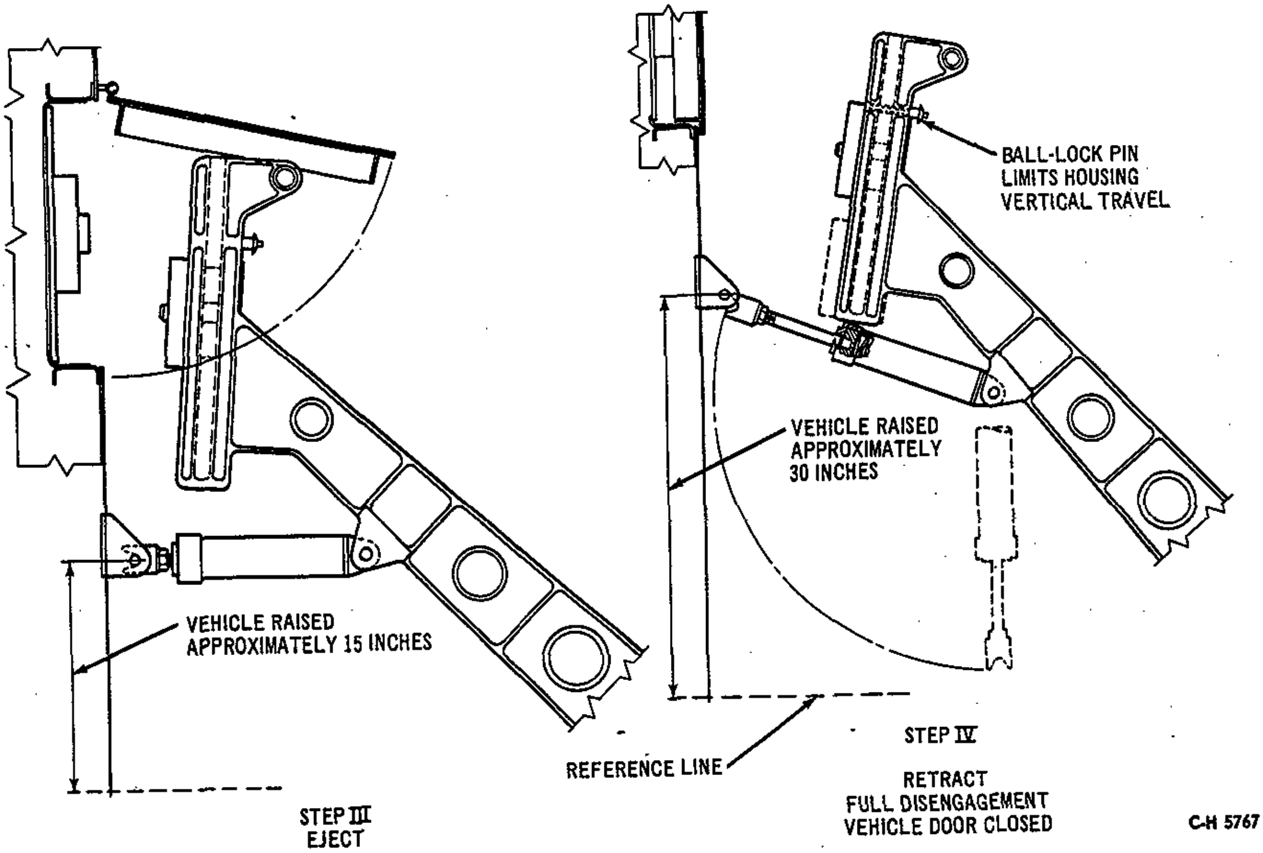

Figure 4-23. Release and Retract Sequence Continued (Block II)

The release and retract sequence of the short cable mast is shown in figures 4-22 and 4-23 and occurs as the vehicle lifts in flight. At vehicle liftoff, the quick-release housing starts moving upward with the vehicle. The vehicle ends of the kickoff cylinders also move upward with the vehicle, further compressing the kickoff cylinder springs. As the release arm roller travels along the mast arm cam slot, the release arm pivots and disengages the release pin after approximately two inches of vehicle motion. The kickoff cylinders and springs provide the force necessary to disconnect the cables and lines from the vehicle and accelerate the mast away from the vehicle. As disconnect occurs, the pneumatically operated retract cylinder pulls the mast out of the way of the vehicle and cushions the mast's travel. The latch-back mechanism prevents the mast from rebounding into the vehicle.

Long Cable Mast (Block I SA-1 and SA-2). A holdover concept from the Jupiter program was the long cable mast (figure 4-24) used on SA-1 and SA-2 of the Saturn I Block I vehicles. The over-75-foot mast was mounted on the launch platform next to rotating arm number 1 near fin line II. The mast assembly consisted of a support frame assembly, screw drive assembly, brake valve installation, stiff leg assembly, mast section assemblies, top support assembly, and a quick-release housing. Wind brace anchor assemblies provided stability during windy conditions. The long cable mast attached to the vehicle service plate mounted on the interstage fairing between fin lines I and II (figure 4-25). The assembly provided the means for routing and connecting electrical cables, pneumatic lines, a liquid nitrogen line, a precooler, and two air-condition ducts to the S-I stage instrument compartments from the ground support equipment.

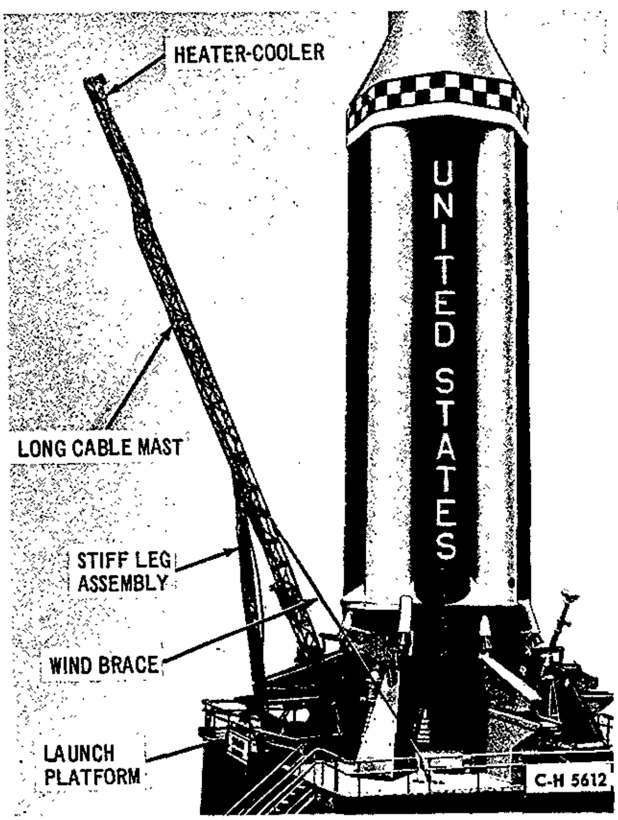

Figure 4-24. Long Cable Mast Retracted (Block I)

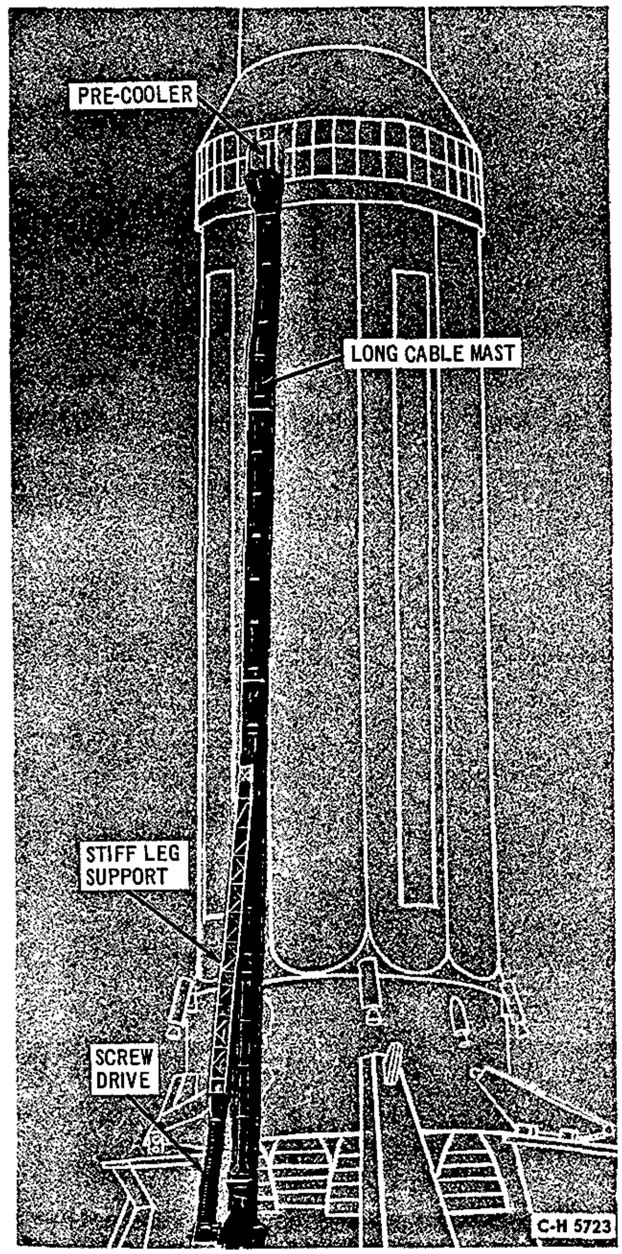

Figure 4-25. Long Cable Mast Connected (Block I)

The quick-release housing (figure 4-26) contained provisions for six electrical connections, six pneumatic connections, a liquid nitrogen connection, and two air-conditioning ducts. A ball lock and release pin and four pushoff pistons were also incorporated in the housing. The quick-release housing and the precooler were mounted on the top support assembly of the long cable mast (figure 4-27). Disconnect features were designed to operate automatically from this vantage point. After erection of the long cable mast, with the electrically driven screw drive, the top support assembly of the mast assembly was locked to the vehicle with the ball lock in the quick-release housing.

Release and retract of the quick-release housing was accomplished pneumatically with 750 psig pressure. Pneumatic pressure moved the release

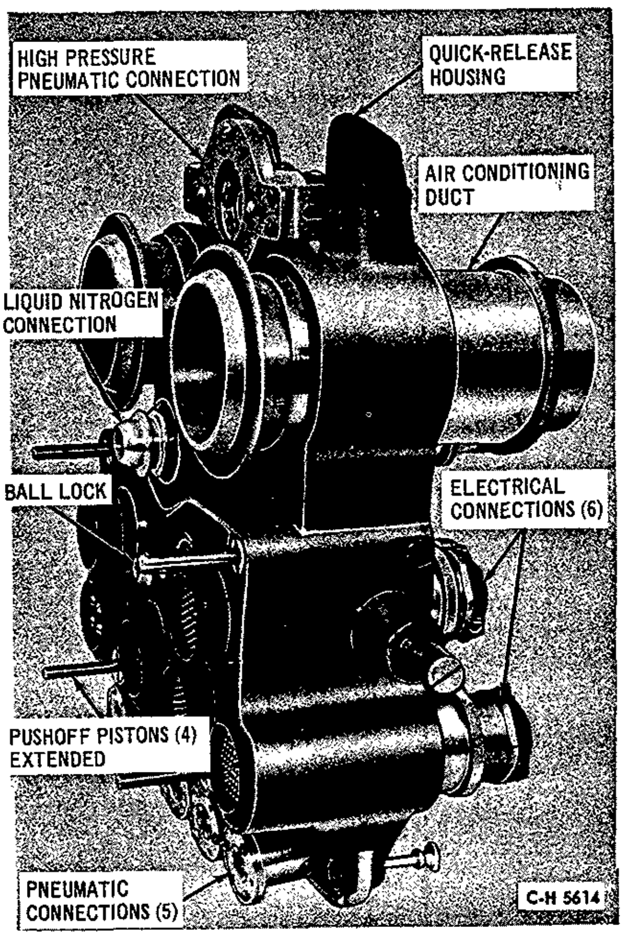

Figure 4-26. Long Cable Mast Quick-Release Housing

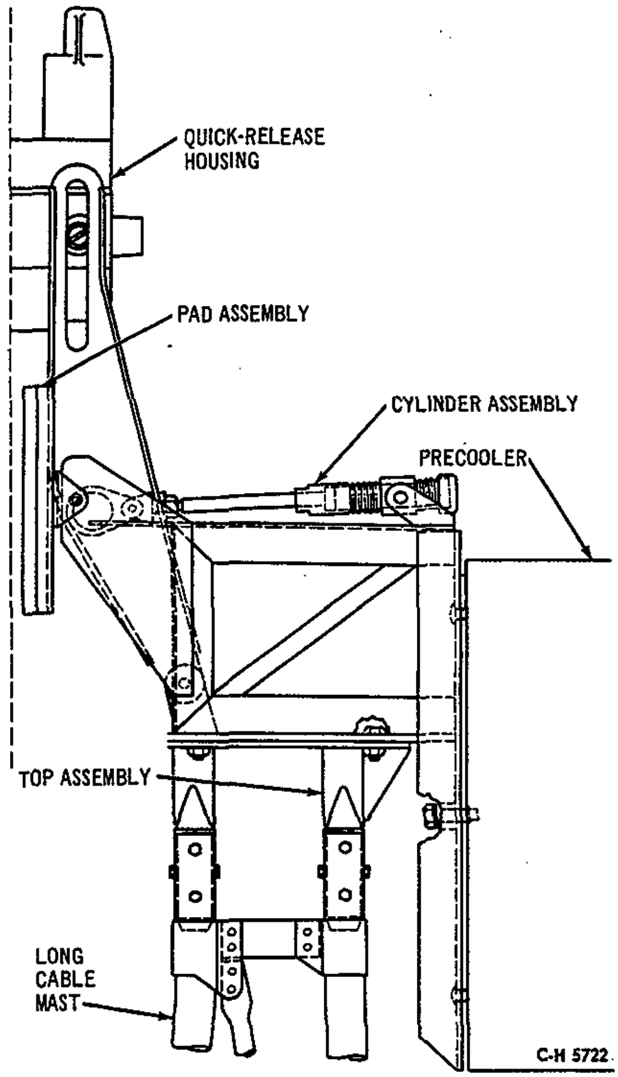

Figure 4-27. Long Cable Mast Top Support Assembly

pin out of the ball lock and simultaneously thrust the pushoff pistons against the missile plate. A cylinder assembly and disconnect arm (figure 4-27) aided in the separation and retraction of the quick-release housing. After release of the housing, the long cable mast assembly was retracted with the screw drive assembly.

During the firing of the first two Saturn I vehicles, the long cable mast in each instance was blown down and destroyed by missile blast. Since the cost of the mast was well over 100, 000 dollars, it was determined that a better method of routing and retracting the forward umbilicals was desirable. This resulted in an acceleration of the development program for the umbilical tower-swing arm concept for the routing, connection, and retraction of the umbilical connections to the forward end of the S-I stage Block I vehicles and to the forward end of the S-I stage and upper stages of the Block II Saturn I vehicles.

Heretofore the basic design of launching facilities had provided permanent or semipermanent reusable umbilical facilities to the launch platform and aft end of the vehicle from the ground support equipment; temporary, expendable umbilical facilities were provided from the launch platform to the forward end of the vehicle. For the mission of a weapons system, the expendability concept is satisfactory; but on an R&D program it is very desirable to be able to reuse the launch equipment with a minimum amount of refurbishing. The umbilical tower provides for a permanent umbilical installation from the ground equipment to the appropriate level on the vehicle, and the swing arm provides the connecting link, structural support, quick-disconnect capability, and retraction for the umbilical connections to the vehicle from the umbilical tower.

The relative positions of the umbilical tower, the launcher, and the vehicle (Block I and Block II vehicles) are schematically shown in figure 4-28. Note that the swing arms are mounted on a corner of the tower and that this corner is toward the launcher. This allows the swing arms to be rotated completely out of the way of the vehicle even if the vehicle were to assume the maximum anticipated drift during its launching.

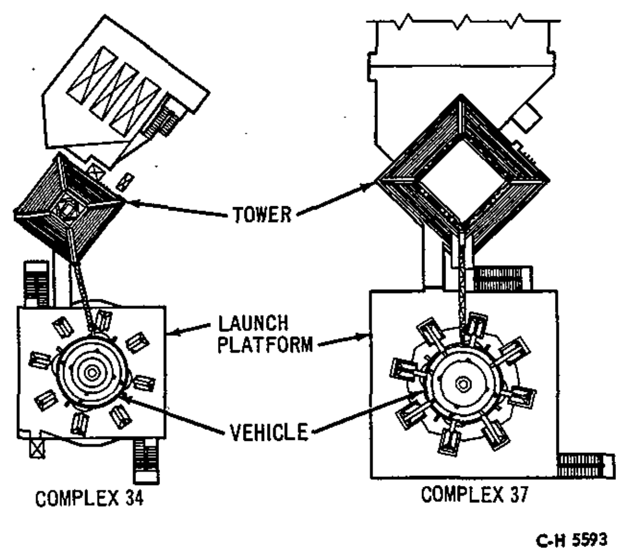

Figure 4-28. Relative Positions of Tower, Launcher and Vehicle

Umbilical Swing Arm (Block I SA-3 and SA-4). The swing arm assembly (figure 4-29) consisted of the basic arm structure, an actuating assembly, an extension arm, a retract cylinder, an LN_2 precooler, hydraulic tubing, pneumatic tubing, electrical cables, and the quick-release housing. The swing arm was mounted on the tower between the 100-foot and 110-foot levels and

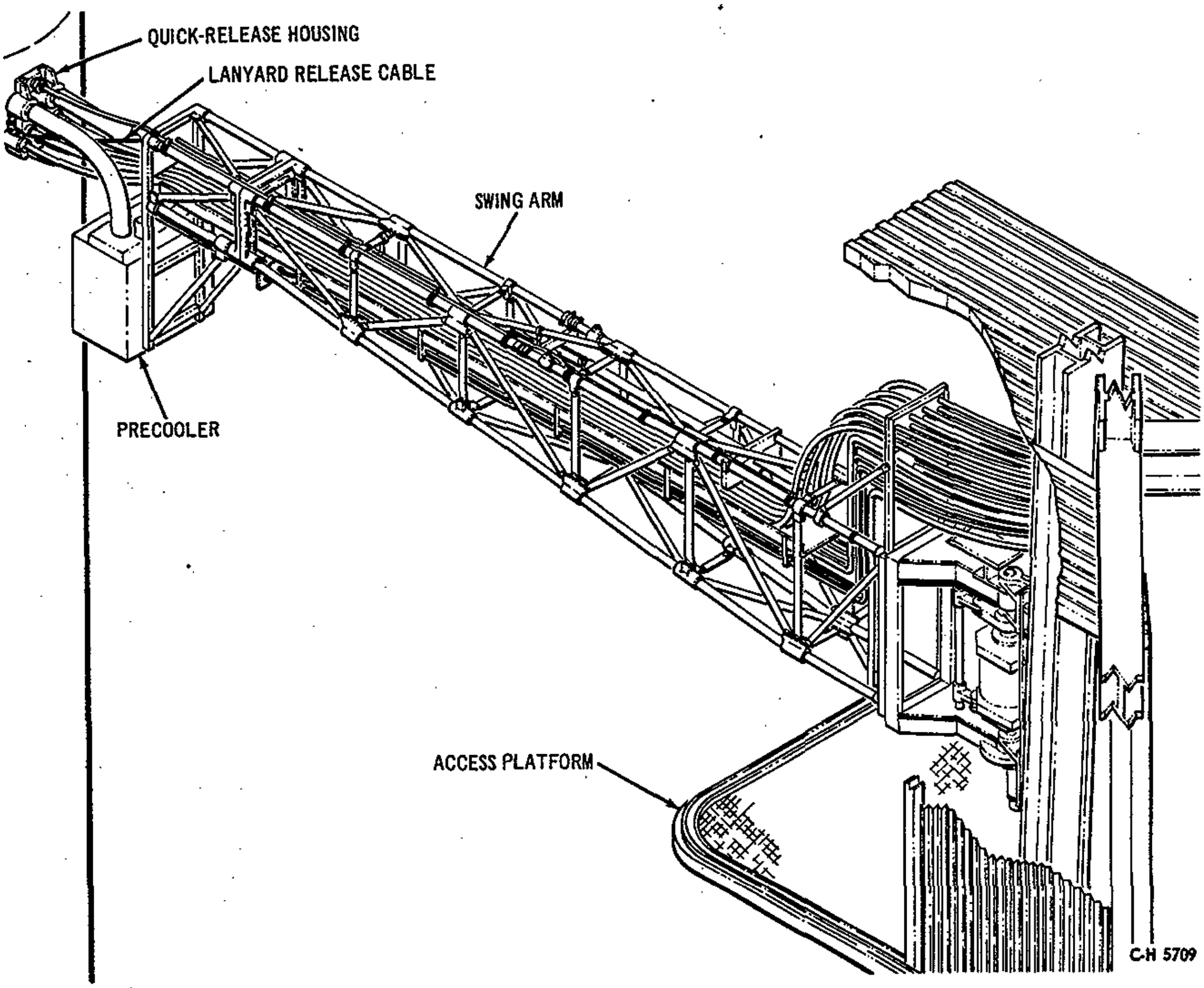

Figure 4-29. Swing Arm Assembly SA-3, -4 (Block I)

performed the same function as the long cable mast. The umbilical connections were made to the service plate on the interstage fairing of the vehicle near fin line II (figure 4-30).

The quick-release housing was the same as that used on the long cable mast. Release of the ball lock was accomplished pneumatically. Four push-off pistons were pneumatically thrust against the vehicle simultaneously with the release of the ball lock, thus separating the housing from the vehicle. There was no redundant release mechanism for this quick-release housing.

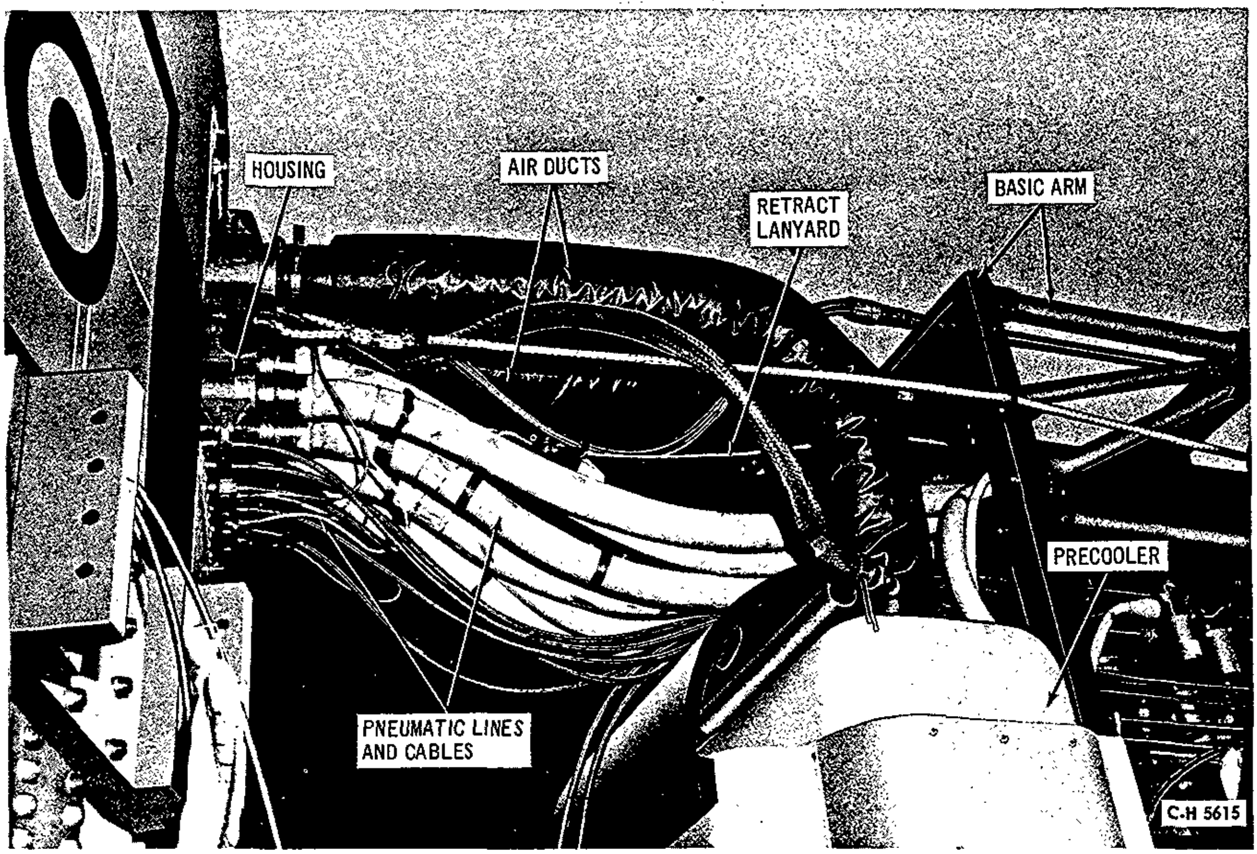

Figure 4-30. Umbilical Connections, Swing Arm (Block I)

Upon release of the housing, a hydraulically operated, lanyard retract cylinder pulled the release housing from the vehicle. Two strands of bungee cord, stretched to fifty pounds tension, aid the retract cylinder in pulling the housing from the vehicle and prevent the housing from rebounding into the vehicle. As the retract cylinder is retracting the release housing, the hydraulic rotary unit (ROTAC) rotates the swing arm 132 degrees, counterclockwise viewing from above, out of the path of vehicle flight.

WATER BALLAST (Block I Vehicles Dummy S-IV and S-V Upper Stages)

The dummy upper stages of the Block I vehicles consisted of two tanks enclosed in an aerodynamic housing as shown in figure 4-31. The hoses from a ground supply source were manually connected to the hand valves located in the bottoms of the tanks. The vent and overflow valves in the tops of the tanks were manually opened while water was pumped into the tanks. When the tanks were full, the fill and air vent valves were manually closed. The water tanks were filled from the service tower before it was removed from the launch area.

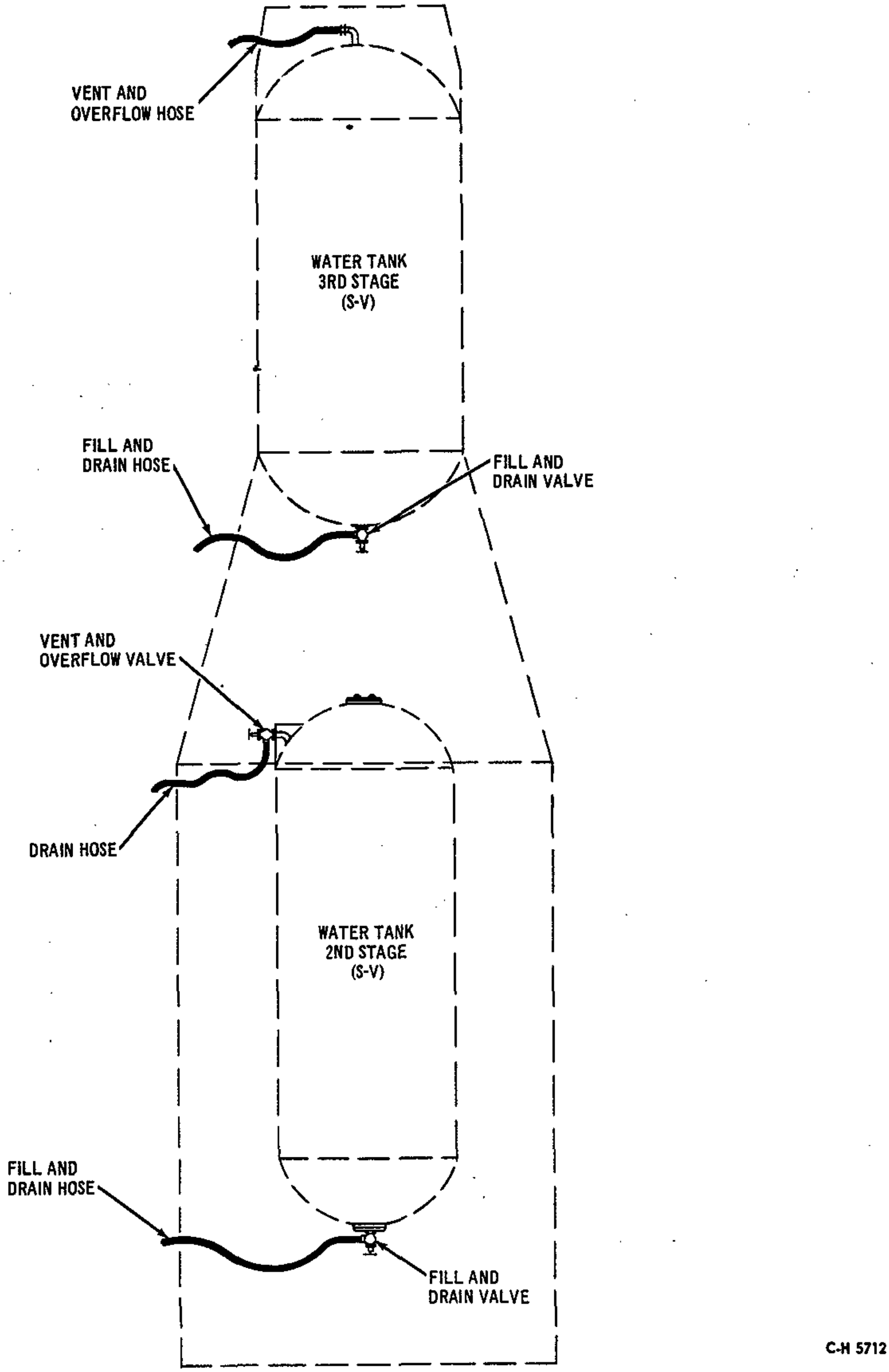

Figure 4-31. Dummy Upper Stages (Block I)

Umbilical Swing Arm Number 1 (Saturn I Block II). All the swing arms (figure 4-32) for Saturn I Block II vehicles are shown at the George C. Marshall Space Flight Center test facility.

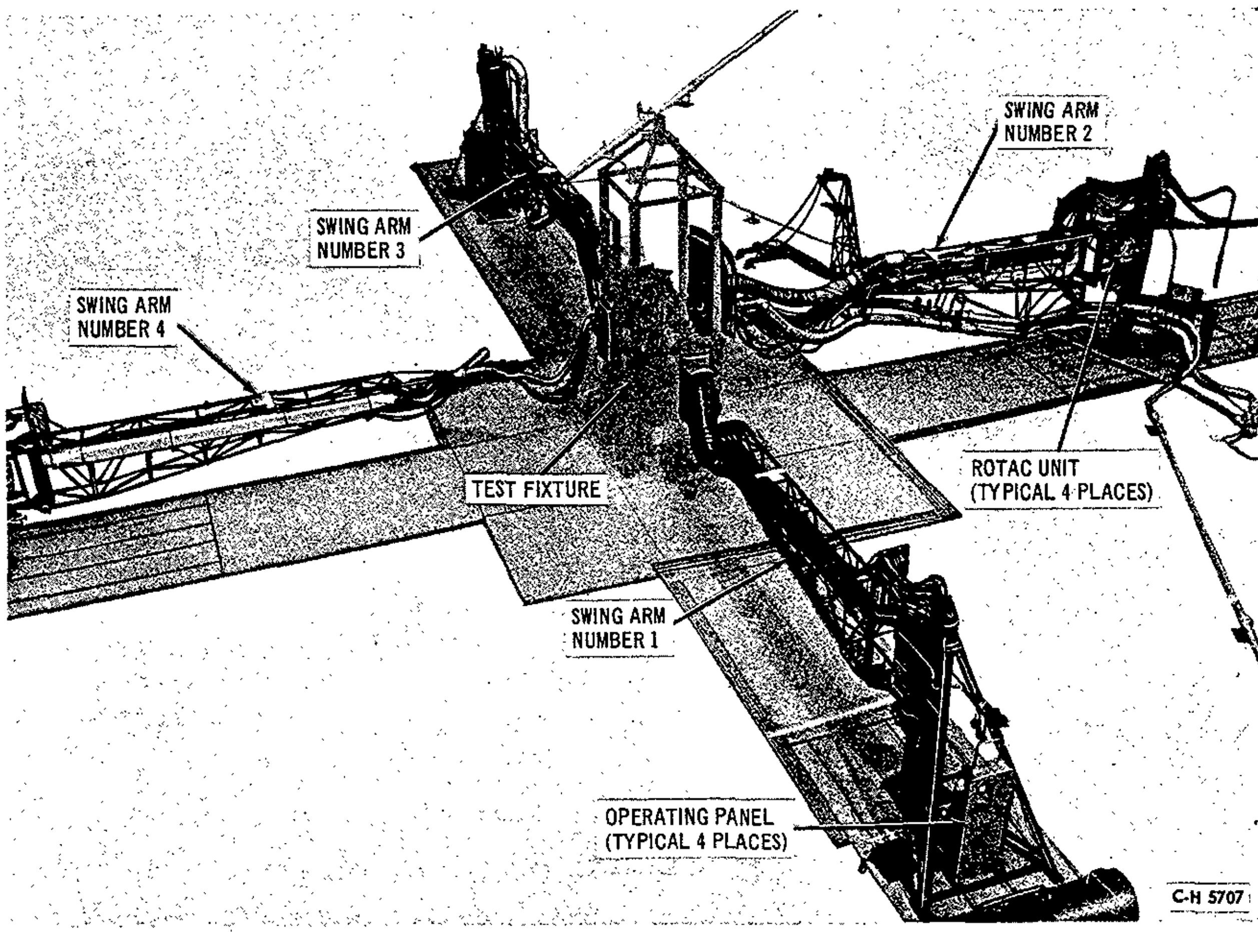

Figure 4-32. Saturn I Block II Swing Arms In Test Fixture

Swing arm number 1 (figure 4-33) performs the same function as the swing arm for SA-3 and 4 of the Block I vehicles. The swing arm is mounted on the tower between the 108- and 118-foot levels. Umbilical connections are made to the vehicle service plate located in the forward skirt of LOX container L2. The major difference between the number 1 swing arm of the Block II vehicles and the swing arm for SA-3 and 4 is that there is no arm extension provided for mounting a precooler unit. Instead, two air-conditioning ducts to the forward end of the vehicle are routed from the central ground support environmental conditioning system (ECS).

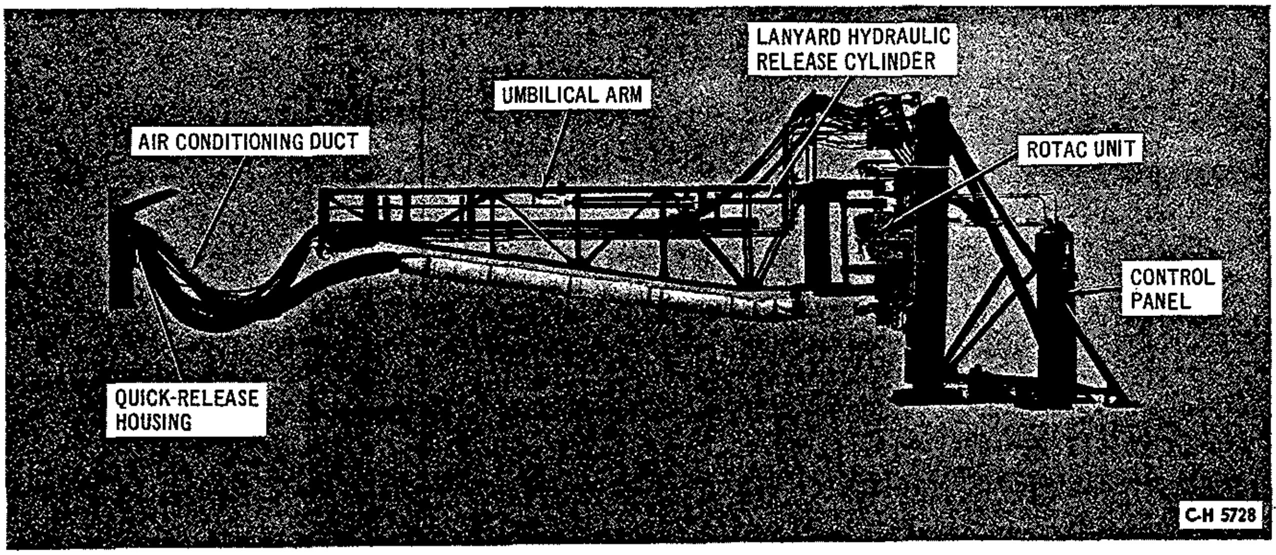

Figure 4-33. Swing Arm No. 1 Block II

The umbilical housing (figures 4-34 and 4-35) for the number 1 swing arm is secured to the vehicle with a ball-lock assembly.

To release the housing, pneumatic pressure releases the lockpin of the ball lock and simultaneously actuates four kickoff pistons that separate the housing from the vehicle plate. When the housing is released, the hydraulically operated lanyard retract cylinder pulls the housing away from the vehicle, and the swing arm rotates out of the way of the vehicle path.

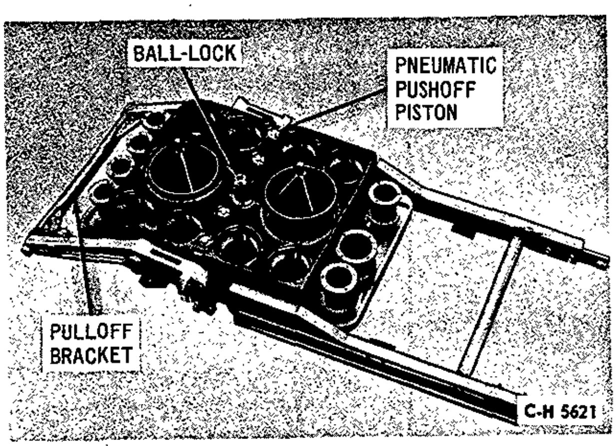

Figure 4-34. Swing Arm No. 1 Umbilical Housing Interface

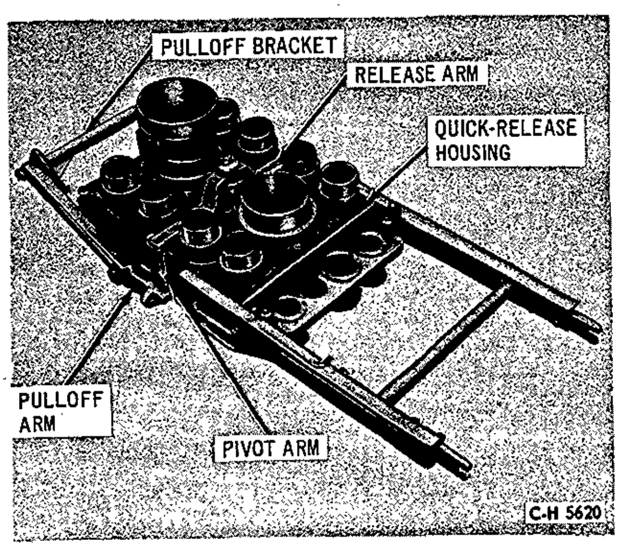

Figure 4-35. Swing Arm No. 1 Umbilical Housing

Figure 4-36 shows the redundant release mechanism of the umbilical housing. In the event of pneumatic failure, the hydraulic lanyard retract cylinder pulling on the pulloff bracket will rotate the pulloff arm. Through mechanical linkage the pulloff arm releases the ball-lock pin. Further rotation of the pulloff arm forces the "hockey stick" end of the arm against the vehicle plate and the housing. If both pneumatic and hydraulic release failure should occur, the mechanical release mechanism would be operated by the lanyard as the vehicle moved upward. This type of redundant release mechanism is provided for all four swing arms and umbilical housings for the Saturn I Block II vehicles.

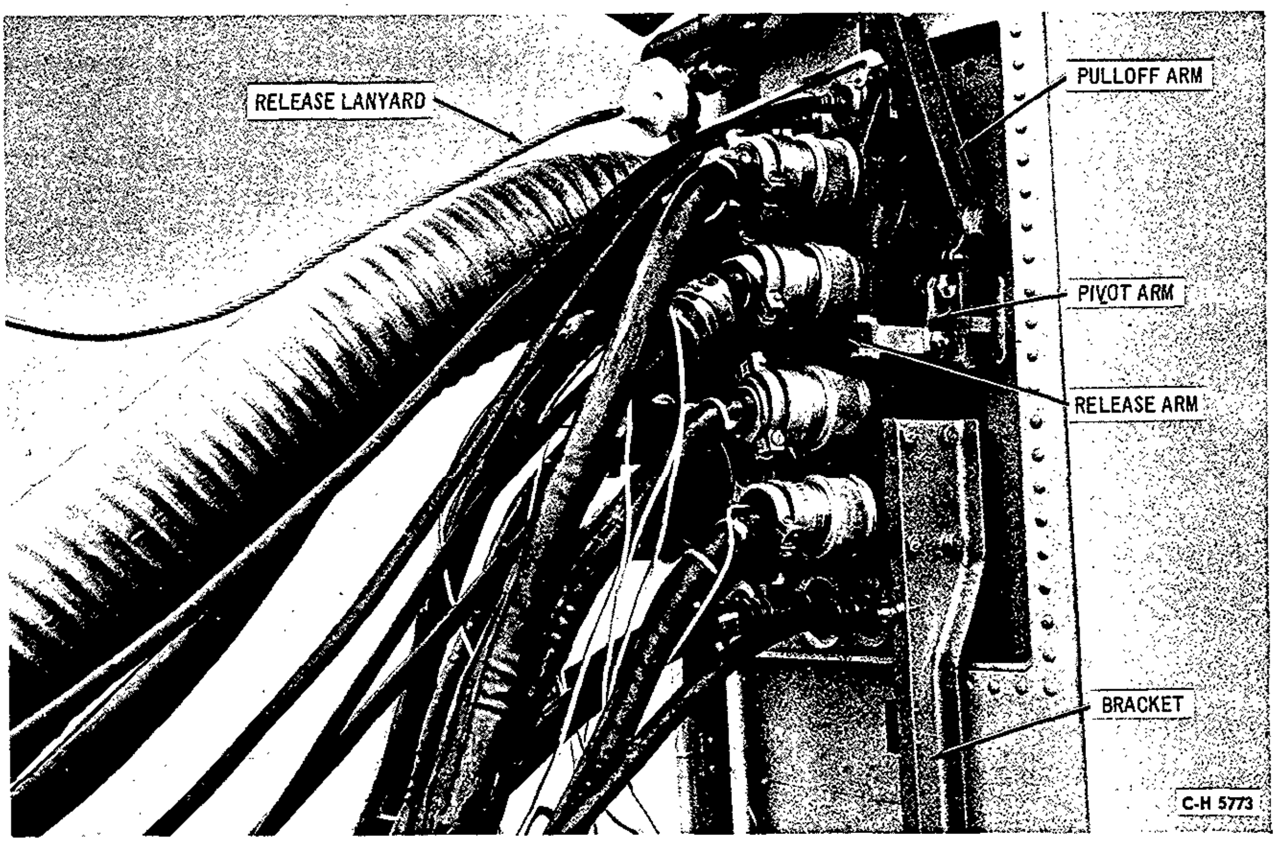

Figure 4-36. Swing Arm No. 1 Umbilical Housing Redundant Release Mechanism

S-IV STAGE

Swing Arm Number 2 (Saturn I Block II). Swing arm number 2 provides for routing and support of the propellant loading lines, air-conditioning duct, electrical cables, and pneumatic and hydraulic lines to the S-IV stage.

basic swing arm has an extension arm added (figure 4-37). This is due to the increased distance between the umbilical tower and the vehicle at the 128-foot

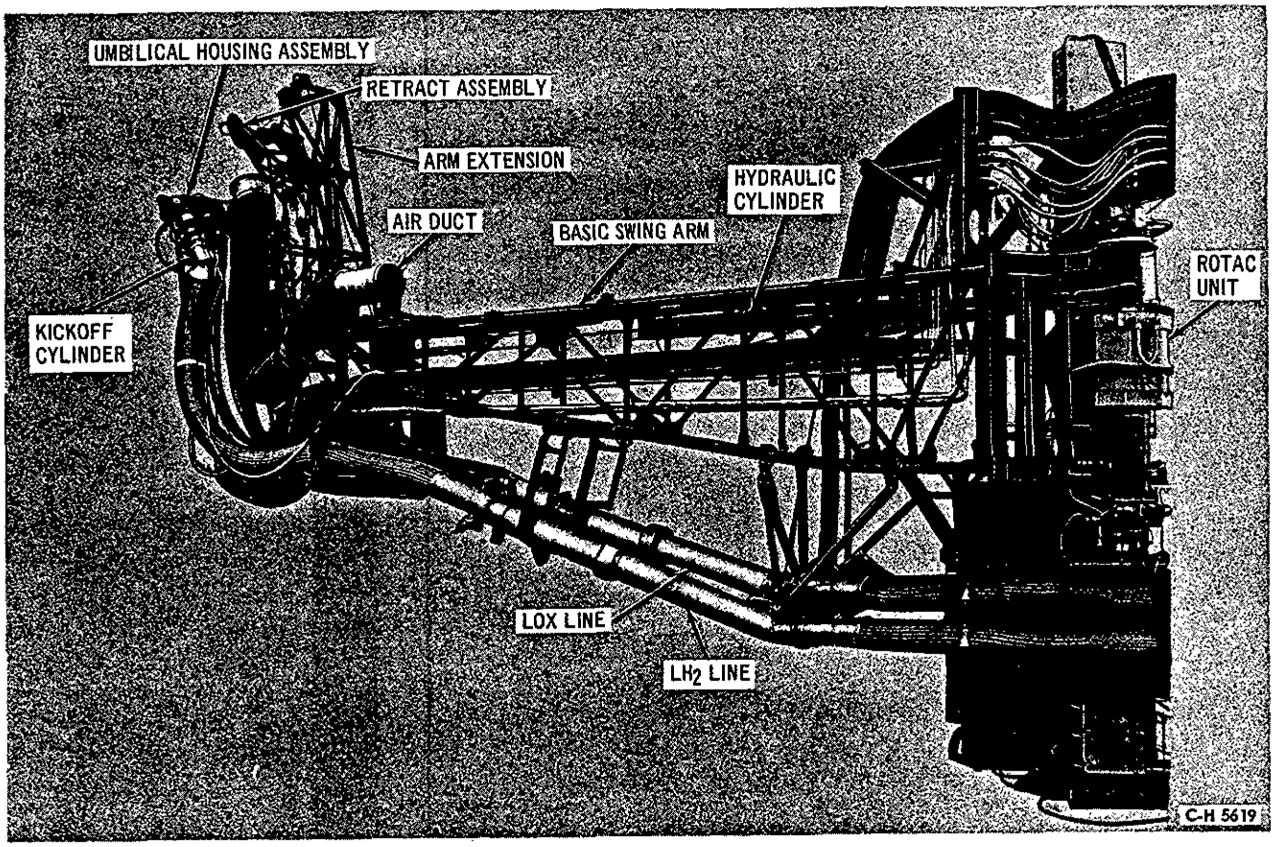

Figure 4-37. Swing Arm No. 2

level. The upper portion of the extension has pulleys and guides to aid in support and movement of the retract arm assembly (figure 4-38) which in turn supports the cables, pneumatic lines, propellant lines, air-conditioning ducts, and umbilical quick-release housing.

All the umbilical connections to the S-IV stage from the number 2 swing arm are combined in one umbilical quick-release housing. The LH_2 vent coupling is located on the number 3 swing arm and has a separate quick-release coupling and mechanism.

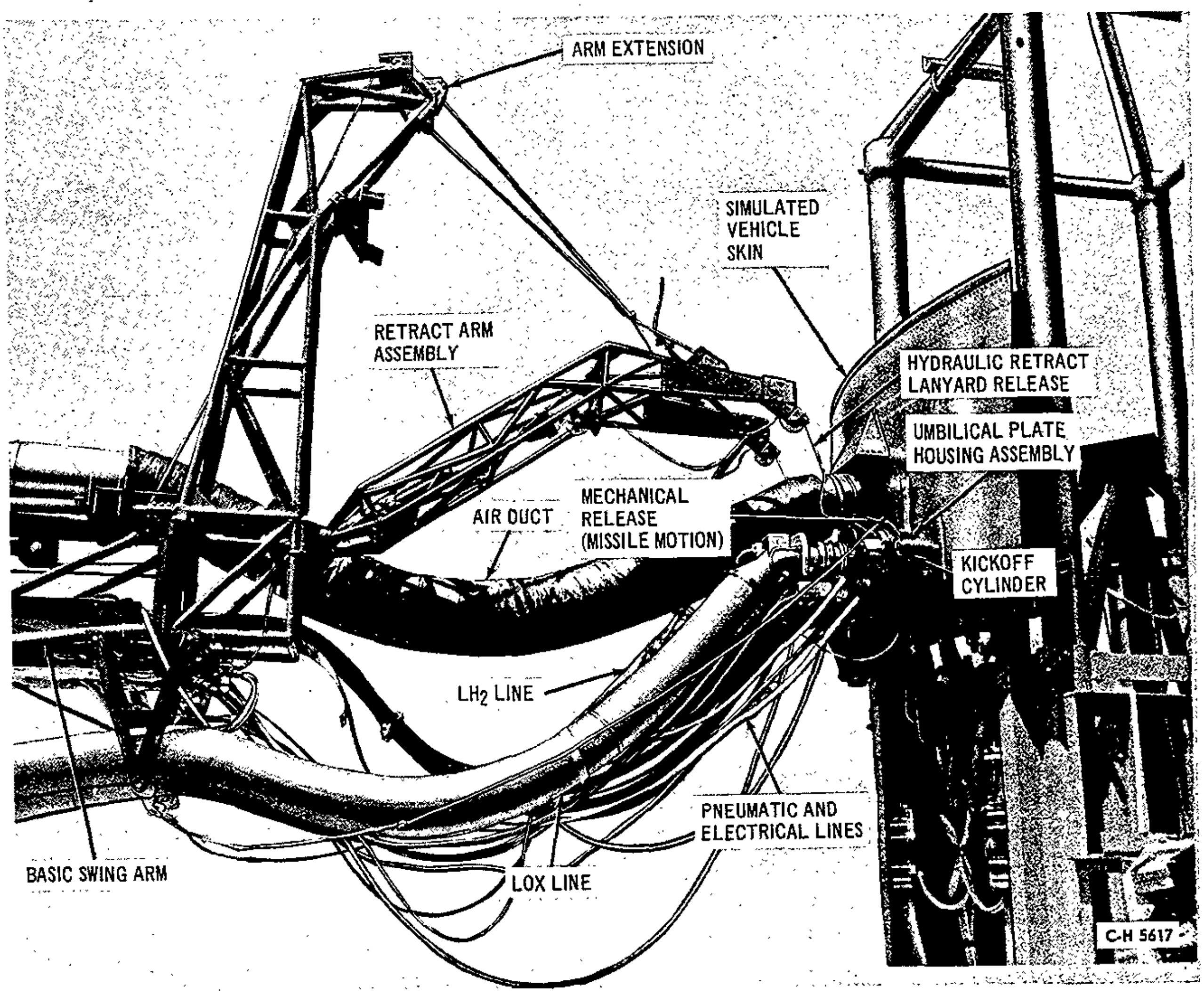

Figure 4-38. Swing Arm No. 2 Connected to Vehicle Simulator

One locking, release, and retract mechanism is all that is required for disconnect of all the umbilical connections to the S-IV stage except the LH_2 vent line (figure 4-39).

Swing arm number 2 is located between the 128- and 138-foot levels of the umbilical tower.

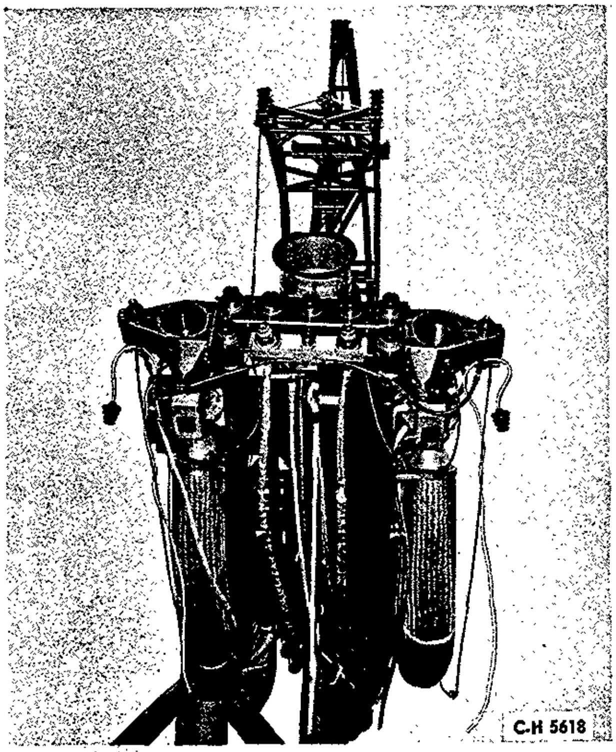

Figure 4-39. Swing Arm No. 2 in Retracted Position

The umbilical housing attaches to the vehicle at station (STA) 1153.693 on the vehicle between fin lines I and II (figure 4-40). The following lines are manually connected to the quick-release housing: air-conditioning duct; LH_2 fill, drain, and replenish; LOX fill, drain, and replenish; cold helium fill; helium control fill; fuel prepressurization; and seven electrical cables (figure 4-41).

Following the manual connection of all connectors to the quick-release housing, prepressurization and fueling of the tanks can begin. The LOX and LH_2 couplings are used for filling, replenishing, and draining the tanks. The LOX tank vents to atmosphere through a vent port and valve located between fin lines III and IV. No umbilical connection is required for LOX venting. The LH_2 vent port is located just beneath and to the lower left of the number 3 swing arm umbilical quick-release housing (figure 4-42). The originally designed propellant couplings incorporated in the quick-release housing assembly were of the sleeve and cylinder-type design. The release and disconnect mechanism incorporated two kickoff cylinders, one on each side of the housing. The kickoff cylinders were linked to arms which hooked over pins on the vehicle umbilical service plate. Operation was intended to proceed as follows: at liftoff pneumatic pressure applied to the cylinders released the arms hooked over the pins, and pneumatic pressure also actuated the two kickoff pistons which disconnected the quick-release housing assembly from the vehicle umbilical service plate (figure 4-43). After release and disconnect, the hydraulic lanyard retract system moved the umbilical housing assembly away from the vehicle and the Rotac unit rotated the swing arm out of the way.

Two redundant systems were intended to release, disconnect, and retract the quick-release housing assembly in the event the pneumatically actuated cylinders failed to achieve release and disconnect. The first redundant system consisted of a hydraulic lanyard retract assembly employing cables and actuated by a hydraulic cylinder (figure 4-44). The function of the hydraulic lanyard retract assembly was to mechanically release the locking cylinder and retract the umbilical quick-release housing assembly away from the vehicle if the pneumatically actuated cylinders had failed to release and

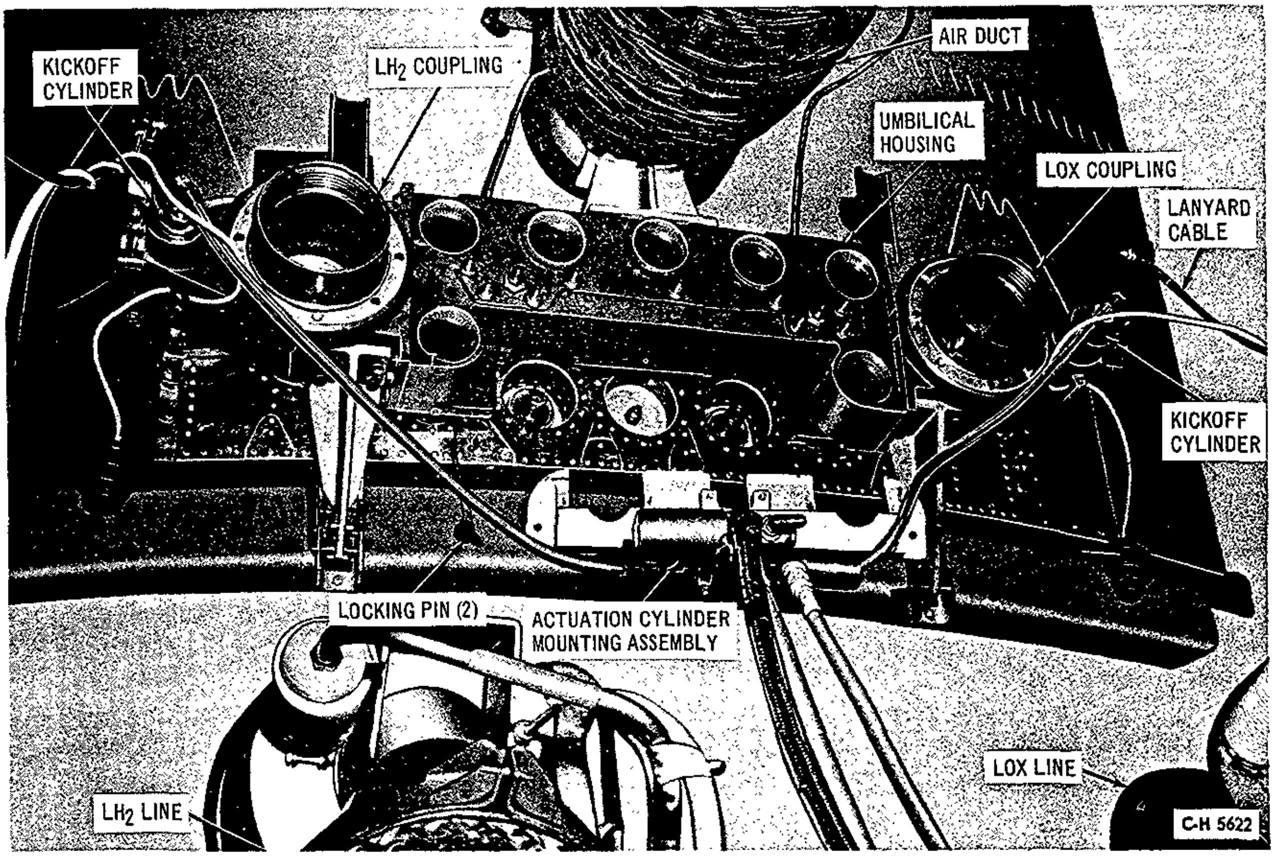

Figure 4-40. Swing Arm No. 2 Umbilical Housing Attached to Vehicle

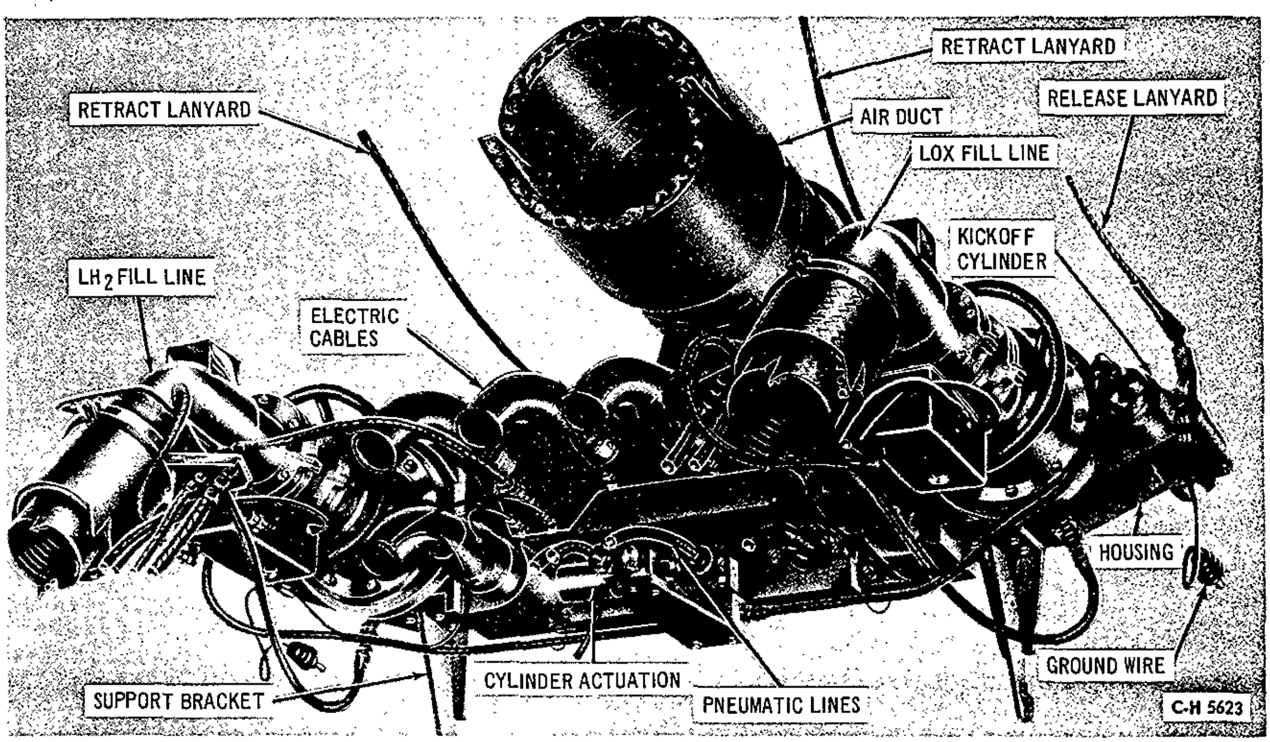

Figure 4-41. Swing Arm No. 2 Umbilical Connections

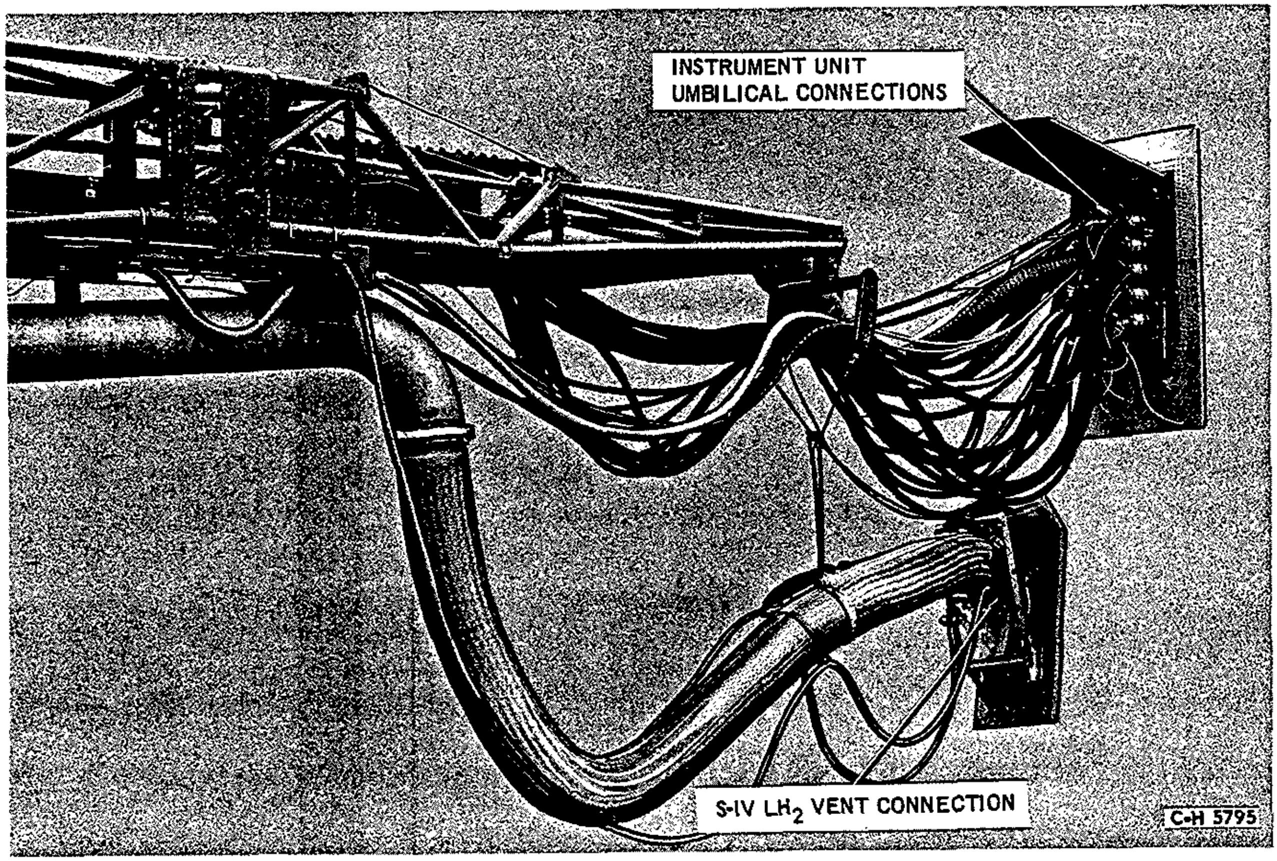

Figure 4-42. S-IV Stage Hydrogen Vent Line, Swing Arm No. 3

disconnect the umbilical quick-release housing assembly. The second redundant method of release and disconnect was provided by vehicle motion. If the pneumatic and hydraulic lanyard release and retract method failed, vehicle motion was supposed to shear the pins on the vehicle umbilical plate and the quick-release housing would be forcibly disconnected due to vehicle travel.

The initially designed cryogenic couplings and release mechanisms, including the LOX fill, LH_2 fill, and LH_2 vent couplings, have not performed satisfactorily during simulated launch tests.

An extensive series of tests approximating simulated vehicle launch conditions was conducted on swing arm number 2 quick-release housing and on the GH_2 vent disconnect coupling (swing arm number 3) on five different occasions between November 1962 and March 1963.

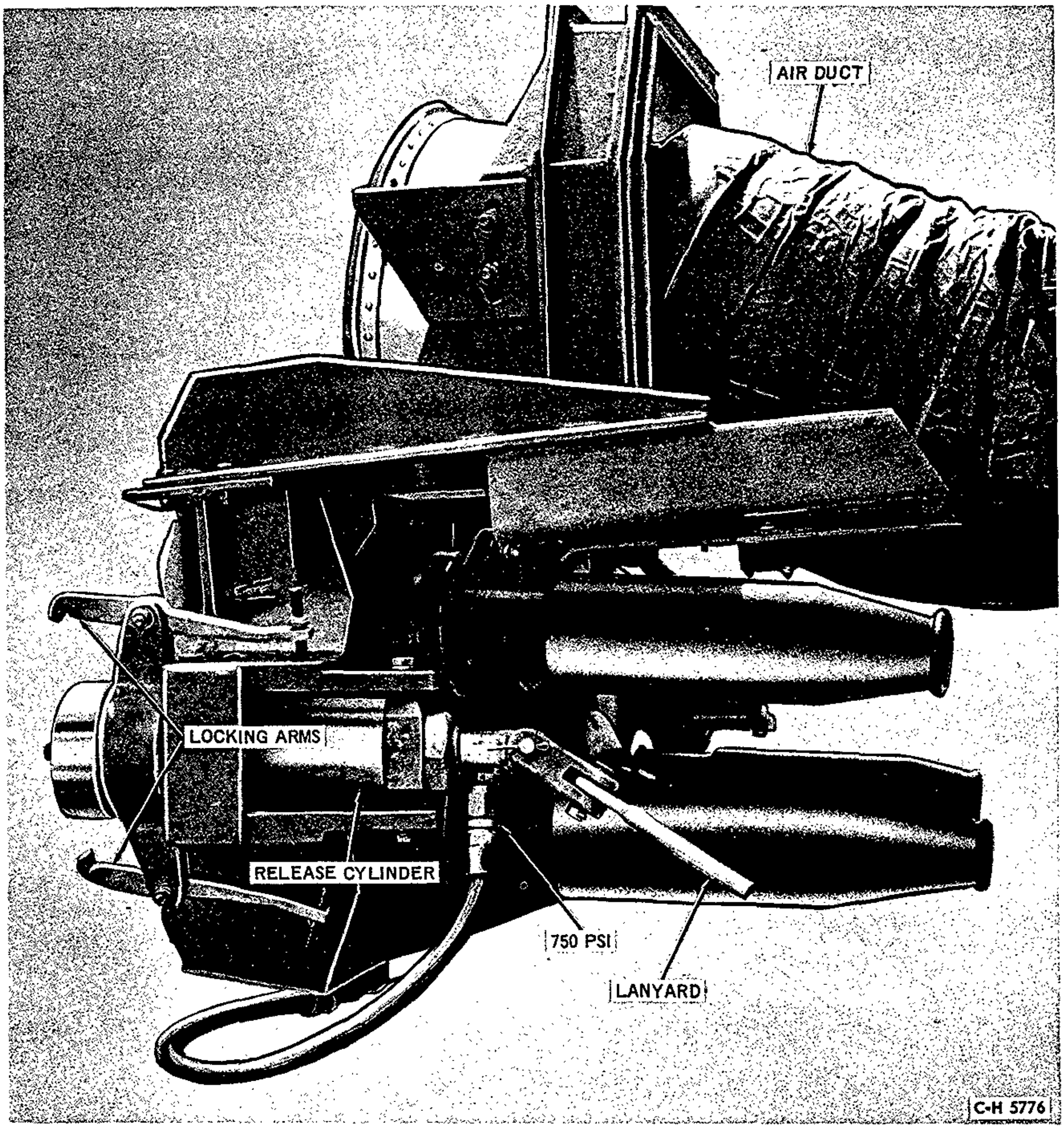

Figure 4-43. Prototype Umbilical Housing S-IV Stage

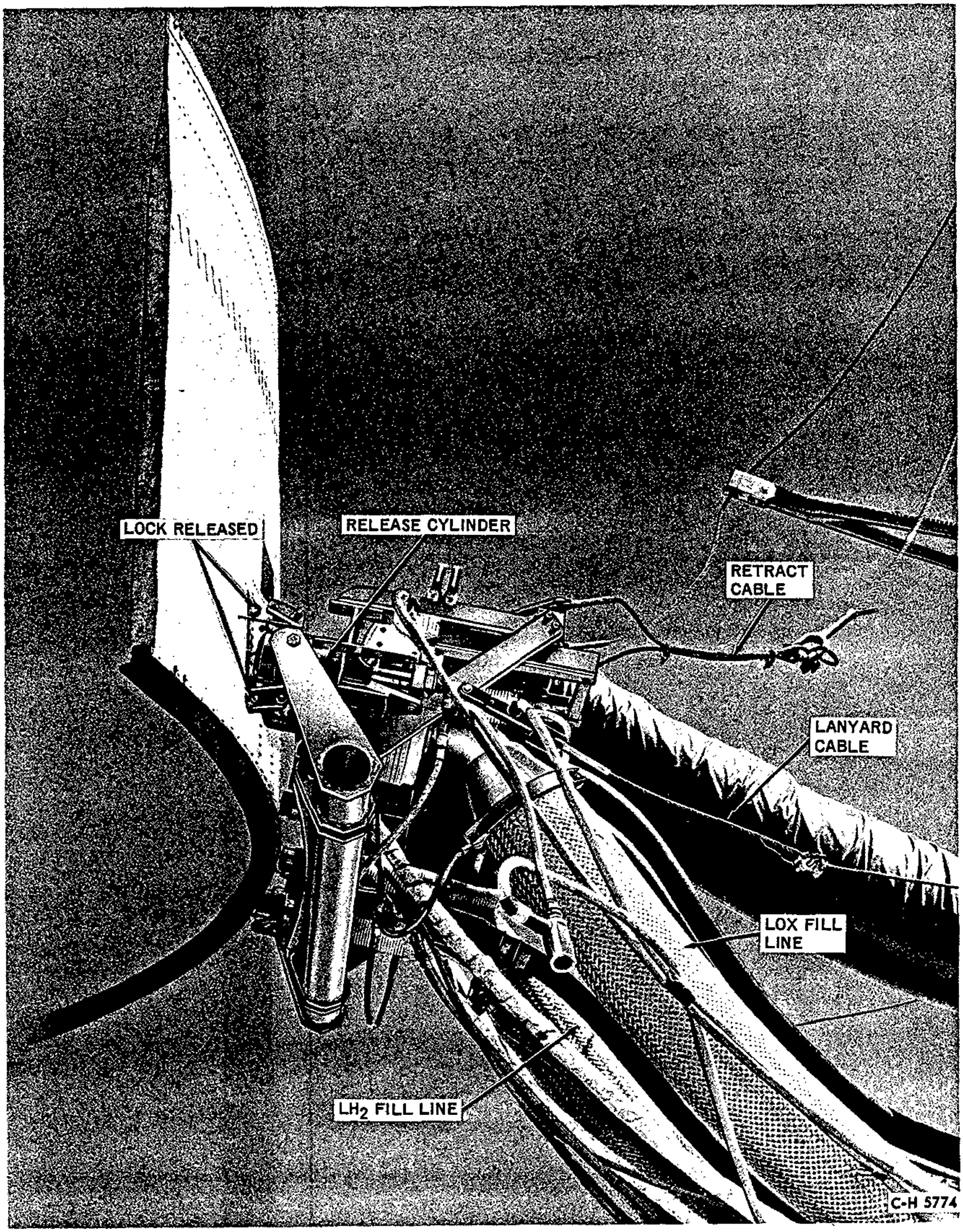

Figure 4-44. Prototype Housing Disconnect Failure, Swing Arm No. 2

A summary of these test results is as follows: One test in a series conducted during a rain resulted in damage to the vehicle LH_2 coupling (figure 4-45) and sheared off one of the mounting pins when the lanyard cable retracted the

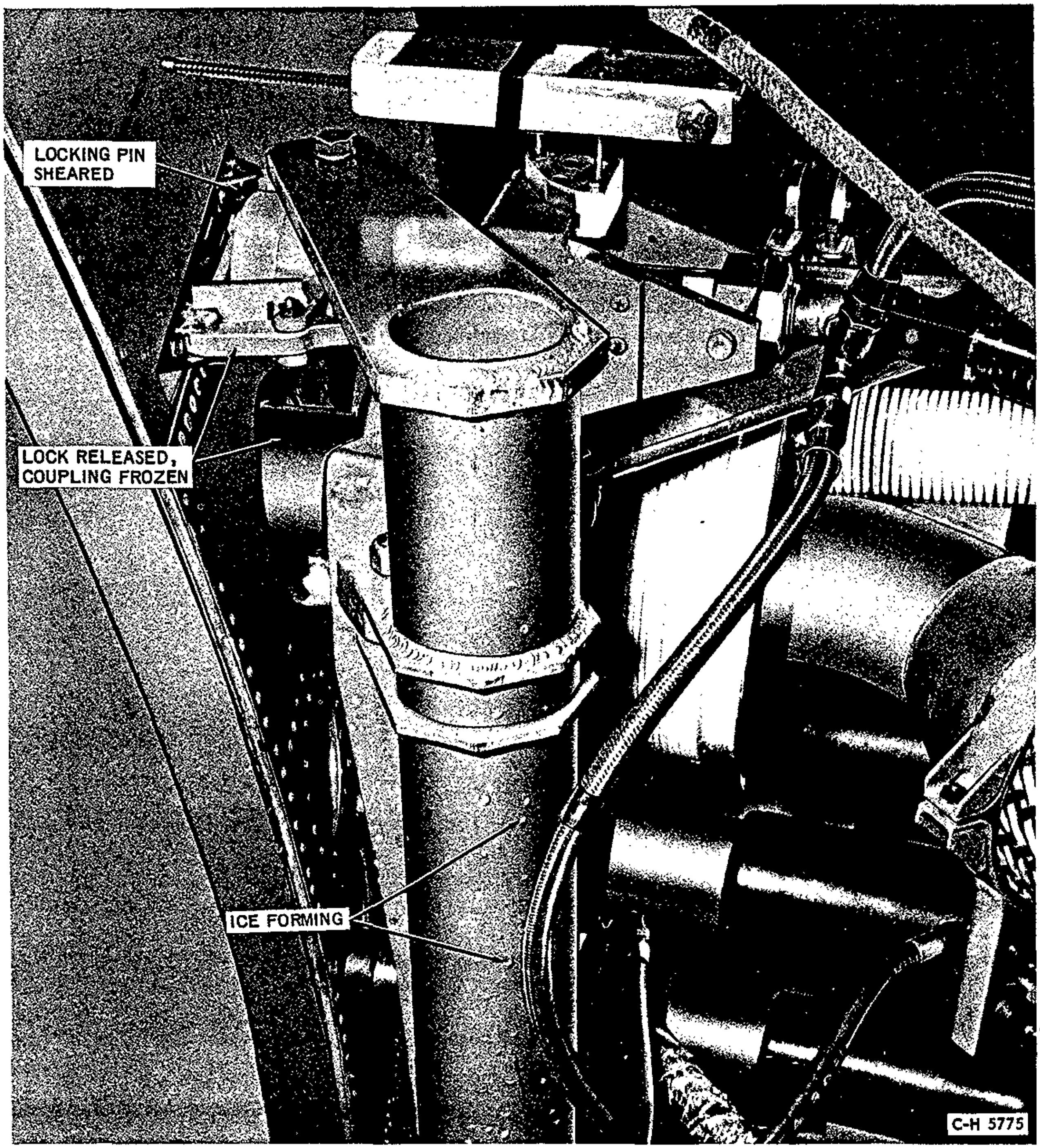

Figure 4-45. S-IV Stage Housing Released, Coupling Frozen

quick-release housing without full pneumatic release and disconnect. Cause of this failure was attributed to freezing inside the LH_2 coupling due to the rain. It was thought that the installation of purge boots and purging around the propellant coupling would prevent this accumulation of moisture and freezing and thereby overcome this malfunction.

During another series, a test was conducted with water sprayed on the quick-release housing to obtain an icing condition. On this occasion release and disconnect functioned satisfactorily.

In one series of tests, ball and sphere-type propellant couplings incorporating a bellows seal were attached to the original umbilical housing. Testing of this assembly indicated this type of propellant coupling would be satisfactory; however, the vehicle mounting pins were sheared off during one test, allowing the quick-release housing to fall from the vehicle simulator to the ground. At this time there was only 150 pounds of force applied by the compressed bellows in the propellant couplings plus the weight of the quick-release housing and lines.

A test was conducted in which the LOX coupling side of the housing failed to release pneumatically and was pulled away by the hydraulic retract lanyard, and the mounting pin on the vehicle was sheared off. In this instance the LOX coupling halves, both male and female, showed signs of galling and binding. This coupling was damaged beyond repair (figure 4-46). This is another example of the intrinsic weakness of trying to adapt the cylinder and sleeve-type coupling to cryogenic use. Following this test it was recommended that the ball and sphere-type couplings be used on this quick-release housing.

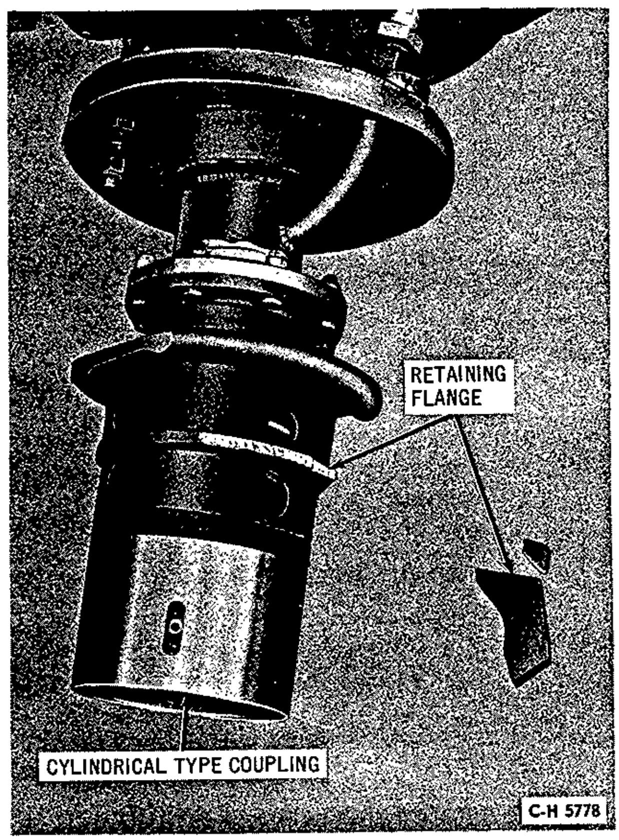

Figure 4-46. Damaged Lox Coupling, Vehicle Half, Prototype

A fourth series of tests was performed on swing arm number 2 after modification of the quick-release housing by the addition of a torque tube connecting the two kick-off cylinders. This was done to assure that both propellant couplings would release simultaneously. The pneumatic pressure was also increased from 750 psig to 1500 psig. Pneumatic release and disconnect with hydraulic retraction was achieved eight times out of nine attempts following these modifications. On the ninth attempt the housing was pulled off the vehicle simulator by the hydraulic lanyard retract system, with no damage to the couplings or vehicle simulator. Pneumatic release and disconnect had failed due to a pressure drop in the pneumatic release system caused by a solenoid valve. It was concluded from this test that the pneumatic release system was not sufficiently reliable.

A fifth series of tests was conducted simulating launch conditions and spraying the quick-release housing with water. All systems failed on this test. The pneumatic and hydraulic lanyard systems failed to release and disconnect the housing and prevented the swing arm from rotating.

Upon examination it was found that the vehicle half of the LH_2 coupling was partially pulled through the vehicle plate and the ground half was broken (figure 4-47). Ice had formed in the purge boot from water running down the side of the simulated vehicle skin. Conclusions drawn from this series of tests were that the quick-release mechanism and couplings had proven to be unreliable when subjected to simulated launch conditions. It was again recommended that the ball and sphere-type of coupling be used on swing arm number 2.

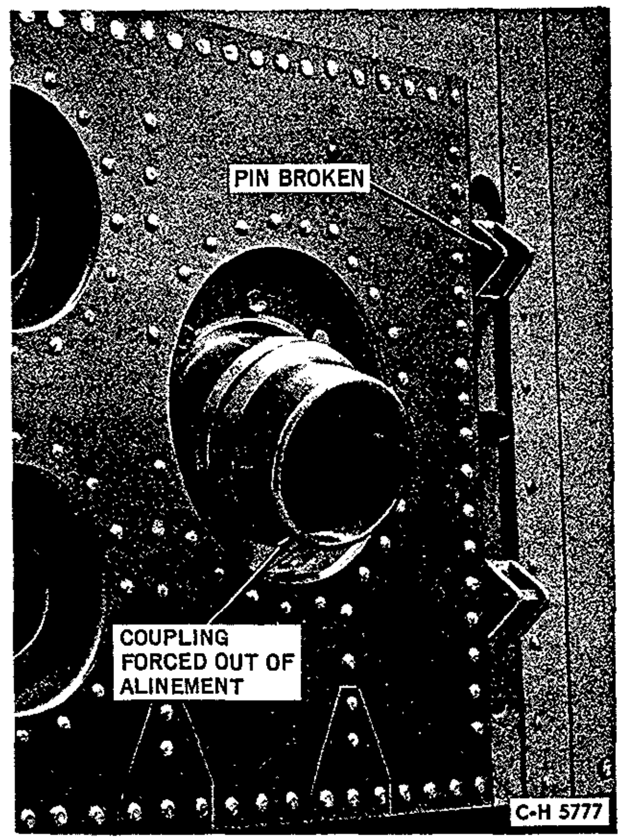

Figure 4-47. Prototype LH_2 Coupling, Ground Half, After Release Test

Following these tests and recommendations, the quick-release housing and propellant couplings were redesigned, using the sphere and ball-type propellant coupling and pneumatically actuated ball lock (figure 4-48). This quick-release housing employs pneumatically actuated kickoff pistons using a type of ball lock (figure 4-49). When pneumatic pressure is applied, the outer sleeve moves away from the vehicle, the ball lock releases, and the piston moves forward disconnecting the housing from the vehicle; at this time, the hydraulic lanyard retracts the umbilical housing and the swing arm rotates away from the vehicle. This

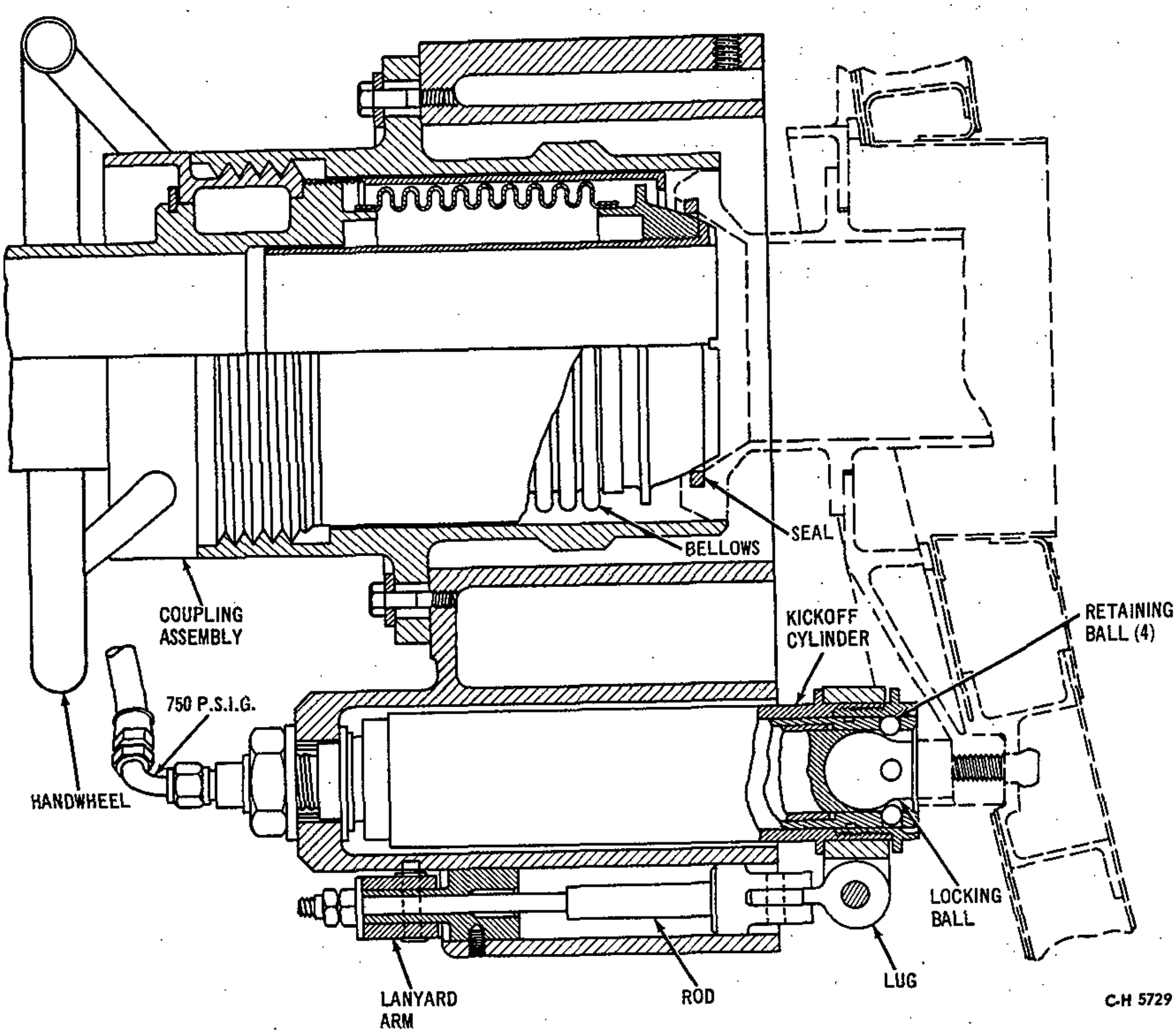

Figure 4-48. Current S-IV Stage Umbilical Housing, Release Mechanism and Propellant Coupling

quick-release housing has two redundant systems of release and disconnect. In event of pneumatic failure, the hydraulic lanyard retract system will mechanically release the ball lock, disconnect, and retract the umbilical housing. The second redundant system is actuated by vehicle travel. This would occur if the pneumatic release mechanism and the hydraulic lanyard retract system failed. This redesigned quick-release housing and propellant couplings have satisfactorily passed all tests simulating vehicle launch conditions and will be used on the S-IV stage, swing arm number 2.

During the same series of tests in which the number 2 swing arm quick-release housing assembly was tested and found unsatisfactory, the GH_2 vent coupling on the number 3 swing arm (used to vent the S-IV stage) was being tested also. The GH_2 vent disconnect coupling (figure 4-50), which is supported and retracted by swing arm number 3, vents the LH_2 tank of the S-IV stage. The GH_2 vent disconnect coupling is secured to the vehicle by a spring-lock assembly inside the coupling. At vehicle liftoff pneumatic pressure is applied to two kickoff pistons. The outside shell of the coupling is pushed back by the pistons, allowing the spring-lock to release and separate from the vehicle.

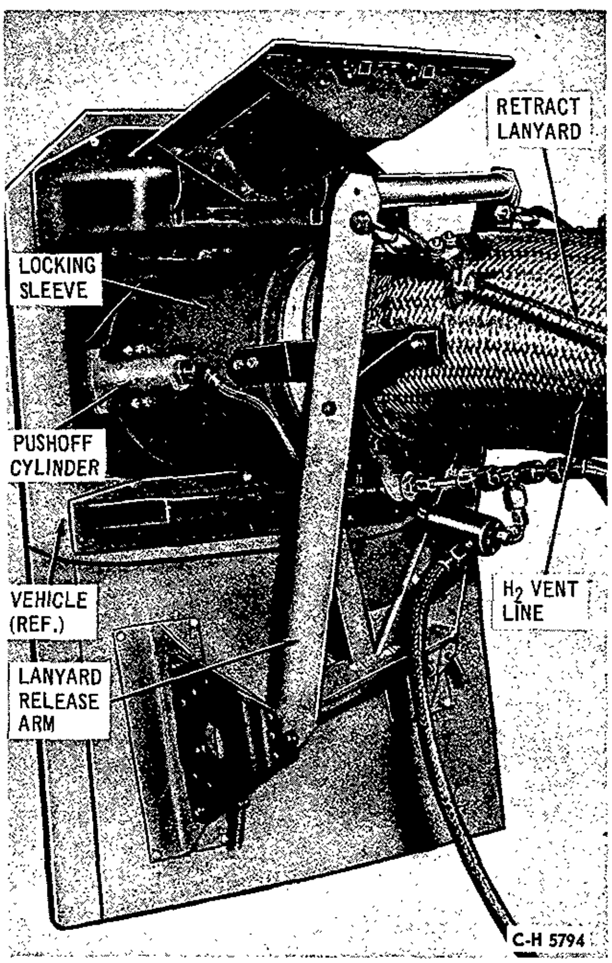

Figure 4-50. *S-IV Stage GH_2 Vent Disconnect Coupling*

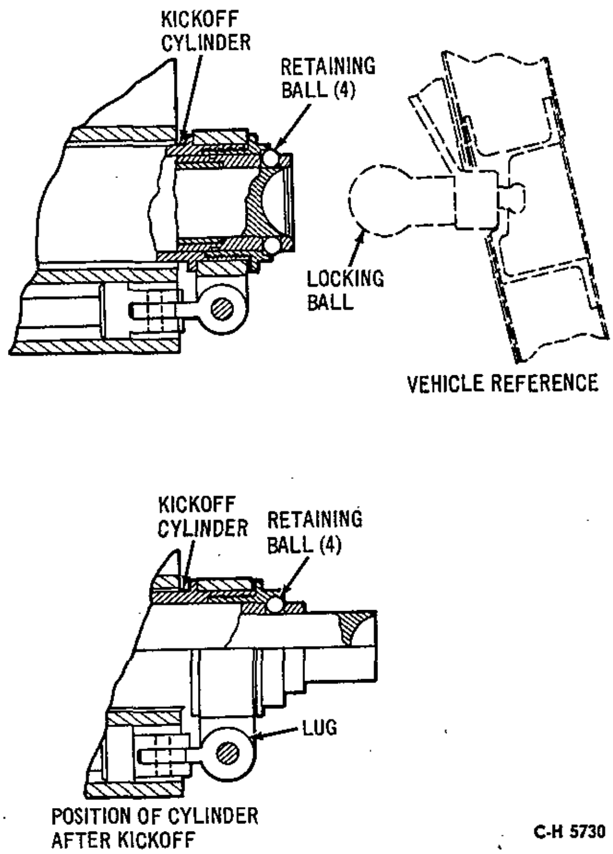

Figure 4-49. S-IV Stage Current Ball Lock and Release Mechanism

In the first series of tests, the poppet on the ground side of the GH_2 vent coupling failed to seat on three occasions. Water was sprayed on the vehicle simulator during these three tests. On one of these three occasions, due to icing, the attachment plate was bent and the two bolts on the vehicle half were sheared off when the vehicle simulator moved up, simulating vehicle motion. Release and retraction were accomplished by the hydraulic lanyard retract system (figure 4-50).

During the subsequent series of tests, the pneumatic release and disconnect system failed repeatedly. When there were occasions of satisfactory pneumatic release and disconnect, there was still the problem of the GH_2 coupling failing to seal. Further tests revealed failure of the pneumatic system to function due to the vent coupling or the kickoff pistons freezing due to icing caused by spraying the vehicle simulator. Following the fourth and fifth series of tests of the vent coupling, it was recommended that this design be abandoned and another design be investigated. The latest approach to utilization of this coupling and release mechanism is to use it on the SA-5 vehicle with some modification. There will not be a launch at this time during a rain (icing conditions). A GH_2 vent coupling is currently being designed for the SA-6 vehicle.

No problems were encountered with the release and disconnect of other pneumatic connections, air duct, and electrical cables on number 2 swing arm umbilical housing.

INSTRUMENT UNIT

The instrument unit umbilical service plate (figure 4-51) is located on the skin of the instrument unit between fin lines I and II. Routing, mounting, and retraction of ground support electrical, pneumatic, air-conditioning, and liquid nitrogen lines to the vehicle is provided by umbilical swing arm number 3 mounted on the umbilical tower at the 158 foot level. The umbilical tower is so designed that it tapers away from the vehicle drift parameter anticipated during a launching. In addition, the diameter of the vehicle at the instrument unit level has decreased from that of the first stage. These combined factors necessitate that an extension arm be provided for the number 3 swing arm to support the large number of umbilical lines to the vehicle at this level. Also, the hydrogen vent line to the S-IV stage is mounted on the number 3 swing arm (figure 4-39).

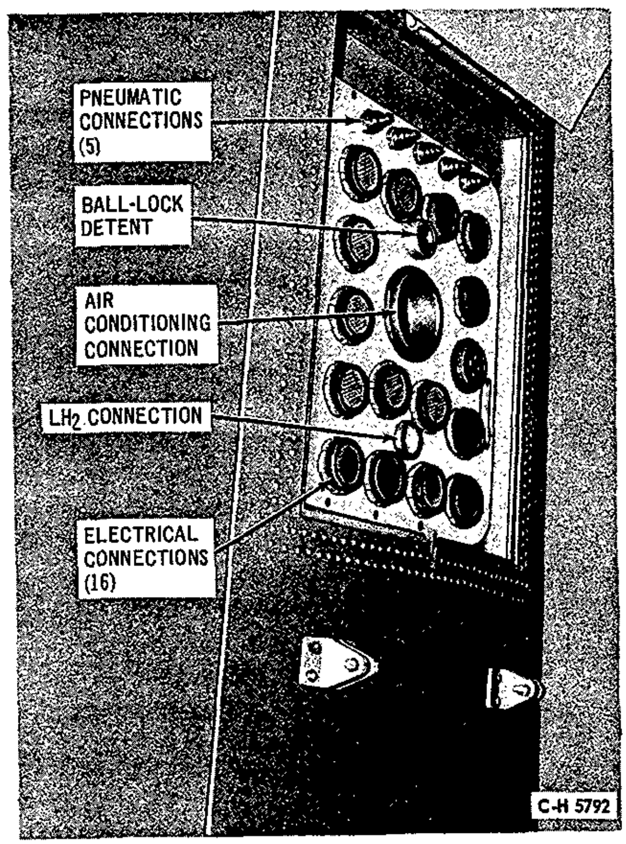

Figure 4-51. Instrument Unit Service Plate

The umbilical housing (figures 4-52 and 4-53) provides for the connection and quick release of sixteen electrical connections, five pneumatic connections, one air-conditioning duct, and one liquid nitrogen line. The housing is similar to the one on swing arm number 1. The housing is secured to the vehicle with the pneumatically actuated ball lock.

The umbilical housing is provided with four pneumatically actuated pushoff pistons, and primary disconnect and release of the housing is accomplished pneumatically. As with the number 1 swing arm umbilical housing, redundant release and disconnect of the housing is accomplished either hydraulically by the lanyard retract cylinder or mechanically by vehicle motion (figure 4-54).

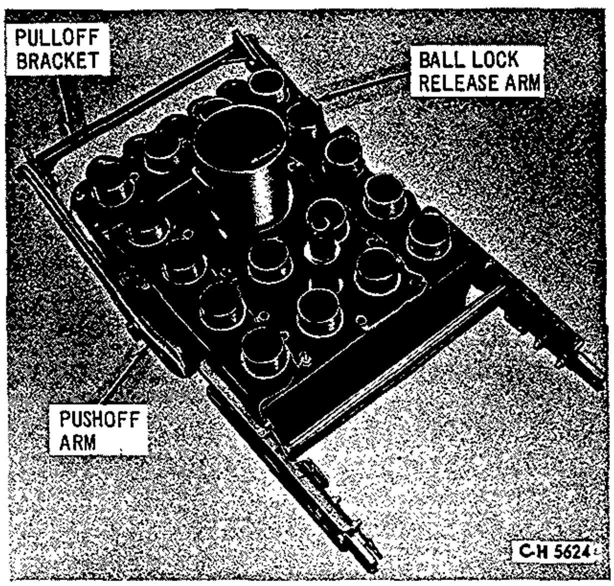

Figure 4-52. Instrument Unit Umbilical Housing

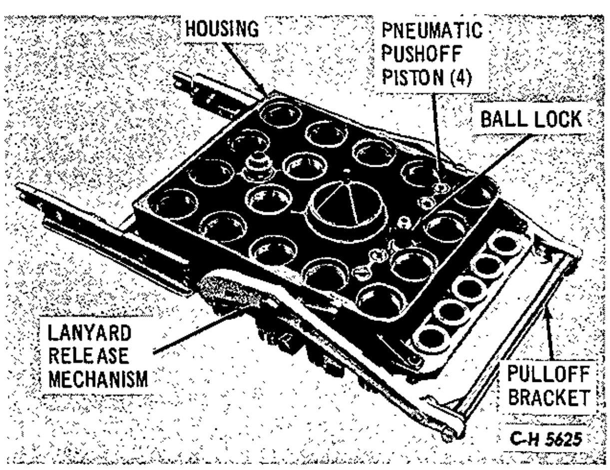

Figure 4-53. Instrument Unit Umbilical Housing Interface

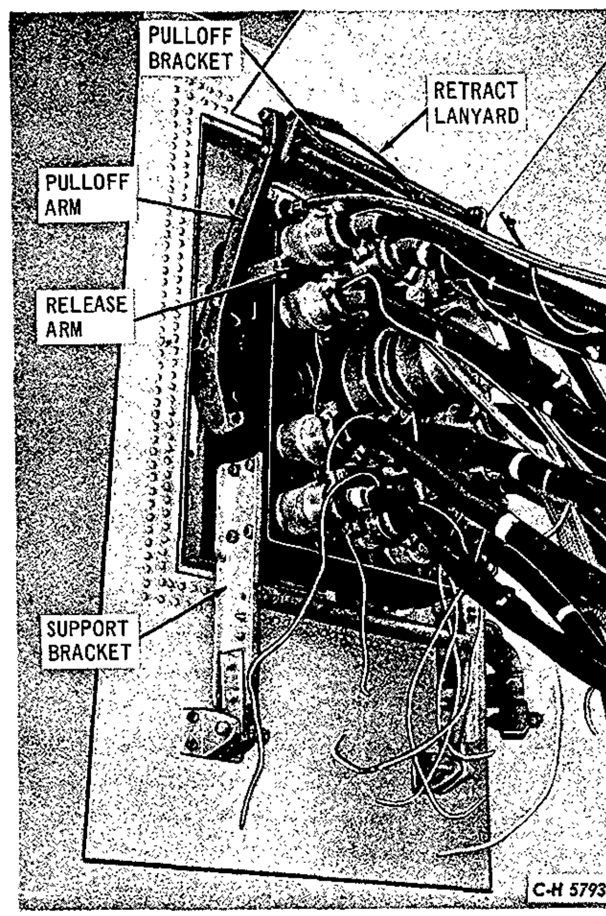

Figure 4-54. Hydraulic and Missile Motion Release, Instrument Unit Umbilical Housing

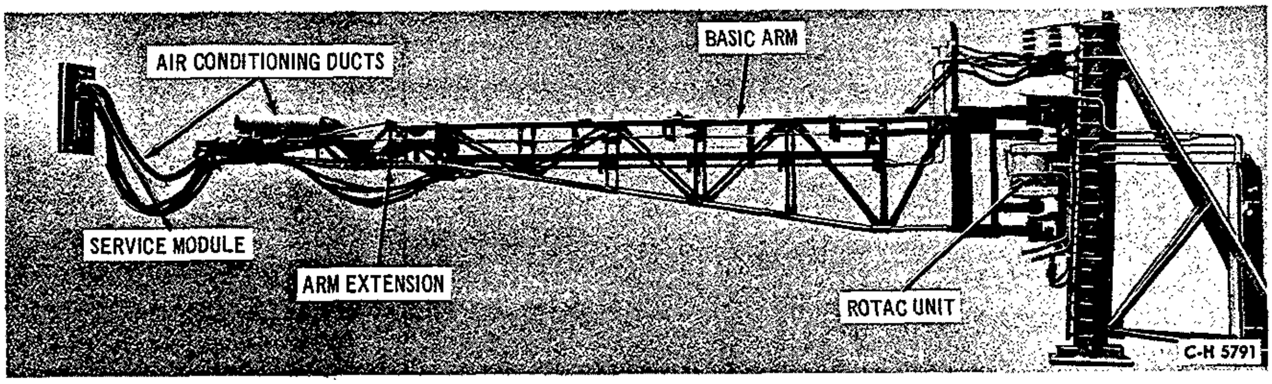

Figure 4-55. Swing Arm No. 4

As the hydraulic retract cylinder is pulling the umbilical housing away from the vehicle, the Rotac unit rotates the arm out of the flight path of the vehicle.

APOLLO SPACECRAFT

Swing arm number 4 (figure 4-55) provides the means of routing and supporting the electrical cables, pneumatic lines, and air-conditioning ducts to the spacecraft service module. An arm extension is used on the basic arm. The vehicle service plate (figure 4-56) is located on the skin of the service module near fin line II. It provides connections for an air-conditioning duct, four electrical cables, and four pneumatic lines. A wye in the air-conditioning duct on the swing arm provides the means of manually connecting and routing a flexible air-conditioning duct to the command module. This duct does not connect to the vehicle but is merely thrown into the open

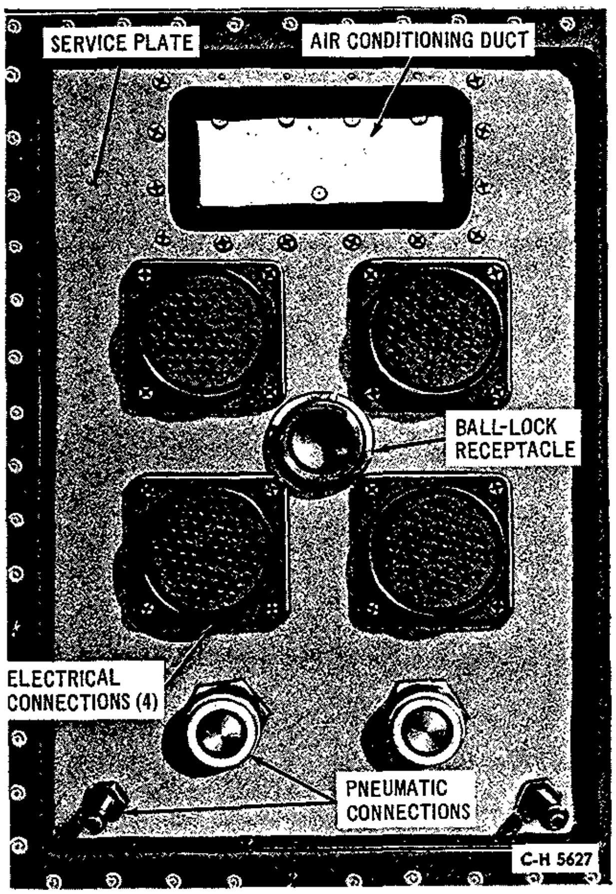

Figure 4-56. Service Module Service Plate

hatch of the command module to provide air conditioning for the technicians during checkout. After checkout is complete, the duct is removed from the hatch and disconnected from the main duct on the swing arm.

The swing arm number 4 umbilical housing (figure 4-57) is secured to the vehicle with a ball lock. The housing provides for the connection to and release from the vehicle of the electrical cables, pneumatic lines, and air-conditioning duct (figure 4-58).

Release, disconnect, and retract of the umbilical housing is accomplished in the same manner as for umbilical housings 1 and 3: primary method pneumatic, secondary method hydraulic-mechanical; and, if these fail, missile motion will release the housing.

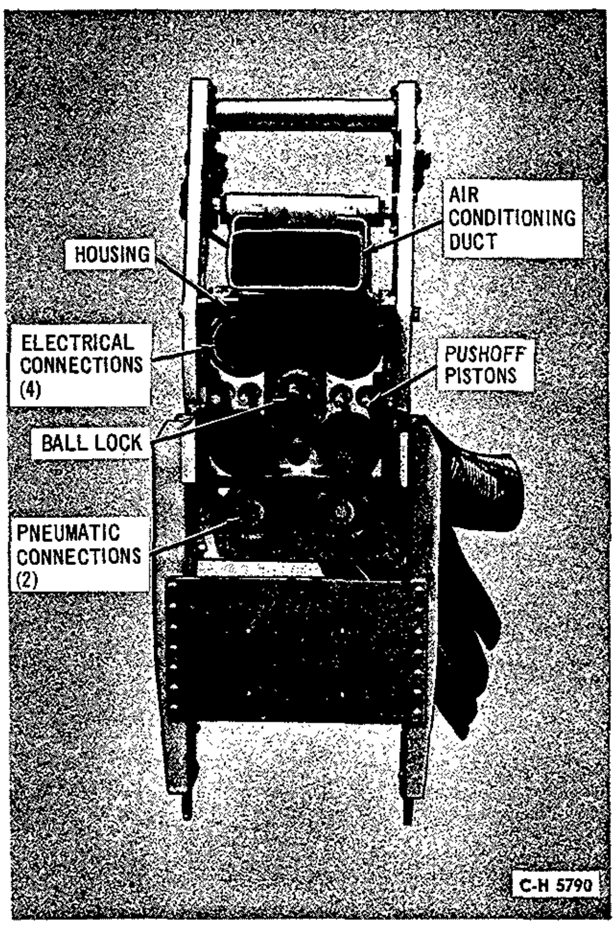

Figure 4-57. Service Module Umbilical Housing Interface

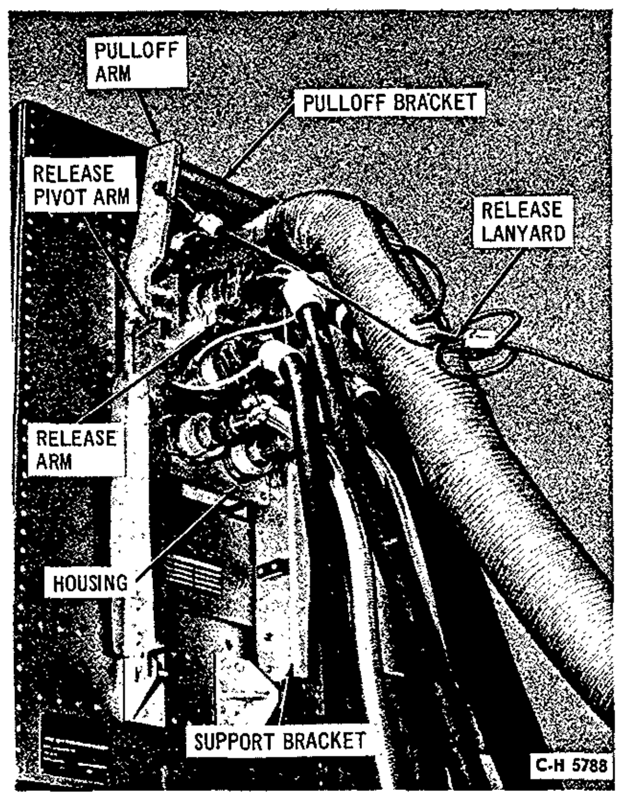

Figure 4-58. Service Module Umbilical Housing Connected

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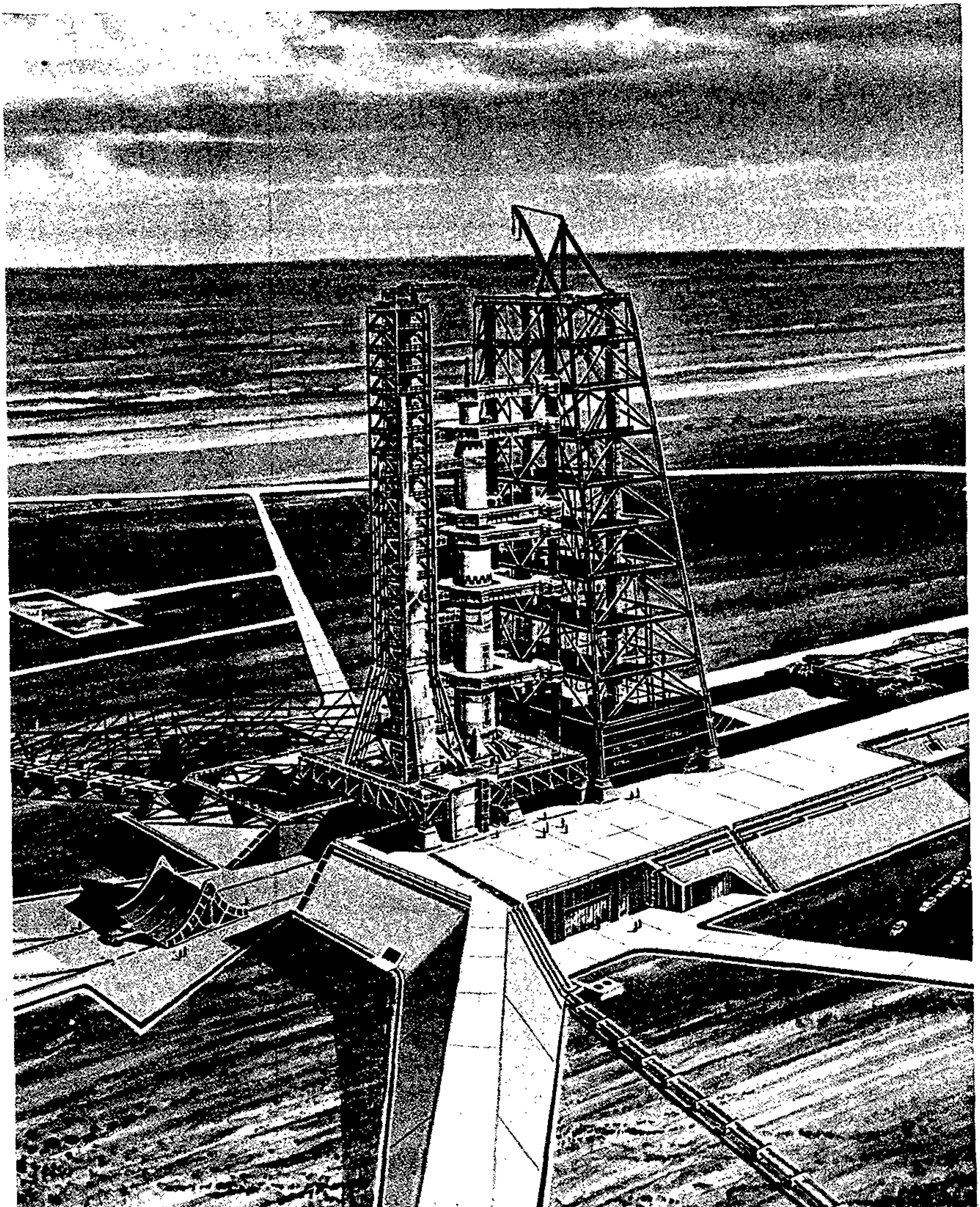
SECTION V
SATURN V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SECTION V

SATURN V

INTRODUCTION

The Saturn V will be a multistage, liquid-fueled launch vehicle used for the Apollo manned lunar and planetary exploration program. Five engines, fueled with a mixture of RP-1 diesel and LOX, power the S-IC, first stage of the launch vehicle. Engines, fueled with a mixture of liquid hydrogen (LH_2) and LOX, power the S-II, second stage, and the S-IVB, third stage of the vehicle. An instrument unit containing in-flight control and monitoring equipment will be located between the S-IVB stage and the Apollo payload. The payload will consist of the lunar excursion module (LEM), the service module (SM), and the command module (CM).

Launching of the Saturn V will occur from Complex 39 at the AMR. The complex facilities provide the firing sites, vertical assembly building (VAB), launcher-umbilical tower (LUT), mobile arming tower, and crawler transporter for the assembly, checkout, transportation, and firing of the Saturn V vehicle. Because of the enormous size of the Saturn V, mating of the stages and checkout of the vehicle will be accomplished on the LUT in the VAB.

During assembly and checkout of the vehicle, complete functional tests of all the service arms and the tail service masts will be accomplished for umbilical housing disconnect, withdrawal mechanism retraction, and arm rotation. Because of space limitation, functional tests of the access arm will be accomplished after the vehicle leaves the VAB and before continuing to the firing site. During all phases of assembly, checkout, and transportation of the vehicle, four holddown arms support the vehicle on the LUT. The LUT with the erect assembled vehicle will be transported to the firing site by the crawler transporter. During the transportation of the vehicle to the firing site, the umbilical carriers including the tail service masts remain connected to the vehicle, with the withdrawal mechanism extended; the service arms remain extended and locked; the extension platforms are withdrawn and locked; and the access arm is retracted and locked to the tower.

Positioning of the LUT at the firing site will be with the tower north, position I east, and fin A 45 degrees north of position I. The flame deflector will be positioned directly below the vehicle, with the flame exits north and south. Permanent foundations at the firing site will support the LUT. Service lines located at the firing site will mate to corresponding service lines on the LUT.

After the arming tower has been positioned by the crawler transporter and the pyrotechnic and other arming services have been completed, the arming tower will then be removed and final vehicle checkout operations begun. During final checkout, an astronaut crew enters the Apollo, via the access arm, for payload checkout. Because propellant loading will be accomplished during this period, the CM hatch will be closed and the access arm retracted and latched to the tower, to allow emergency escape of the CM. Upon completion of propellant loading, the access arm will be extended, the checkout crew removed, and the flight crew boarded. The access arm will retract at T minus 60 seconds.

The service arms for the Saturn V have their foundation in the development and test results of the Saturn I swing arms. The arms support service lines required to sustain the vehicle at the firing site before launch. The dimensions of the arms are sufficient to permit personnel passage through the arm to an extension platform. The extension platform provides for personnel entrance into the vehicle and allows access to the various umbilical service areas. The arms are retracted by pneumatically charged hydraulic systems. Retraction is initiated by disconnect of the umbilical services. There are two general classifications or types of service arms, preflight and in-flight. The preflight arms (the S-IC intertank, S-IC forward, and S-II aft) are retracted and locked to the tower at T minus 10 seconds. The in-flight arms (the S-II intermediate, S-II forward, S-IVB aft, S-IVB forward and SM) are retracted at liftoff after receiving a command signal from the liftoff switches actuated by the vertical motion of the vehicle. The S-IC intertank arm is capable of reconnecting if the launch is aborted during the last 10 seconds of the countdown.

Much of the development work for the Saturn V vehicle is still in the preliminary stage. The information contained in this section of the manual reflects the concept that will be used and the state of development at this time.

S-IC STAGE

Tail Service Masts. Three tail service masts located on the deck of the launcher (figure 5-1) provide the means of routing, connecting, releasing, and retracting the umbilical service lines to the tail section of the S-IC stage from the LUT interface.

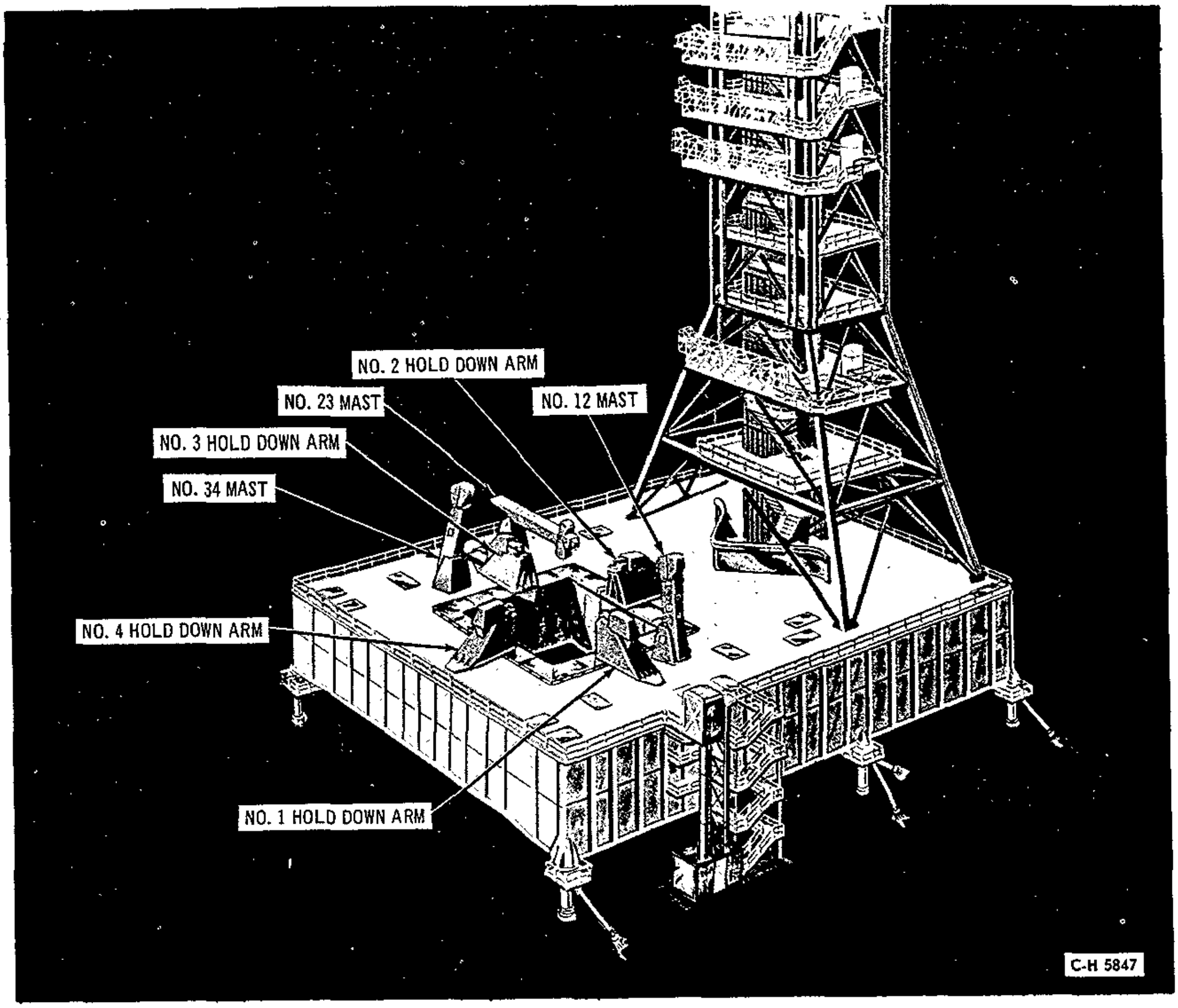


Figure 5-1. Tail Service Mast Locations (Preliminary)

Each tail service mast (figure 5-2) is basically the same for all locations. The number, kind, and type of service lines differ at each location.

Service mast number 12 is located north of position I next to the holddown arm and services the number 2 umbilical plate of the vehicle.

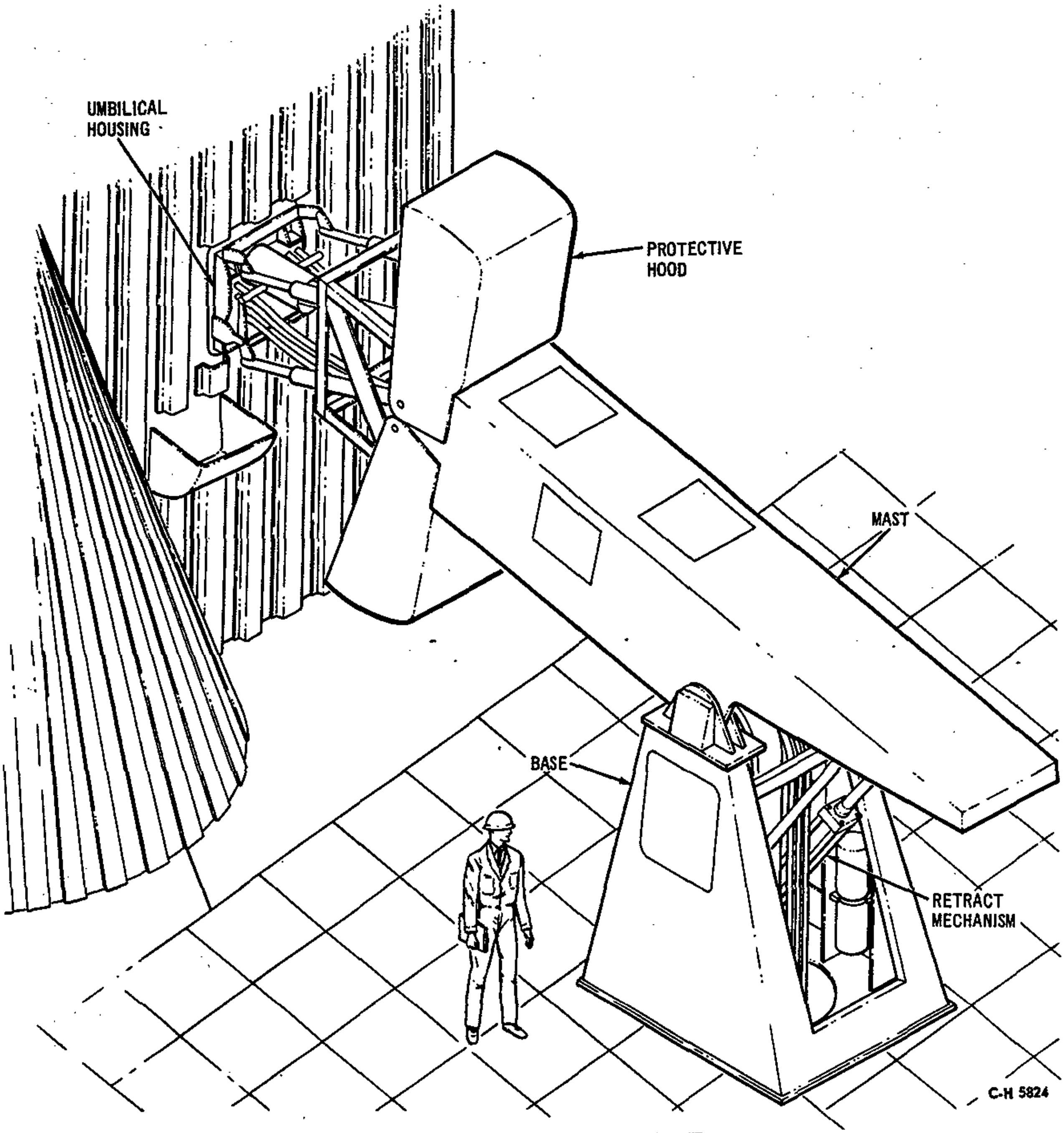


Figure 5-2. Tail Service Mast Typical (Preliminary)

The umbilical carrier has provisions for connecting the RP-1 fuel line, 8 electrical connections, and 10 pneumatic, hydraulic, and cryogenic connections (figure 5-3).

Service mast number 23 is located north of position III next to the holddown arm and services the number 3 umbilical plate (figure 5-4). The umbilical carrier has provisions

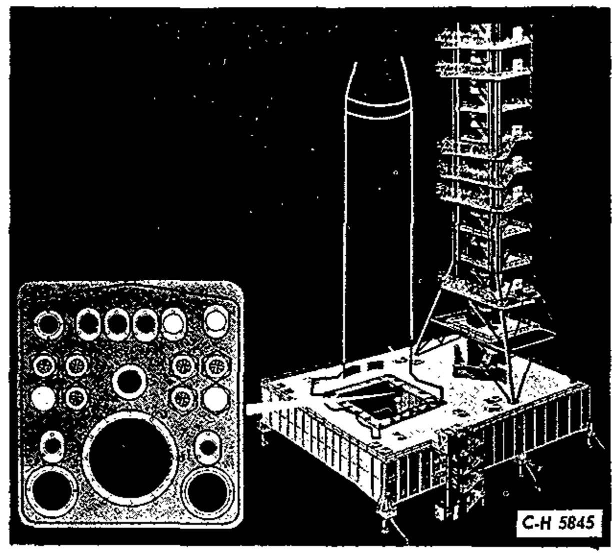


Figure 5-3. Umbilical Plate Number 2 (Preliminary)

for connecting two air-conditioning and deluge purge ducts and 10 pneumatic connections.

Service mast number 34 is located south of position III next to holddown arm number 3 and services

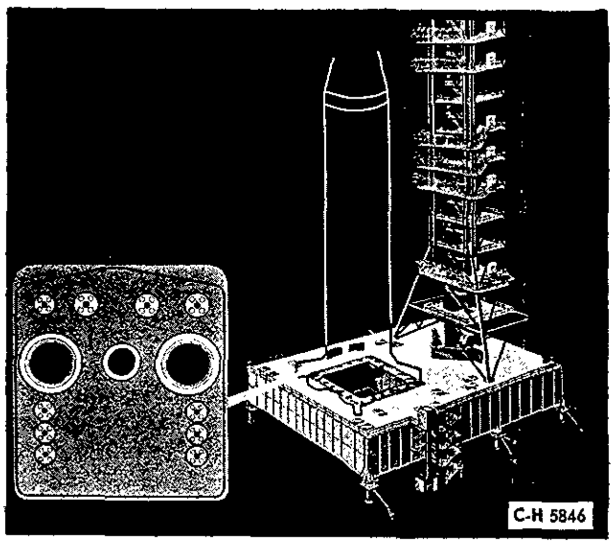


Figure 5-4. Umbilical Plate Number 3 (Preliminary)

umbilical plate number 1 (figure 5-5). The umbilical carrier has provisions for connecting a LOX fill and drain line, 8 electrical connections, and 11 cryogenic, pneumatic, and hydraulic connections.

The umbilical carrier of the tail service mast (figure 5-6) is secured to the vehicle with the locking and

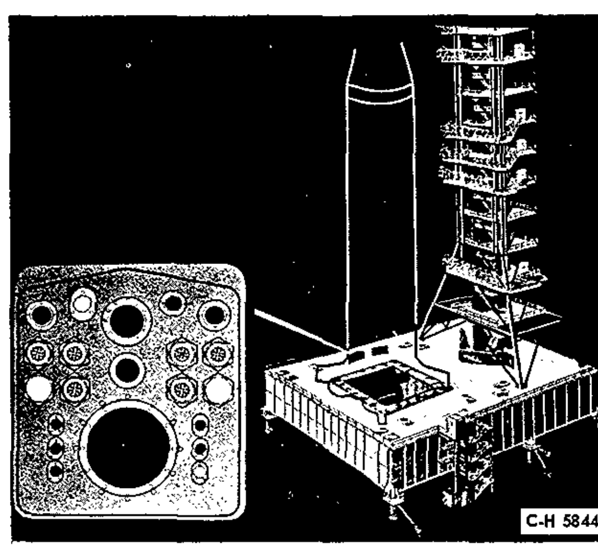


Figure 5-5. Umbilical Plate Number 1 (Preliminary)

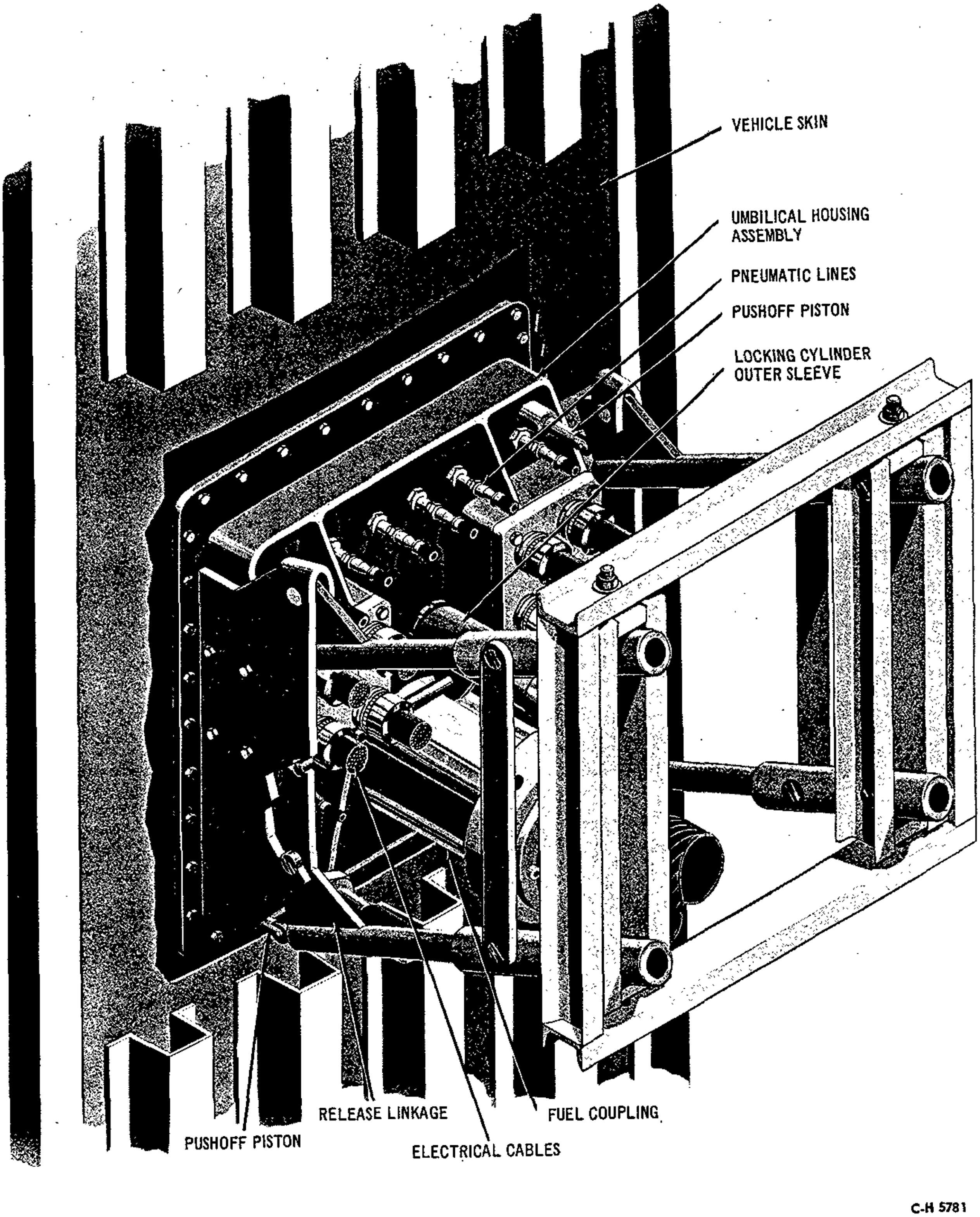


Figure 5-6. S-IC Tail Service Mast Umbilical Carrier and Withdrawal Mechanism (Preliminary)

release mechanism (figure 5-7). (Not shown in figure 5-7 is the outer sleeve that attaches to the yoke assembly and the mechanical release linkage of the tail service mast.) To secure the lock to the vehicle, the locking piston is manually forced into the vehicle receptacle with the aid of the outer sleeve attached to the yoke assembly. As the locking piston is moved in toward the vehicle, the locking ball expands the locking fingers into the vehicle receptacle, thus securing the umbilical carrier to the vehicle.

Release and disconnect of the umbilical carrier is accomplished mechanically through vehicle motion with an assist by the pneumatically charged pushoff foot. As the vehicle moves upward at launch, mechanical linkage of the tail service mast withdrawal mechanism forces the outer sleeve of the lock away from the vehicle. This pulls the locking piston and ball out of the vehicle receptacle, releasing the locking fingers. Further movement of the locking piston releases the trigger pins, allowing the pneumatically loaded pushoff foot to extend against the vehicle service plate and accelerate the release of the umbilical carrier. The disconnect, release, and retraction

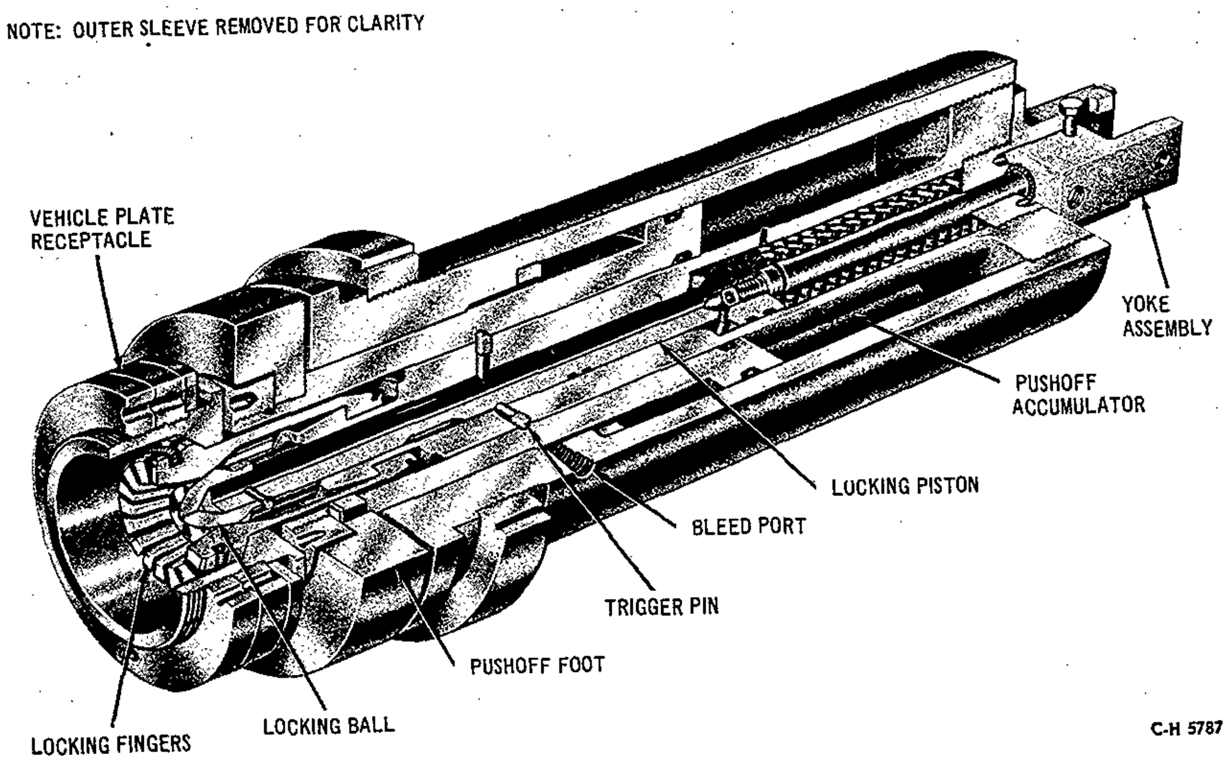


Figure 5-7. Tail Service Mast Carrier Locking and Release Mechanism (Preliminary)

cycle is shown in figure 5-8. Mast retraction is accomplished through a closed hydraulic system that is pneumatically charged and electrically controlled. Normal disconnect, release, and retraction time is 3.0 seconds. In the event of pneumatic failure of the pushoff foot, continued vehicle motion will, through mechanical linkage, cause four pushoff pistons to extend and aid the release of the umbilical carrier. In addition, the tail service mast is counterbalanced so that, in the event of hydraulic or pneumatic failure in the mast retraction system, the counterweights will complete the mast retraction when the umbilical carrier reaches the point of emergency disconnect. Emergency disconnect, release, and retraction time is 3.2 seconds.

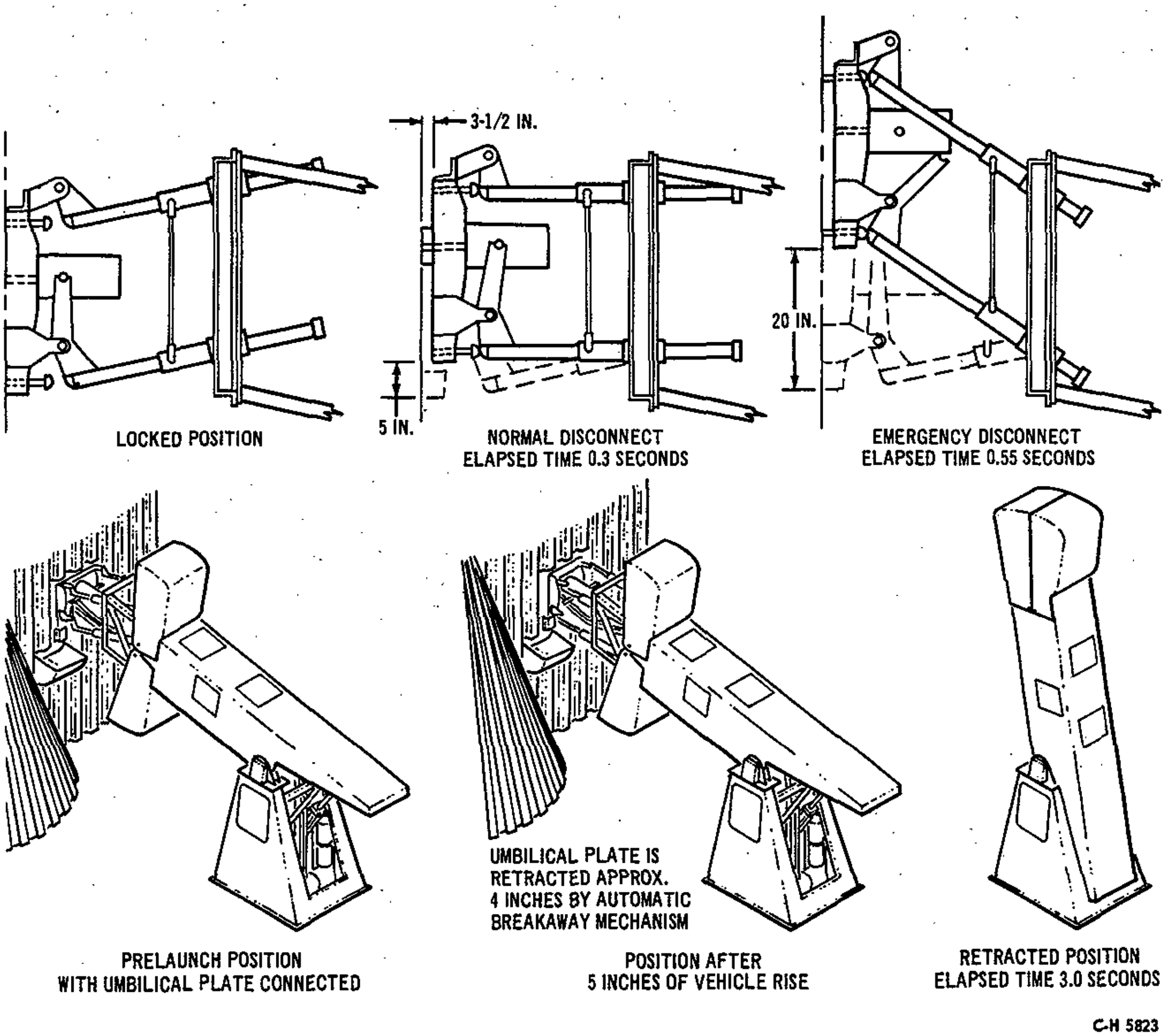


Figure 5-8. Tail Service Mast Disconnect Release and Retracting Cycle (Preliminary)

S-IC Intertank Arm. The S-IC intertank LOX fill and drain couplings at vehicle station 772.000 are serviced by the S-IC intertank service arm (figure 5-9). The S-IC intertank tank arm is located at the 60 foot level on the LUT. The arm is classified as a preflight arm because it is remotely disconnected and retracted before liftoff, but the arm is singular in that it has reconnect capability for LOX draining in the event of launch abort or LOX replenishing in the event of a hold after T minus 10 seconds.

The arm provides the means of routing, supporting, and connecting two 8-inch propellant lines from the tower interface to the umbilical carrier. Two 6-inch ball and sphere couplings connect the service lines to the vehicle as shown in detail AA of figure 5-9. Preflow sealing pressure is supplied by the bellows. The carrier is secured to the vehicle with a locking device that incorporates the principles of the locking device used for the tail service mast umbilical carriers. The locking fingers are actuated with a pneumatically operated locking piston. The fingers, in the locked position, protrude through the surface of the reconnect probe and engage surfaces of the vehicle receptacle. A pneumatic device, concentric with the pneumatically operated locking mechanism, controls the release and reconnect of the couplings.

Release and disconnect of the carrier is accomplished pneumatically. Pneumatic pressure retracts the locking piston, releasing the locking fingers. Further retraction of the locking piston releases the trigger pins and allows the precharged pushoff foot to extend against the vehicle and accelerate the carrier away from the vehicle. After release and disconnect, the service arm is hydraulically rotated against the tower out of the vehicle flight path.

Remote reconnect of the umbilical carrier and couplers is provided through the parallel linkage device that supports the umbilical carrier. This device is spring loaded to the neutral position and is driven by a single pneumatic cylinder. The probe on the umbilical carrier is guided by the funnel-like recess in the vehicle until the locking mechanism is in position to be secured. The pushoff foot is retracted by the pneumatic device concentric with the locking device. The foot is held in the retracted position by the engagement of the trigger pins when the locking piston is extended to the "lock" position.

S-IC Forward Arm. The S-IC forward arm provides the means of routing, supporting, connecting, and withdrawing the air-conditioning, electrical and pneumatic service lines from the LUT to the S-IC forward umbilical service plate located at vehicle station 1516.600. The S-IC forward arm is located at the 120 foot level on the LUT. The arm is a preflight arm and a single disconnect and withdrawal mechanism is used.

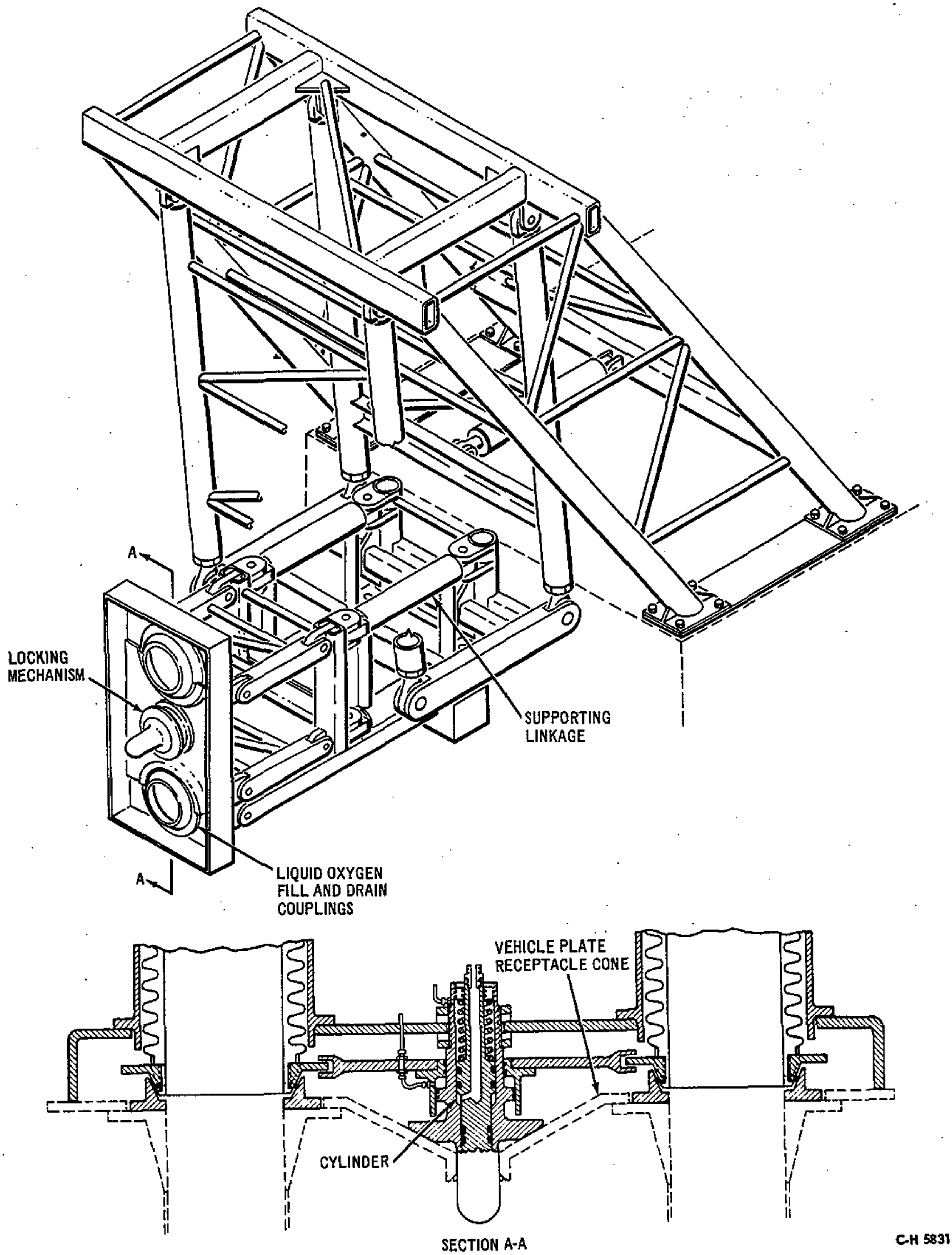


Figure 5-9. S-IC Intermediate Service Arm Umbilical Carrier, Lock, Retract and Reconnect Mechanism (Preliminary)

The umbilical carrier (figure 5-10) is the same as that used for the *Saturn I* Block II, number 1 swing arm. The carrier provides for connection of eight electrical cables, seven pneumatic lines, a liquid nitrogen line, and two air-conditioning ducts. The carrier connects to the vehicle with a pneumatically released ball-lock mechanism.

Primary release of the umbilical carrier is accomplished pneumatically with 750 psig pressure. The pressure releases the ball lock and simultaneously thrusts the four pushoff pistons against the vehicle, disconnecting the umbilical connections. A lanyard, routed from the umbilical carrier to a block and tackle retraction device driven by a pneumatic cylinder, withdraws the carrier to the end of the boom. Additional lanyard travel rotates the boom away from the vehicle and back to a small structure on top of the service arm where the boom is latched.

The lanyard withdrawal mechanism also provides a redundant release and disconnect of the umbilical carrier. If the ball lock and pushoff pistons have failed, the lanyard connected to the pulloff bar between the carrier cam levers will release the ball lock and disconnect the carrier.

S-II STAGE

S-II Aft Service Arm. This is a preflight service arm. The S-II aft service arm serves to route, support,

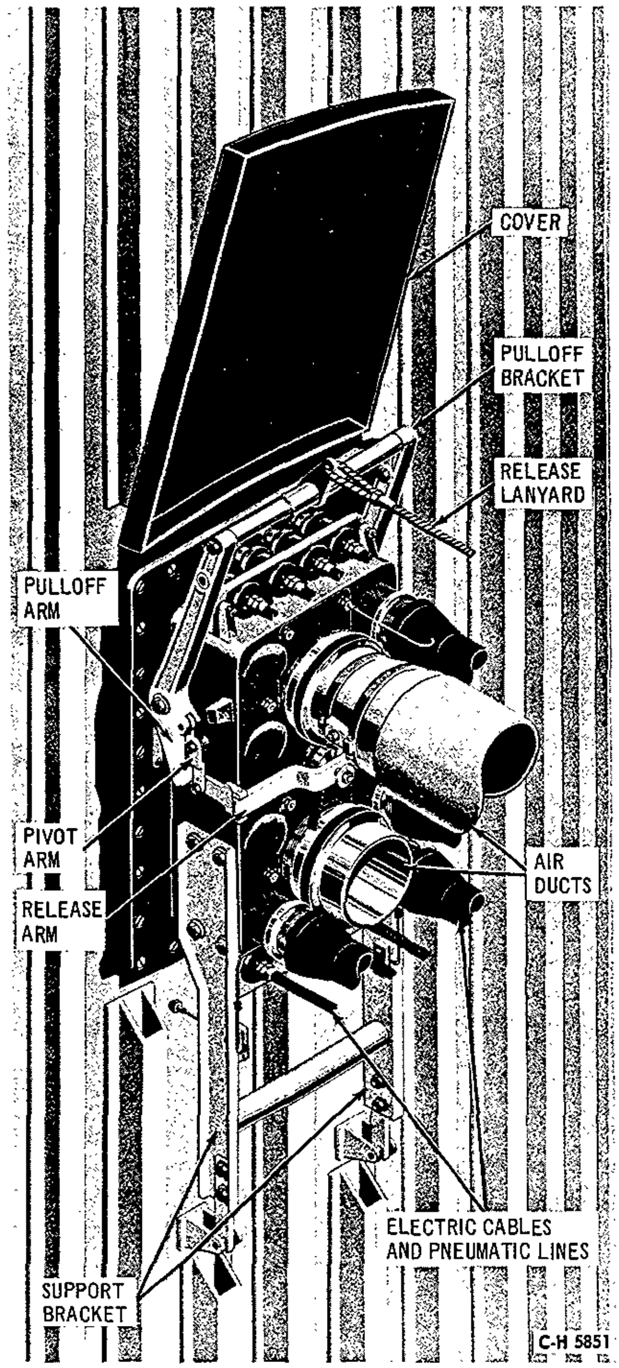


Figure 5-10. S-IC Forward Umbilical Carrier (Preliminary)

connect, disconnect, and withdraw a 1-inch LOX pump drain line from the vehicle to the LUT. This service connection is located on the vehicle at station 1606.200. This service arm is located between the 120 and 140 foot levels on the LUT. A 2-inch quick disconnect coupling joins the service line to the vehicle.

A lanyard attached to a collar on the coupling and to the retract device on the service arm disconnects and withdraws the line. The retract device is driven by a pneumatic cylinder that reels the lanyard cable through a block and tackle until withdrawal is complete.

S-II Intermediate Arm. This service arm provides the means of routing, supporting, connecting, disconnecting, and withdrawing the propellant lines, small cryogenic lines, pneumatic lines, and electrical cables servicing the S-II stage intermediate section. This service arm is located between the 140 and 160 foot levels on the LUT. Instrumentation cooling and purge lines connect at vehicle station 1767.000. Engine compartment purge lines, electrical and pneumatic services, and the LOX line connect at vehicle station 1771.000. The LH_2 line connects at vehicle station 1905.000.

The 8-inch inside diameter (ID), vacuum jacketed, LOX and LH_2 propellant lines connect to the vehicle with liftoff ball and sphere propellant couplings (figure 5-11). The couplings are secured to the vehicle with ball-lock quick-release mechanisms. All electrical cables, air-conditioning and purge lines, small cryogenic lines, and pneumatic lines interface in a common umbilical carrier (figure 5-12).

Two ball locks secure the carrier to the vehicle. Pneumatic pressure provides the primary release and

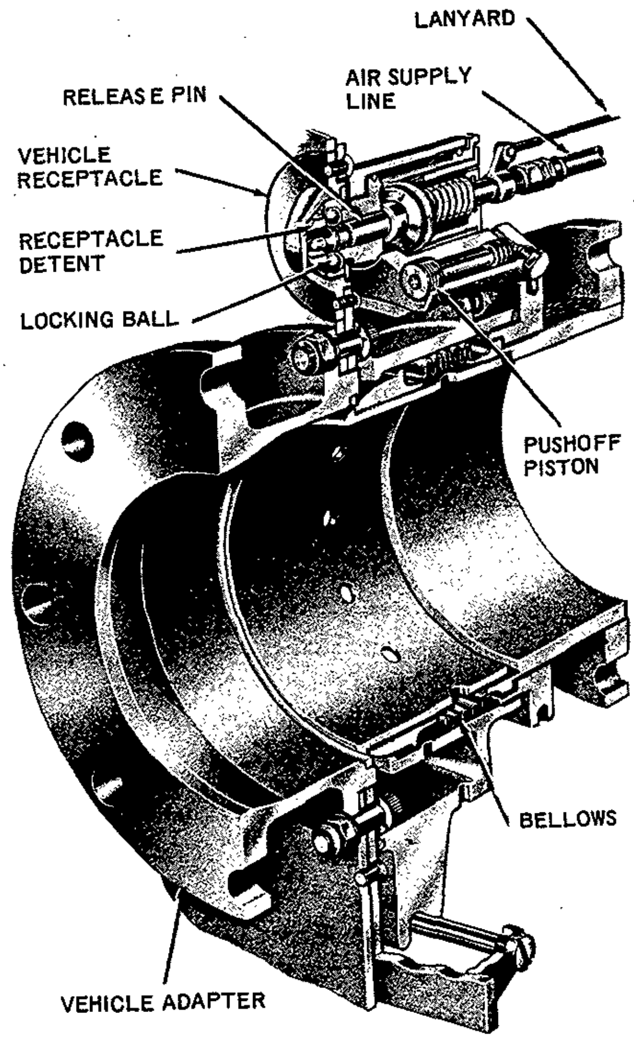


Figure 5-11. S-II Intermediate Propellant Coupling (Preliminary)

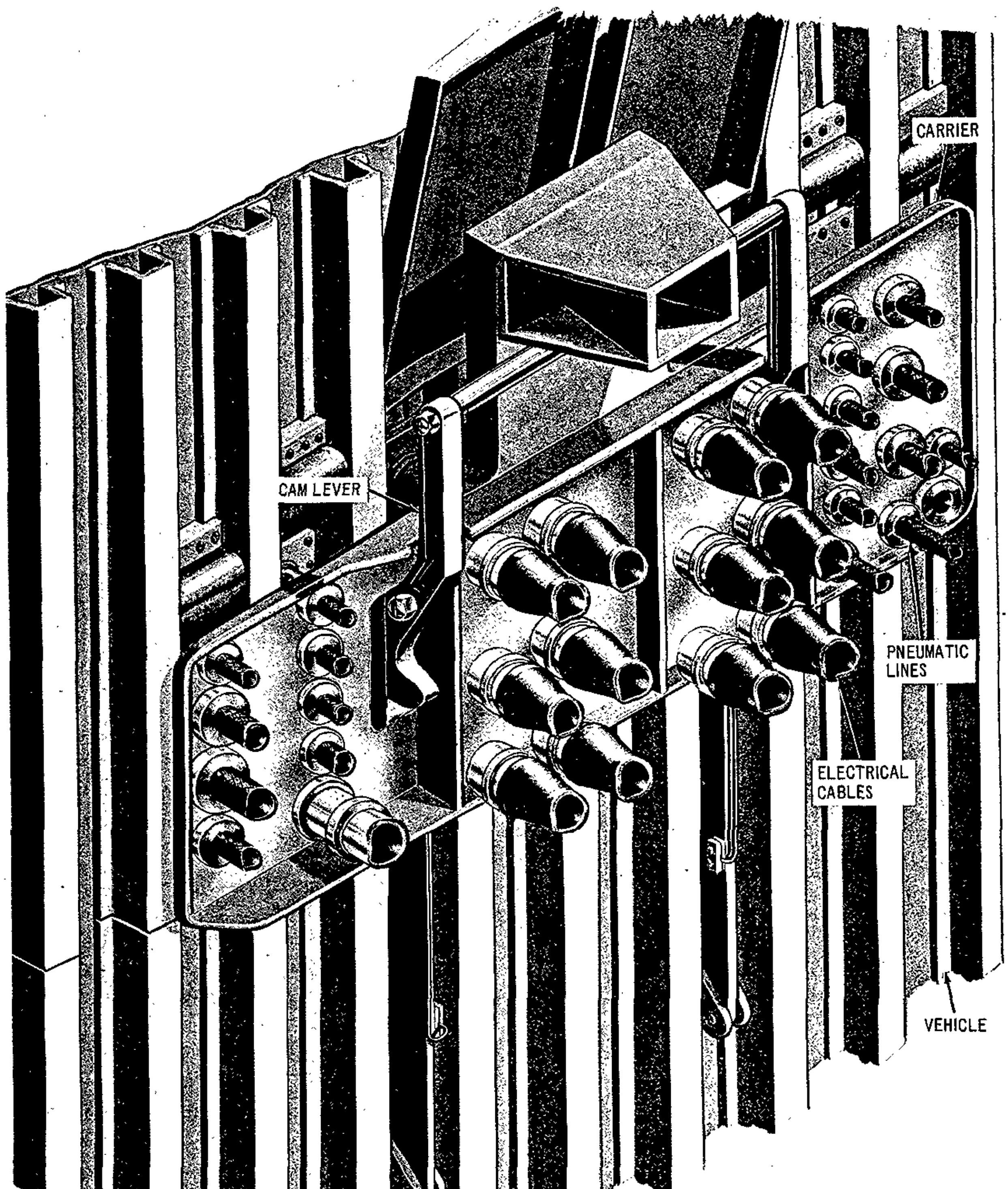


Figure 5-12. S-II Intermediate Umbilical Carrier (Preliminary)

disconnect of the propellant couplings and the umbilical carrier. Simultaneously with the pneumatic release of the ball-lock pins, pushoff pistons (four in the carrier and two at each propellant coupling) extend, disconnecting the umbilical connections. Disconnect of the carrier starts the withdrawal and retract sequence.

The spacing of two propellant lines and the large umbilical carrier requires three separate withdrawal mechanisms on the special second element of the S-II intermediate service arm. The arrangement of the mechanisms has been simplified by placement of an extension platform on the S-II aft arm for service of the lower umbilicals at the S-II intermediate arm.

A dual-cylinder-type withdrawal mechanism is mounted inside the arm on the bottom chord members to handle the umbilicals carrier at vehicle station 1771. The major component of the withdrawal mechanism is a high-pressure pneumatic cylinder of special design, which has a 5-inch bore, 4-inch rod, and a stroke of approximately 60 inches. The piston rod is constrained against rotation by a feather key mounted near the piston. The feather key rides in a milled slot in the piston guide rod. The guide rod is keyed to the blind-end cylinder head, extends through the barrel, and telescopes inside the piston rod. The forward end of the piston guide rod serves as a barrel for a 1-1/2-inch bore and 7-inch stroke hydraulic shock absorber. The fluid column contained within the piston guide rod discharges through a metering orifice to provide deceleration during the last five inches of cylinder stroke. The pneumatic cylinder is trunnion mounted in a universal joint located at the cylinder midpoint. A ring-mounted clevis is also threaded to the cylinder barrel to receive a self-aligning bearing on the rod end of the hydraulic cylinder.

The withdrawal mechanism hydraulic cylinder is a standard high pressure hydraulic actuator with a 3-inch bore, 1-1/2-inch rod, and a modified rod-end head that receives a large spherical bushing. The bushing is housed directly below the pneumatic cylinder universal joint and is supported by a common structure which ties the withdrawal mechanism to the service arm.

This dual cylinder combination and arrangement of universal joints allows tracking of vehicle motion while the umbilical carrier is connected. The arrangement also provides a self-centering feature during retraction. Vehicle loading is minimized by the introduction of balancing pressures in both cylinders. The retraction motion is a combination of straight line displacement along the axis of the pneumatic cylinder and simultaneous rotation of this axis applied by the hydraulic cylinder. All the umbilical lines except the 14-inch air-conditioning duct are clamped near the mechanism mount and allowed to sag in the retracted position. Thus, no special handling devices are required.

The 8-inch LOX line at vehicle station 1771 is retracted by a lanyard-type withdrawal device mounted at the upper left side of the arm. The lanyard is connected directly to the ball-lock pin in the coupler to provide a secondary means of release. The flex line section of the propellant line is supported by rollers to reduce vehicle loading. The propellant line slack generated by vehicle motion is taken up by an arrangement of two hinged joints and a pressure-compensated expansion joint. These components are set in their neutral positions at full retraction. Thus, the spring forces generated in the system cause impending motion away from the vehicle. An additional lanyard is connected to the ball-lock pin and anchored to the arm such that vehicle rise past a predetermined level will cause release of the coupler.

The 8-inch LH_2 line at station 1905.000 is handled by a second lanyard-type mechanism. A hard line section rides on a trolley between two sections of flex line. The flex line into the coupler is supported by a band to reduce vehicle loading. The aft flex section is directed down the side of the arm and deflects to allow approximately 40 inches of translation along the trolley. Both the coupler, with attached flex line, and the hard line section are retracted by a single pneumatic cylinder as follows: The cylinder is connected to the hard line section by a 2-to-1 lanyard-pulley arrangement. The lanyard from the coupler is connected to the hard line support by another 2-to-1 pulley system. Thus, one unit of motion by the cylinder produces two units of motion by the hard line and four units by the coupler. This action produces the required bending in the aft section of the flex line and simultaneous retraction of the two flex lines without violating the minimum bend radius of either section. The systems described above will meet the requirement for positive drain of propellants during vehicle tracking.

To provide a redundant system of release and disconnect of the umbilical carrier, a cam-off mechanism (figure 5-13) is located on a short link at the vehicle end of the withdrawal mechanism. This mechanism consists of a pneumatic cylinder (2-inch bore and 6-inch stroke), a pair of driving arms, a pair of overcenter springs, a splined output shaft, and two small cams. The two small cams are attached to the large clevis at the end of the withdrawal mechanism pneumatic cylinder.

The cam-off cylinder body is trunnion-mounted to the driving arms; the piston rod is pinned to a clevis which is part of the support link; and the overcenter springs are arranged to prevent inadvertent actuation of the mechanism. When the cylinder is pressurized, the arms are rotated toward the vehicle driving the springs overcenter and producing a torque at the output shaft. The torque is transmitted through a simple linkage to the cam levers on the sides of the umbilical carrier. As the levers are revolved, the ball lock is mechanically disengaged. The lower surfaces of the levers then contact the vehicle

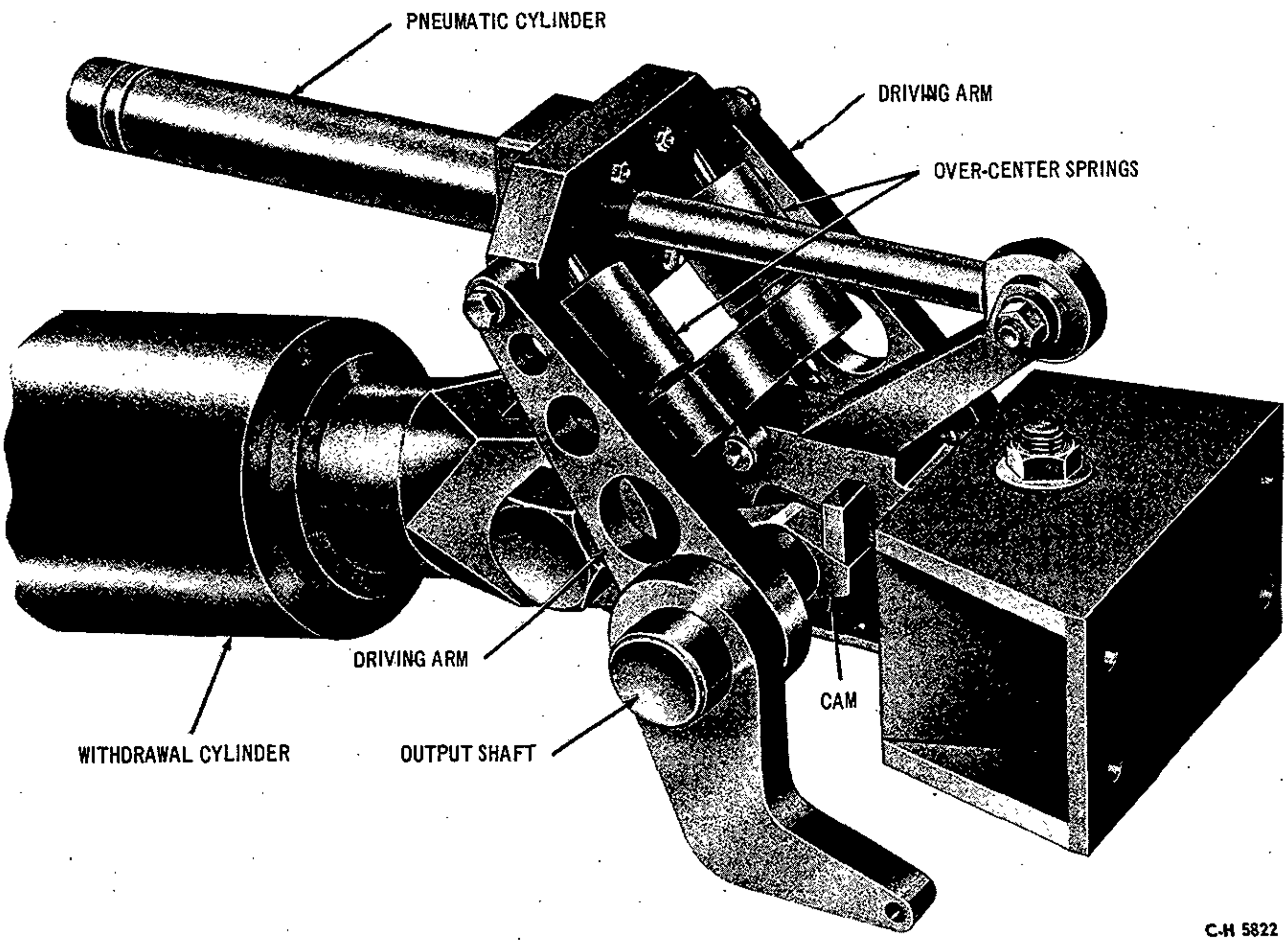


Figure 5-13. Cam-Off Mechanism (Preliminary)

to produce a prying action that rotates the umbilical carrier about its support feet. The support feet release completely before an 11 degree rotation angle is attained.

A third method of disconnecting the umbilical carrier is produced by the vertical liftoff motion of the vehicle. This phenomenon is known as "vehicle motion cam-off" and is available in case of complete failure of all electrical and pneumatic systems. The method has no effect on normal cam-off operations. When the vehicle has risen past a predetermined level, the angular change between the umbilical carrier and the withdrawal mechanism pneumatic cylinder causes engagement of cam surfaces to drive the cam-off mechanism output shaft. The driving cams are splined to the clevis of the pneumatic cylinder to allow proper adjustment. The driven cams are integral parts of the arms which rotate the output shaft.

The S-II stage intermediate arm is an in-flight arm that will retract at liftoff after receiving a command signal from the liftoff switches located on the holddown arms.

S-II Forward Arm. Two 8-inch ID hydrogen vent lines, a 1-inch cryogenic line, six pneumatic lines, eight electrical cables, and one 4-inch air-conditioning duct are routed over the S-II forward arm and connect to the vehicle at station 2506.000. The forward arm is located between the 200 and 220 foot levels on the LUT. The arm is an in-flight arm.

The service lines interface in one umbilical carrier that is secured to the vehicle with a ball-lock quick-release mechanism. Primary release of the ball lock is accomplished pneumatically with disconnect aided by the pneumatically actuated pushoff pistons. A few milliseconds after application of pressure to the primary disconnect system, pressure is applied to the cam-off pneumatic cylinder, providing redundant release of the carrier. Emergency disconnect is provided by the "vehicle motion cam-off" operation previously described for the S-II intermediate arm.

A dual-cylinder-type withdrawal mechanism is mounted off center on the top of the S-II forward arm to handle the umbilical carrier. The hydraulic cylinder is located above the pneumatic cylinder and is attached to the barrel forward of the main trunnion. The hydrogen vent lines are routed through rollers on the side of the service arm. The remainder of the service lines are routed so the retraction slack may be accommodated inside the arm structure.

S-IVB STAGE

S-IVB Aft Arm. All the service lines on the arm interface in a common umbilical carrier (figure 5-14). This arm is located at the 220 foot level on the LUT. The lines include two 6-inch ID propellant lines, a 10-inch air-conditioning line, six electrical cables, and eleven pneumatic and small cryogenic lines. The carrier connects at vehicle station 2760.000.

The propellant couplings are the ball and sphere type, with an expandable bellows providing the sealing force. Pneumatic and electrical couplings are of the quick disconnect slip type. The umbilical carrier is secured to the vehicle with two ball-lock quick-release mechanisms. Release and withdrawal of the umbilical carrier is the same as that described for the S-II intermediate and forward arms.

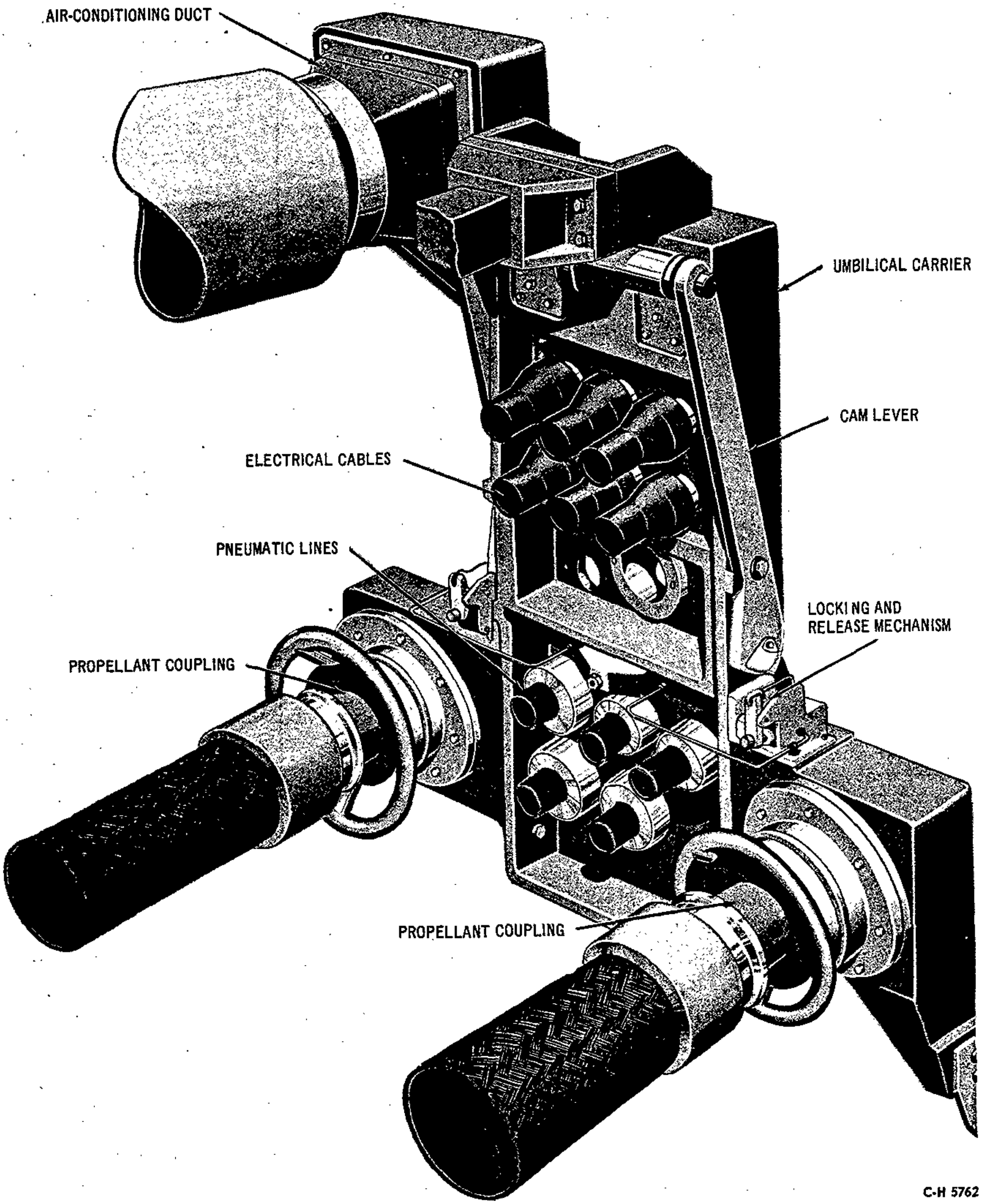


Figure 5-14. S-IVB Aft Umbilical Carrier (Preliminary)

Because of the number and type of service lines on this arm, two types of line handling devices are required to supplement the withdrawal mechanism: propellant handling devices; and electrical cable, air-conditioning duct, and pressure-line handling devices. The following paragraphs describe these devices.

Vacuum-jacketed flex-line assemblies extend from the couplers in the umbilical carrier to flanged joints at the forward ends of the hard line assemblies. The portions of the hard line assemblies on the top of the arm are supported on trolleys which roll along I-beams. Three vacuum-jacketed hinge joints are contained in sections of the hard line assemblies that are suspended on the sides of the service arm. During vehicle motion and umbilical carrier retraction, the hinged joints deflect to allow straight line motion along the I-beams. This arrangement ensures positive drain of propellants throughout the range of vehicle motion. The installation must have enough free motion to extend 16 inches out and 30 inches up from nominal position and yet not allow pockets to form in the lines when the umbilical carrier is 16 inches in and 6 inches below the nominal position.

A propellant line retract system is installed on top of the arm behind the lines. This system consists of a pneumatic cylinder which drives a 4-to-1 ratio block and tackle. The output cable is connected to a beam that joins the two hard line assemblies. This system provides a pull on the propellant lines during retraction to prevent destructive compressive bending of the flex lines. A second use of the retract system is to provide an adjustment of the tension in the flex line during vehicle tracking.

The remaining service lines for the S-IVB aft arm are handled by a pivoted frame located directly behind the support structure for the withdrawal mechanism. The various lines are clamped to the tubular members of the frame and are arranged to provide proper bend configurations at both ends. The frame follows vehicle motion to some extent since any increase in line tension, as the vehicle moves out, tends to rotate the frame forward. A cable connects the frame to the beam across the aft end of the propellant lines. Thus, as the vehicle moves in and the propellant lines move away from the vehicle, the line handling frame is rotated back. When the umbilical carrier is withdrawn, the frame is rapidly revolved backward by the propellant line retract system. When in final position, the frame is locked in place and is restrained against motion induced by service arm acceleration.

<u>S-IVB Forward and Instrument Unit Arm</u>. The umbilical lines on this arm service both the S-IVB forward section and the instrument unit (IU). This arm is located between the 260 and 280 foot levels on the LUT. The lines interface with two umbilical carriers supported in a common frame (figure 5-15). The S-IVB carrier facilitates connection and release of a 6-inch

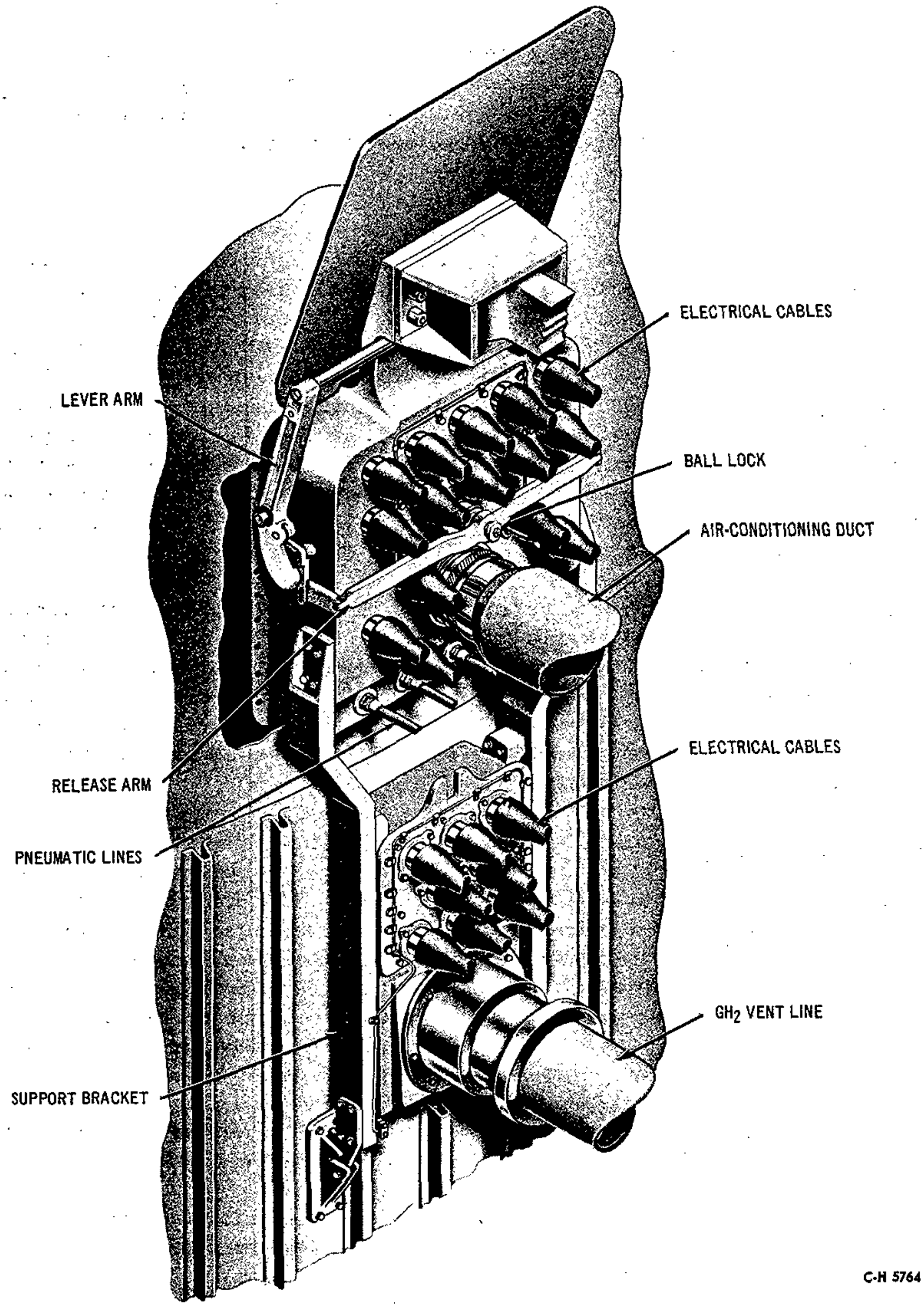


Figure 5-15. S-IVB Forward Umbilical Carrier (Preliminary)

hydrogen vent line and eight electrical cables. This carrier connects at vehicle station 3203.555. The instrument unit carrier provides connection and release of a 6-inch air-conditioning duct, sixteen electrical cables, a pneumatic line, and two lines for water-methanol conditioning. This carrier connects at vehicle station 3214.992.

The carriers within the common frame are secured to the vehicle with a ball-lock quick-release mechanism located in the instrument unit carrier only. Additional support is supplied by the frame support brackets on the vehicle. Primary pneumatic release and disconnect, secondary cam-off release and disconnect, and "vehicle motion cam-off" release are provided for the umbilical carriers.

The withdrawal mechanism is of the dual cylinder type and is mounted on the side of the service arm. The mechanism, handling two carriers in a common frame, employs the "hydraulic cylinder above" configuration and a special bent clevis at the end of the piston rod of the pneumatic cylinder. The special clevis compensates for the geometrical conditions imposed by the offset location and radial orientation of the umbilical carriers. A pivoted frame similar to the one on the S-IVB aft arm handles the service lines. During retraction, this frame is pulled by a lanyard connected to the blind-end head of the pneumatic cylinder.

APOLLO SPACECRAFT

<u>Service Module Arm.</u> The umbilical requirements for the arm have not been definitely established at this time; however, all lines will interface in a common umbilical carrier similar to that used for the Saturn I Apollo spacecraft (figure 5-16). This arm is located between the 300 and 320 foot levels on the LUT. Tentatively, the lines will include a 6-inch air-conditioning duct,

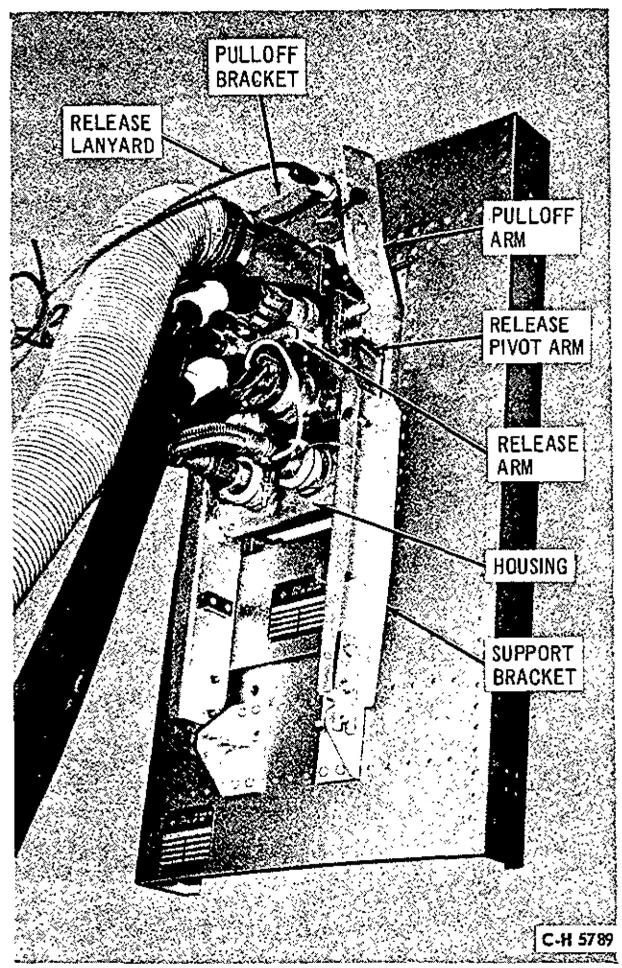


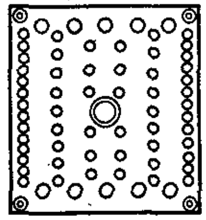
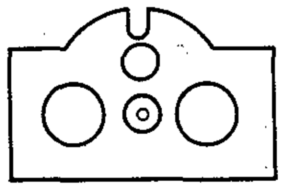
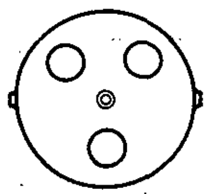
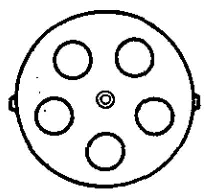
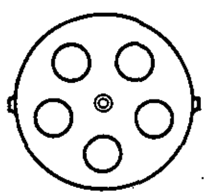
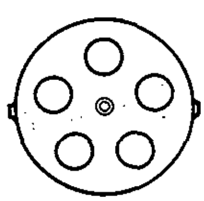
Figure 5-16. Service Module Umbilical Carrier.(Preliminary)

three electrical cables, five pneumatic and small cryogenic lines, and two coolant lines. The carrier will connect at vehicle station 3721.552.

A ball-lock quick-release mechanism secures the carrier to the vehicle. Primary disconnect and release of the carrier is accomplished pneumatically. A cam-off release mechanism operated by the lanyard retract system provides a secondary release.

A modified pivoted boom-type disconnect and withdrawal mechanism is mounted on top of the service module arm to retract the umbilical carrier. The boom for this device has a central pivot that allows the boom to collapse as the umbilical carrier is withdrawn. This feature ensures impending motion away from the vehicle skin. A lanyard clamping device is included at the end of the boom to accomplish vehicle motion cam-off within a reasonable amount of vehicle rise. The magnitude of horizontal vehicle displacement at this station prohibits the use of an ordinary cable tension cam-off device. The special device senses the vertical motion of the vehicle and clamps the lanyard so that additional vehicle motion releases the umbilical carrier.

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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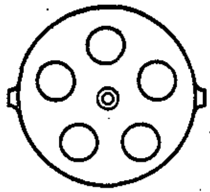
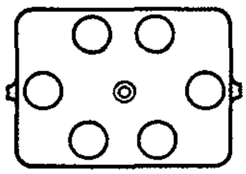
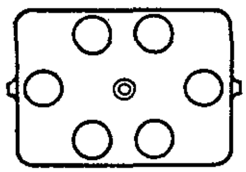
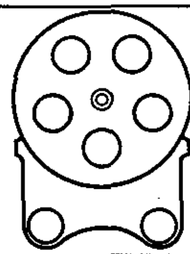
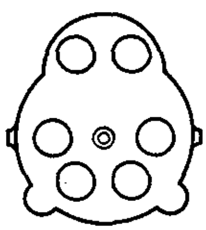
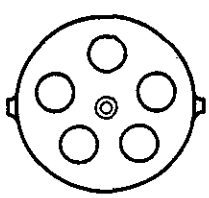
Appendix

USED ON	HOUSING ASSEMBLY	RELEASED BY
JUPITER NO. 5 - 8 NO. 9 TACTICAL TEST FOR TAIL CABLES		PULLOUT PIN
JUPITER NO. 5 - 8 LONG CABLE MAST		EXPLOSIVE LINK
JUPITER NO. 5 - 8 TEST FOR LONG CABLE MAST		BURNOUT WIRE
JUPITER NO. 9 LONG CABLE MAST		EXPLOSIVE LINK 750 PSI
JUPITER NO. 9 TACTICAL TEST FOR LONG CABLES		BURNOUT WIRE
JUPITER NO. 9 SHORT CABLE MAST		1/8-INCH ALUMINUM SHEAR PIN

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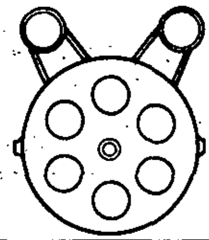
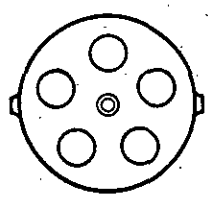
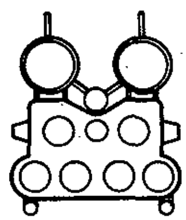
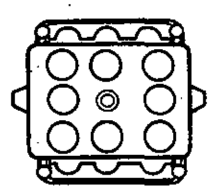
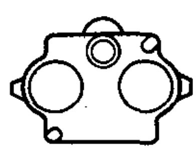
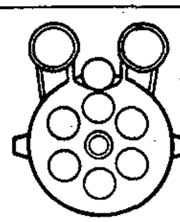
Appendix

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

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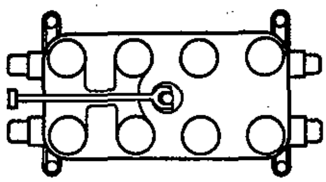
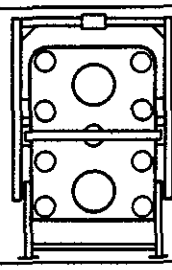
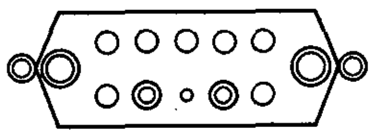
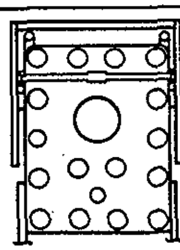
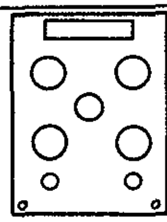
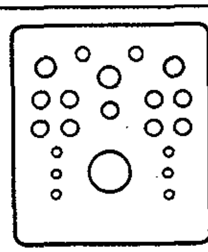
Appendix

USED ON	HOUSING ASSEMBLY	RELEASED BY
SATURN I, BLOCK II SHORT CABLE MAST		VEHICLE MOTION
SATURN I, BLOCK II SWING ARM NO. 1 (BLOCK I, SA-3 & 4)		1. AIR PRESSURE 750 PSI 2. HYDRAULIC CYLINDER RELEASE 3. VEHICLE MOTION
SATURN I, BLOCK II S-IV STAGE SWING ARM NO. 2		1. AIR PRESSURE 750 PSI 2. HYDRAULIC CYLINDER RELEASE 3. VEHICLE MOTION
SATURN I, BLOCK II SWING ARM NO. 3		1. AIR PRESSURE 750 PSI 2. HYDRAULIC CYLINDER RELEASE 3. VEHICLE MOTION
SATURN I, BLOCK II APOLLO SWING ARM NO. 4 (APOLLO, SATURN V)		1. AIR PRESSURE 750 PSI 2. HYDRAULIC CYLINDER RELEASE 3. VEHICLE MOTION
SATURN V, S-IC TAIL SERVICE MAST UMBILICAL PLATE NO. 1		VEHICLE MOTION

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Bibliography

V-2

Bitzer and Woerner, Trans. A-4 Fibel. Army Ballistic Missile Agency, Redstone Arsenal, Alabama, 1957.

German V-2 Missile Technical Data and Descriptive Summary. Chrysler Corporation, Missile Operations, 1953.

Her Britannic Majesty's Government. Report on Operation "Backfire." 5 Vols. Prepared for printing by The Ministry of Supply, The War Office, London, S. W. 1.

REDSTONE

This is Redstone. Chrysler Corporation Missile Division, n. d.

ME-M48, Boom Flexure Study of the Redstone External Cooler Assembly. Technical Memorandum, Chrysler Corporation, Missile Division, 1961.

ME-M72, LOX Replenishing Valve Icing Failures. Technical Memorandum, Chrysler Corporation, Missile Division, 1961.

B-480, Liquid Nitrogen Heater Cooler Coupling Device Test and Drop Tests. Technical Bulletin, Chrysler Corporation, Missile Division, 1958.

B-481, Evaluation Test of the Redstone Missile External Cooler Retaining Lock Assembly. Technical Bulletin, Chrysler Corporation, Missile Division, 1961.

Technical Manuals:

Field Artillery Guided Missile System Redstone.

TM9-1410-350-14/1, Ballistic Guided Missile M8: Shipment, Handling, and Storage. 1960.

TM9-1410-350-14/2, Ballistic Guided Missile M8: Ballistic Shell. 1960.

TM9-1410-350-14/5, Ballistic Guided Missile M8: Guidance and Control System and Electrical System Maintenance. 1961.

Bibliography

TM9-1410-350-14, Guided Missile Platform Launcher M74 and Truck-Mounted Guided Missile Erector-Servicer M478. 1961.

TM9-1410-350-14/7, Accessories Transportation Truck. 1961.

JUPITER

DI-CC-104, Jupiter Missile Ground Equipment Handbook Launch Site. Vol 1. Army Ballistic Missile Agency, Redstone Arsenal, Alabama, 1958.

ML-M102J, Qualification Tests of the Jupiter Fuel Disconnect Elbow and Missile Flange - Jupiter Missile Weapons System. Technical Memorandum, Chrysler Corporation, Missile Division, 1959.

ML-M106J, Qualification Testing of the Liquid Oxygen Disconnect Elbow 8944106 and Liquid Oxygen Fill Flange 8944101 - Jupiter Missile Weapons System. Technical Memorandum, Chrysler Corporation, Missile Division, 1959.

ML-M130J, Environmental Evaluation Test of the Jupiter Valve Box 8988791 - Jupiter Environmental Evaluation Program. Technical Memorandum, Chrysler Corporation, Missile Division, 1960.

ML-M137J, Environmental Evaluation Test of LOX Quick Disconnect Coupling 8935530 and LOX Fill Flange 8944101. Technical Memorandum, Chrysler Corporation, Missile Division, 1960.

B-717J, Investigation of Failures Encountered with the LOX Quick Disconnect Assemblies 8945530, During Repeated Operations on the Training Site At ABMA. Technical Bulletin, Chrysler Corporation, Missile Division, n. d.

Technical Manuals:

T.O. 21-SM78-2-1, Organizational Maintenance Instructions Missile Airframe USAF Model SM-78 Missile. USAF, 1960.

T.O. 21-SM78-2J-6, Installation Job Manual Inspection Assembly and Preparation for Launch USAF Model SM78 Missile. USAF, 1962.

Bibliography

T.O. 21-SM78-2J-9, Operation Maintenance Job Manual Propellant Transfer USAF Model SM78 Missile. USAF, 1962.

T.O. 35M6-4-2-1, Operation, Service, and Repair Instructions Liquid Oxygen Filling Assembly. USAF, 1962.

T.O. 35M6-4-2-12, Operation, Service, and Repair Instructions Fuel Filling Assembly USAF Model SM78 Missile. USAF, 1961 (Rev. 1962).

T.O. 35M6-4-2-14, Illustrated Parts Breakdown Fuel Filling Assembly Part No. 8987698 USAF Model SM78 Missile. USAF, 1960 (Rev. 1962).

T.O. 35M6-6-2-2, Service Instructions Cable Masts USAF Model SM78 Missile. USAF, 1962.

T.O. 35M6-6-2-4, Illustrated Parts Breakdown Cable Masts Part No. 8990296 and 8987430 USAF Model SM78 Missile. USAF, 1962.

SATURN I

Manuals:

Launch Operations Center, NASA, Launcher with Firing Accessories for Launch Complex 34. LTM-4-2, Vol. I, Huntsville, Alabama, 1963.

Launch Operations Center, NASA, Pneumatic Installation and Equipment for Launch Complex 37 Saturn I, Block II Vehicles. LTM-4-3, Vols. III and IV, Huntsville, Alabama, 1962.

Launch Operations Center, NASA, Installation, Operation and Service Manual for Umbilical Swing Arm Complex 34 SA-3 and SA-4. LTM-4-6, Huntsville, Alabama, 1963.

Launch Operations Center, NASA, Umbilical Tower Swing Arms Engineering Report Saturn I, Block II Vehicles. LTM-4-8, Huntsville, Alabama, 1963.

Launch Operations Center, NASA, Launcher with Firing Accessories, Ground Support Equipment for Saturn Vehicles. SGSEM Vol. V, Huntsville, Alabama, 1962.

Bibliography

George C. Marshall Space Flight Center, NASA, Ground Support Equipment Handbook for the Saturn Missile System. Huntsville, Alabama, 1961.

George C. Marshall Space Flight Center, NASA, Description of Saturn Launch Complex and Vehicle Systems SA-3, Drawing 10M04012. Huntsville, Alabama, 1962.

Internal Notes:

George C. Marshall Space Flight Center, NASA, Saturn Fuel Fill Mast, 10425667. Test-11-61, Huntsville, Alabama, 1961.

George C. Marshall Space Flight Center, NASA, VLF-34 Umbilical Tower Swing Arm Test. Test-11-62, Huntsville, Alabama, 1962.

Memorandums:

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Results of Tests to Determine the Functional Characteristics of the Saturn Fuel Mast. Huntsville, Alabama, 1961.

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Functional Test Results of the Saturn SA-1 Tail Cable Mast Assembly (Drawing J-10426744) Prior to Shipment to AMR. Huntsville, Alabama, 1961.

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Test Results, Saturn Long Cable Mast (S/N002, Drawing 10435700 Rev. D). Huntsville, Alabama, 1961.

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Test Results, Saturn LOX Mast (S/N001, J-10425543 Rev. B). Huntsville, Alabama, 1961.

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Results of Tests to Determine the Functional Characteristics of the Saturn Fuel Mast (S/N002, Drawing J-10425667 Rev. C). Huntsville, Alabama, 1961.

Bibliography

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Test Results Saturn Long Cable Mast (Spare) (S/N003, Drawing J-16435700 Rev. D). Huntsville, Alabama, 1961.

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Results of Acceptance Test on the Saturn LOX Mast (S/N003, Drawing 10425543 Rev. G). Huntsville, Alabama, 1962.

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Results of Acceptance Test on the Saturn Fuel Mast (S/N004, Drawing 10425567 Rev. J). Huntsville, Alabama, 1962.

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Results of Acceptance Test on Saturn Fuel Mast (S/N003, Drawing 10425667 Rev. J). Huntsville, Alabama, 1962.

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Flash Test Report on Umbilical Tower Swing Arms for SA-5. Huntsville, Alabama, 1963.

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Flash Results of Flow Tests on LOC Quick Disconnect Propellant Couplings for Umbilical Swing Arm No. 2. Huntsville, Alabama, 1962.

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Flash Results of Test on DAC Quick Disconnect Propellant Couplings for Umbilical Swing Arms No. 2 and 3. Huntsville, Alabama, 1963.

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Flash Results of Test on DAC Quick Disconnect Propellant Couplings for Umbilical No. 2 and 3. Huntsville, Alabama, 1963.

M-TEST-CD, George C. Marshall Space Flight Center, NASA, Flash Results of Tests on DAC Quick Disconnect Couplings for Umbilical Swing Arms No. 2 and 3 (VLF-37B). Huntsville, Alabama, 1963.

Reports:

George C. Marshall Space Flight Center, NASA, Saturn Short Cable Mast Test. Report No. MTP-M-TEST-60-6, Huntsville, Alabama, 1960.

Bibliography

George C. Marshall Space Flight Center, NASA, Saturn LOX Fill Mast 10424780. Report No. MTP-M-TEST-60-7, Huntsville, Alabama, 1960.

George C. Marshall Space Flight Center, NASA, Saturn LOX Fill Mast 10425543. Report No. MPP-M-TEST-61-7, Huntsville, Alabama, 1961.

ME-M83-S67, Reliability Test of the Saturn Long Cable Mast Pneumatic Brake Element, P/N 10437723. Chrysler Corporation, Missile Division, 1962.

ME-M97-S81, Reliability Test Report Retractable Coupling Assembly, P/N 10426666. Chrysler Corporation, Missile Division, 1962.

ME-M103-S87, Reliability Test Report Retractable Coupling Assembly, P/N 10426984. Chrysler Corporation, Missile Division, 1962.

ME-M121-S104, Reliability Test of the Saturn Quick Release Plate Assembly, P/N 10423514 and Quick Release Housing Assembly, P/N 10423593. Chrysler Corporation, Missile Division, 1962.

ME-M128-S111, Reliability Test Report for the Short Cable Mast Assembly, P/N 75M62632. Chrysler Corporation, Missile Division, 1962.

ME-M136-S119, Reliability Test Report for the Boattail Conditioning and Water Quench Valve and Coupling Assembly, P/N 75M02152. Chrysler Corporation, Missile Division, 1962.

ME-M152-S135, Reliability Test Report for the Retractable Coupling Assembly 75M00253. Chrysler Corporation, Missile Division, 1962.

ME-M168-S151, Reliability Test Report for the Quick Disconnect Assembly, VPN 261712 (Back-Up for P/N 10414034 and 10424710). Chrysler Corporation, Missile Division, 1963.

SE-M3-S3, Reliability Test of the Saturn Short Cable Mast Assembly, P/N 10424395. Chrysler Corporation, Missile Division, 1961.

Bibliography

SATURN V

Launch Operations Center, NASA, Saturn V Service Arms Preliminary Engineering Report Complex 39. TR-4-4-2-D, Vol. I. Huntsville, Alabama, 1963.

Launch Operations Center, NASA, Launch Complex 39 Umbilical Arms Concept Study Report. LTIR-2-DE-62-2, Huntsville, Alabama, 1962.

Launch Operations Center, NASA, Engineering Report Saturn V Tail Service Mast Design and Operation. Huntsville, Alabama, 1963.

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APPROVAL

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V-2 TO SATURN V

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