STUDENT STUDY GUIDE

AIR TRAINING COMMAND

MISSILE LAUNCH/MISSILE OFFICER

FLUID

FUEL TRANSFER SYSTEM

March 1962

COURSE OZR1821B/3121B-4
TECHNICAL TRAINING

FOR INSTRUCTIONAL PURPOSES ONLY

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Missile Launch/Missile Officer
Atlas Branch
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Student Study Guide
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FLUID TRANSFER SYSTEM

OBJECTIVE

To provide the student with a clear understanding of the construction and operation of the propellant transfer and storage systems. To teach the student the launch control and checkout procedures of the propellant transfer and storage systems.

INTRODUCTION

The ATLAS "F" series silo propellant transfer system is made up of the fuel, liquid oxygen, and liquid nitrogen/helium subsystems. These subsystems will rapidly load liquid oxygen, maintain the fuel within the missile at the proper level, and supply the airborne helium bottles with chilled helium to pressurize the propellant tanks during flight.

FUEL (RP-1) TRANSFER SUBSYSTEM

The fuel storage subsystem in the silo is a simplified subsystem in that the fuel will be stored in the missile tank. This removes the requirement for large storage tanks and rapid loading equipment for fuel within the silo. The time required to launch the missile has been reduced because the fuel is stored in the missile prior to countdown.

The quantity of fuel loaded aboard the missile must be regulated to within $\pm$ 0.5% of the required volume. This is necessary to insure the correct weight and volume for a maximum range flight. Fuel density, and hence the weight for a given volume, varies with the liquid temperature. The temperature within the missile storage area on the silo launcher will be maintained at 70° F $\pm$ 5°F. The temperature of the fuel when loaded may vary considerably more than this: therefore, as the fuel temperature stabilizes to that of the silo, the missile tank fuel level will vary from the desired level. A fuel loading system capable of tanking the missile to the proper level and maintaining that level is required. The fuel system performs the following functions:

1. Controls initial filling of the missile fuel tank to the proper level.

2. Adds to or drains quantities of fuel to maintain the missile tank at the desired level as temperature changes cause expansion and contraction of the fuel.

3. Drains the missile fuel tank as required for missile recycle. 11,500 gallons of fuel are required to tank the missile.

The fuel used in the Atlas missile is RP-1. It is a straw-colored liquid similar to kerosene. It is lighter than water (specific gravity 0.815), moderately volatile, and its vapor is heavier than air. It will detonate from heat, but not from shock. Its flash point is approximately 110°F.

Fuel Transfer Subsystem Components

FUEL ~~Silo~~ Purification Unit (Figures 1 and 2)

The function of this unit is to remove water and impurities from the RP-1 fuel prior to loading the missile fuel tank. This unit will process fuel from the facility underground catchment tank, or from an Air Force fuel transport tank truck during missile loading. This purification process is necessary because water in the fuel will cause corrosion of the missile during standby. Missiles have a life expectancy of 10 years, and during the majority of this time there will be fuel in the missile fuel tank. The smallest amount of free water would present serious corrosion problems.

The fuel purification unit consists primarily of a pump, filter-separator and dehydrator. The unit assembly is mounted on a four-wheel mobile trailer designed for intrabase use. One unit is required per base. The positive displacement pump delivers fuel from a suction lift of 7 to 0 PSIG and a suction head of 0 to 50 PSIG to a discharge head of 7 to 65 PSIG. Fuel is pumped through a filter-separator where all but 5 parts per million (PPM) of free water is removed from the fuel. The fuel from the filter-separator is then passed through the dehydrator where silica gel absorbs dissolved water molecules. There is sufficient quantity of silica gel in the dehydrator to process 45,000 gallons of RP-1 fuel to less than 15 PPM total water content.

The silica gel within the dehydrator tank must be replaced after a total of 45,000 gallons of fuel has been processed. New charges of silica gel must be installed before the unit may be used again.

The unit contains a moisture monitor which senses fuel at the dehydrator outlet and continuously monitors the water content of the fuel.

A control valve is located at the outlet of the unit to stop the fuel flow in the event of excessive pressure differential across the filter-separator assembly, or in the event of excessive water in the filter-separator sump.

An accessory hose is provided for use when processing fuel from the fuel catchment tank. When processing fuel from an Air Force fuel tank truck, the tank truck discharge hose connects directly to the fuel purification unit inlet.

A control panel is provided on the purification unit. The pump and moisture monitor controls are located on the panel. Power is supplied to the unit through a single cable. This cable also contains the grounding conductor which is automatically connected by plugging in the cable connector to the facility receptacle.

Fuel Catchment Tank (Figures 1)

The function of the underground fuel catchment system is to receive fuel from the missile tank during unloading operations. It is also used as a means to bring the fuel temperature from extreme ambient temperature to between 36° and 75° F before loading the missile. Missile range cannot be assured if fuel temperature is outside these limits, or good engine performance if fuel is outside 32°F to 80°F. By using the underground tank to adjust fuel temperature prior to loading, the missile is capable of immediate launch without limitation.

The tank and lines are made of carbon steel externally coated for underground use. During filling, the tank exhausts to atmosphere through a vent. ~~Air inflow to the tank, during draining, is through a dessicant to remove moisture~~. A pit, located adjacent to the tank, houses the ~~dessicant cans and~~ valves used for draining the tank.

Three fuel stubups with self-sealing couplings are provided at ground level near the silo cap perimeter. The fuel stubups are numbered F-15, F-17, and F-19. Valves F-16 and F-18 are manual shutoff valves that are normally closed. Valve F-20 is a one way check valve. Fuel can be loaded into the silo directly from the fuel tank trucks, through the fuel purification unit and into either stubup F-15 or F-17. Fuel transferred to the catchment tank will be loaded through stubup F-19. To transfer fuel from the catchment tank to the silo, fuel will be withdrawn from the catchment tank with the pump on the fuel purification unit. Fuel will flow out of

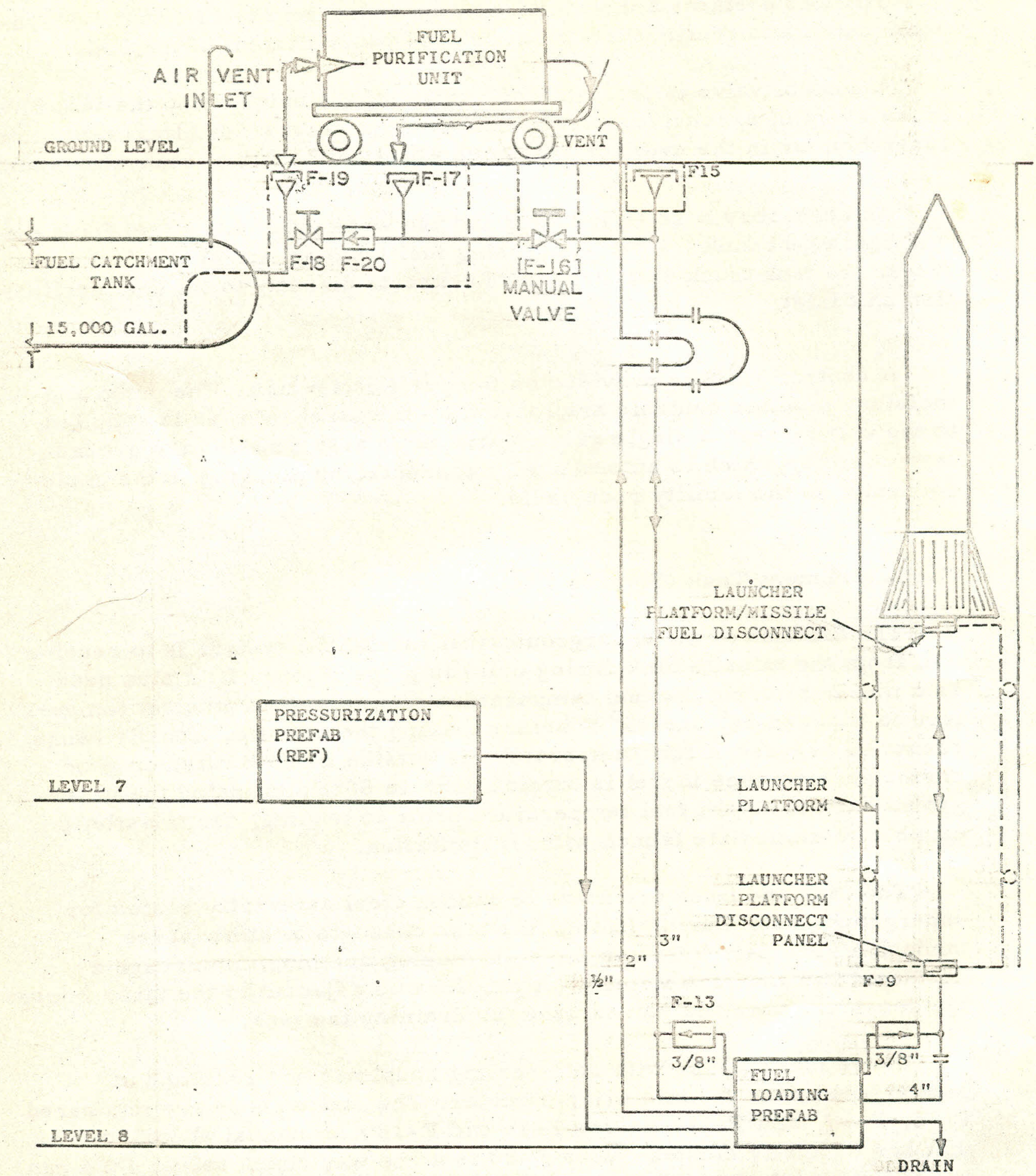


Figure 1 - Silo Fuel System

the catchment tank, through F-19, through the purification unit, through F-17 into the silo. Fuel transferred from the missile into the catchment tank will be transferred through F-16, F-20, and F-18.

The purification unit power receptacle is located at the silo cap near the fuel stubup connections.

Fuel Loading Prefab (Figure 1)

The function of the fuel loading prefab is to control tanking or draining of the missile fuel tank from (or to) an Air Force fuel tank truck, or the facility storage (catchment) tank.

It is also used to adjust the missile fuel level during temperature stabilization. Because of the extreme ambient temperatures at site locations, considerable expansion or contraction of the fuel will take place within the missile tank if fuel is loaded at these temperatures. The maximum time required for fuel stabilization within the fuel tank is estimated to be as much as seven days. During this period the missile fuel level shall be adjusted in order to maintain the missile in a standby condition. After this period the missile fuel level need only be checked periodically as no significant variations in fuel level will take place from temperature variations. When fuel is transferred from the leveling tank to the missile, the leveling tank is pressurized to 50 PSIG to push fuel into the missile fuel tank.

The fuel loading prefab consists of a 630 gallon fuel leveling tank, fuel leveling tank GN_2 pressurization supply bottle, filter, pump assembly, valves, switches, gages, and associated fittings and piping. All hardware is located on a prefab which is installed as a single unit.

The fuel loading prefab is located at the bottom of the silo crib on level eight directly below the launch platform.

The fuel pressurization system supplies pneumatic pressure for control valve operation and pressurizes the fuel leveling tank for supplying fuel to the missile for leveling. It is also used to prevent impurities from entering the system during standby. The fuel leveling tank is maintained under a blanket pressure of 2 PSIG.

The fuel leveling tank is sized for maximum fuel temperature variations to be encountered. The tank is filled to one of three levels depending on fuel temperature at tanking. For a fuel temperature of less than 55°F the tank is left empty. For 55°F to 85°F the tank is filled one-half full (to float switch FS-10) and for temperature above 85° the tank is completely filled (to float switch FS-9).

The fuel fill line to the missile (FFM) passes through the launch platform hot disconnect panel. This panel permits FFM to be connected and disconnected as the launch platform is raised or lowered. The fuel fill line, for safety reasons, is separated from the liquid oxygen fill line on the opposite side of the launching platform.

System Operating Sequence

Missile Loading from Tank Trucks (Figure 2)

When the missile is loaded from tank trucks, up to three truck loads of fuel will be required depending on truck capacity. It has been determined that the temperature of the fuel in these trucks may vary from approximately -40°F to approximately + 120°F. Fuel Tanking is accomplished as follows:

1. Connect the discharge line from the fuel purification trailer to the refuel stubup F-15 or F-17. If F-17 is used, manual valve F-16 must be opened.

2. The fuel purification trailer is connected to the electrical power receptacle and the moisture monitor is turned on and allowed to warm up.

3. The discharge line from the first tank truck is connected to the inlet connection of the purification trailer.

4. Fuel delivery from the truck to the inlet of the fuel purification trailer is initiated by turning on the truck pump.

5. The panel operator at the fuel subsystem logic unit panel on the crib third level is informed that preparations for tanking have been made.

6. The airborne fuel fill and drain valve is opened by operating its control switch on the logic control panel (Figure ~~1~~ 2). The position of this valve is indicated by lights on the panel.

7. Valve F-1 is opened by operating its control switch on the logic control panel. This signal is hooked up in the logic unit through a contact indicating that the missile fuel level is below 99.6% full. F-1 is opened by energizing SF-1 a four-way solenoid valve for controlling the flow of 750 PSIG GN_2 into the double-acting piston actuator on F-1. F-1 is a four-inch ball valve.

8. The pump in the fuel purification trailer is started. Fuel will be delivered from the tank truck, processed through the purification trailer, transferred through the fuel prefab, and into the missile.

9. The panel operator shall note whether the temperature of the incoming fuel is below 55°F, between 55°F and 85°F, or above 85°F.

10. When the first tank truck is empty, the fuel purification trailer pump is stopped, the truck pump is stopped and the truck discharge line from the trailer is disconnected.

11. The discharge line from the second truck load of fuel is connected to the inlet of the purification trailer and fuel delivery from the truck is initiated. The pump in the purification trailer is started and the second truckload of fuel will be processed into the missile.

12. The panel operator shall note whether the temperature of the incoming fuel is below 55°F, between 55°F and 85°F, or above 85°F.

13. When the second tank truck is empty, the fuel purification trailer pump and the truck pump are stopped, and the truck discharge line from the trailer is disconnected.

14. The discharge line from the third truck load of fuel is connected to the inlet of the purification trailer and fuel delivery from the truck is initiated. The pump in the purification trailer is started and the third truck load of fuel will be processed into the missile.

15. The panel operator shall again note the temperature of the incoming fuel.

16. Using the information regarding the temperature of the incoming fuel, the panel operator decides whether to leave the fuel leveling tank empty, half full, or full.

17. If the decision is made to put fuel into the leveling tank, the panel operator opens valve F-3 by operating its control switch.

18. The panel operator shall monitor the panel (Figure 3) and close valve F-3 when the fuel level in the leveling tank reaches the desired level. This operation is to be completed without stopping missile fill and before missile fill is complete.

19. When the fuel in the missile reaches the 99.6% level, the signal for opening the fuel fill valve F-1 is lost, SF-1 is deenergized, and F-1 is closed, stopping fuel transfer to the missile.

20. The pump in the purification trailer is stopped. The tank truck pump is stopped.

21. The airborne fuel fill and drain valve is closed and the fuel tank truck discharge line is disconnected from the fuel purification trailer inlet.

22. The fuel purification trailer discharge line is disconnected from the fuel fill stubup F-15 or F-17.

Missile Loading From the Fuel Catchment Tank (Figures 2 and 3)

When loading the missile from the fuel catchment tank, it is assumed that the temperature of the incoming fuel will be between 36° and 75°F. Fuel tanking is accomplished as follows:

1. The discharge line from the fuel purification trailer is connected to the refuel stubup F-17.

2. The fuel purification trailer is connected to the electrical power receptacle and the fuel purification trailer moisture monitor is turned on and allowed to warm up.

3. The purification trailer accessory hose is connected from the fuel catchment tank discharge stubup, F-19, to the trailer inlet.
MANUAL VALVE F-16 IS OPENED

4. The logic unit fuel tanking operator is informed that preparations for tanking have been made.

5. The airborne fuel fill and drain valve and valve F-1 are opened.

6. The pump in the fuel purification trailer is started. Fuel will be delivered from the fuel catchment tank, processed through the purification trailer, transferred through the fuel prefab, and into the missile.

7. The panel operator shall note whether the temperature of the incoming fuel is above 85°F or between 55°F and 85°F. The panel operator shall decide whether to fill the leveling tank completely full, or one-half full.

8. Valve F-3 is opened.

9. The logic unit panel is monitored and valve F-3 is closed when the fuel level reaches the required level. This is accomplished prior to the completion of missile loading.

10. When the fuel level in the missile reaches the 99.6% probe, the Propellant Level Control Unit (PLCU) sends a signal to the logic unit closing valve F-1 automatically.

11. The fuel purification unit pump is stopped and the airborne fill and drain valve is closed.

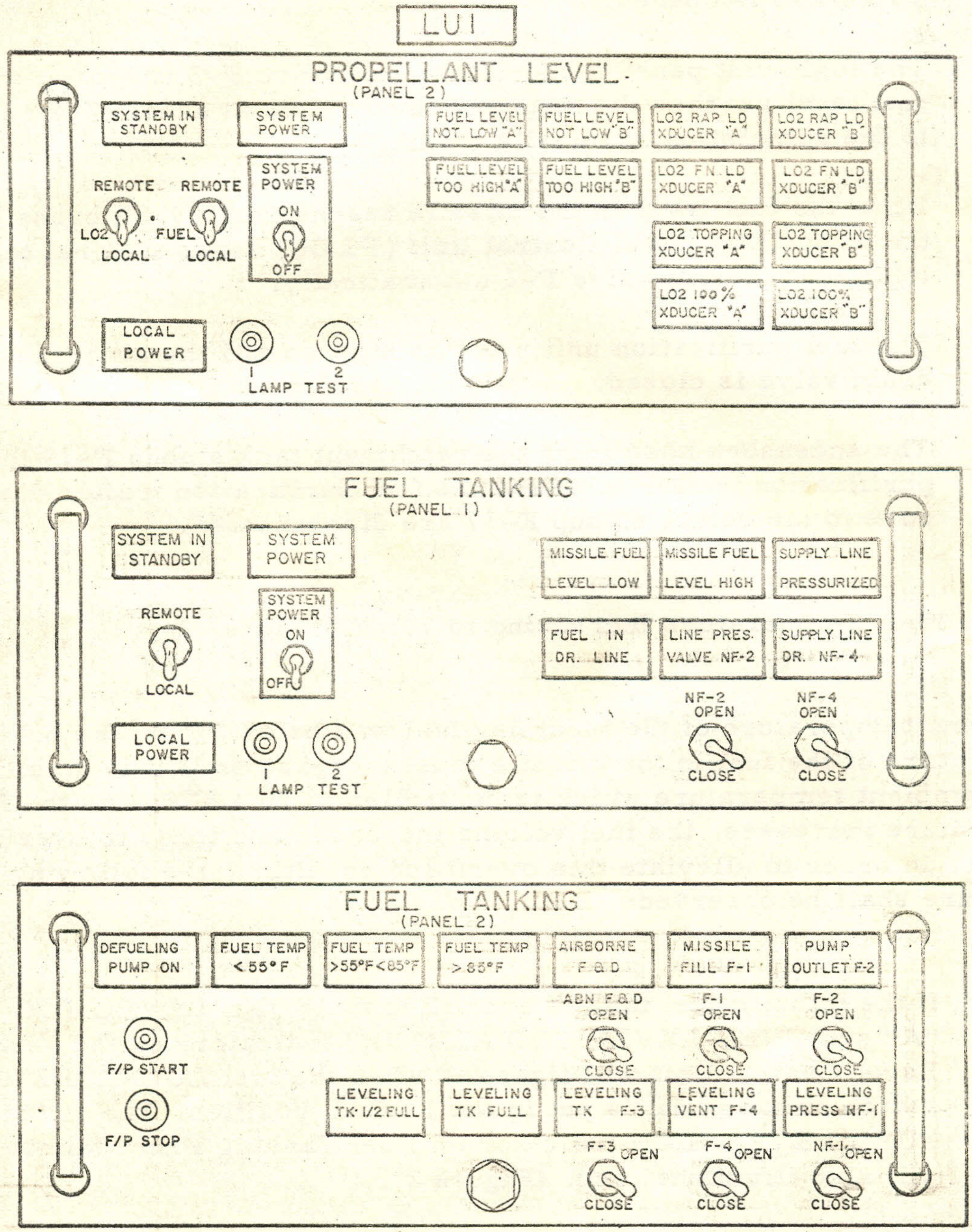
12. The accessory hose from the catchment tank stubup F-19 to the purification trailer inlet and the fuel purification trailer discharge hose to the refuel stubup F-17 are disconnected.

Missile Fuel Temperature Increasing to 70° F (Figure 2)

If the temperature of the incoming fuel was below 70°F, the bulk temperature of the fuel in the missile must increase until it is stabilized at the ambient temperature which is controlled to 70 $\pm$ 5°F. As the fuel temperature increases, the fuel volume increases and tends to overfill the missile. In order to alleviate this overfilled condition, the following procedure shall be observed:

1. If the missile fuel tank is overfilled the FUEL LEVEL TOO HIGH "A" and FUEL LEVEL TOO HIGH "B" indicators on the Propellant Level Control Unit will light red when the fuel LOCAL/REMOTE switch on the (PLCU) panel is put in the LOCAL position. The MISSILE FUEL LEVEL HIGH indicator on Fuel Tanking Panel Number 1 will also illuminate red. (Figure 2).

2. To lower the fuel level the Fuel Tanking Panel is switched to LOCAL Control and the airborne fill and drain valve and valve F-3 are opened.



GREEN OPEN } VALVE POSITION
AMBER CLOSED }

Figure 2 Fuel Tanking and Propellant Level Panels

3. The above indicators are monitored and when they extinguish valve F-3 and the airborne fill and drain valve are closed.

4. Steps 1-3 are repeated periodically until the bulk temperature of the fuel in the missile tank stabilizes.

5. When the temperature stabilizes, the fuel fill line to the prefab (FFP), and the fuel fill line to the missile (FFM), are to be drained.

6. Valves F-2, NF-4, and NF-2 are opened and when the FUEL IN DR. LINE amber indicator extinguishes the valves are closed.

Missile Fuel Temperature Decreasing to 70°F (Figure 2)

If the temperature of the incoming fuel was above 70°F, the bulk temperature of the fuel in the missile must decrease until it is stabilized at the ambient temperature which is controlled to 70 ± 5°F. As the fuel temperature decreases, the fuel volume decreases and tends to underfill the missile. In order to alleviate this underfilled condition the procedure is as follows:

1. With the Fuel LOCAL/REMOTE switch on the Propellant Level Control Unit panel in the LOCAL position the FUEL LEVEL NOT LOW "A" and FUEL LEVEL NOT LOW "B" indicators on the panel will be out if the missile tank is underfilled (less than 99.6% full). The MISSILE FUEL LEVEL LOW indicator on Fuel Tanking Panel Number 1 will be red. (Figure 2)

2. To raise the fuel level the Fuel Tanking Panel LOCAL/REMOTE switch is placed in the LOCAL position and the leveling tank vent valve, F-4, is closed.

3. The leveling tank pressurization valve, NF-1, the airborne fill and drain valve, missile fill valve, F-1, pump outlet valve, F-2, and leveling tank valve, F-3, are all opened. Fuel under pressure in the leveling tank is forced up into missile tank.

4. When the missile fuel tank becomes greater than 99.6% full valve F-1 closes automatically. The indicators on the PLCU Panel light green and the indicator on the Fuel Tanking Panel goes out.

5. Valves F-2, F-3 and the airborne fill and drain valve are closed.
AND NF-1 IS CLOSED AND F-4 IS OPEN

6. Steps 1-5 are periodically repeated until the bulk temperature of the fuel stabilizes.

7. When the temperature stabilizes, the lines are drained as in steps 5 and 6 in the previous procedure under Missile Fuel Temperature Increasing to 70°F.

Missile Unloading Into Tank Trucks (Figure 2)

When detanking the missile fuel tank into tank trucks, three tank truck loads of fuel must be pumped from the missile to the surface of the ground. Fuel detanking shall be accomplished as follows:

1. The fuel tank truck inlet line is connected to the refuel stubup, F-15. Open truck valving.

2. The airborne fuel fill and drain valve is opened.

3. F-2 is opened.

4. The defueling pump in the fuel leveling prefab is started.

5. When the first tank truck is full, F-2 is closed and the defueling pump is stopped.

6. The first tank truck is disconnected and the second tank truck fill line is connected to the refuel stubup, F-15.

7. F-2 is opened and the defueling pump is started.

8. When the second tank truck is full, F-2 is closed and the defueling pump is stopped.

9. The second tank truck is disconnected and the third tank truck fill line is connected to the refuel stubup, F-15.

10. F-2 is opened and the defueling pump is started.

11. The logic unit control panel is monitored. When the pump discharge pressure decays, the defueling pump is stopped. (Fuel Tanking Panel 1 Supply Line Pressurized indicator goes out.)

12. The airborne fuel fill and drain valve is closed.

13. The leveling tank vent valve F-4 is closed.

14. The pressurizing valve, NF-1 is opened.

15. F-3 is opened.

16. The defueling pump is started.

17. The logic unit control panel is monitored. When the pump pressure decays, the defueling pump is stopped.

18. NF-1, F-2, and F-3 are closed.

19. F-4 is opened.

20. The third fuel tank truck from the refuel stubup is disconnected.

Missile Detanking into Catchment Tank (Figure 2)

When detanking the missile into the fuel catchment tank, the following procedure shall be followed.

1. The manual fuel valves F-16 and F-18 located under a hand hole cover adjacent to the refuel stubup, F-15 are opened.

2. The airborne fuel fill and drain valve is opened.

3. F-2 is opened.

4. The defueling pump in the fuel leveling prefab is started.

5. The logic unit control panel is monitored. When the pump discharge pressure decays, the defueling pump is stopped.

6. The airborne fuel fill and drain valve and the leveling tank vent valve, F-4 are closed.

7. The pressurizing valve, NF-1 and F-3 are opened.

8. The defueling pump is started.

9. The logic unit control panel is monitored. When the pump pressure decays, the defueling pump is stopped. (Fuel Tanking Panel 1 Supply Li Pressurized indicator goes out.)

10. NF-1, F-2 and F-3 are closed.

11. F-4 is opened.

12. The manual fuel shutoff valves F-16 and F-18 are closed.

LIQUID OXYGEN TRANSFER SUBSYSTEM

The silo launcher liquid oxygen system (Figures 3 and 4) is capable of rapidly loading the missile LOX tank during countdown. Approximately 18,500 gallon of LOX must be transferred to the missile tank at a nominal flow rate of 5000 GPM. In addition, the system shall be capable of topping off the missile tank to replenish boiloff losses during hold periods and to bring the missile to 100% against flight pressure during commit. Fluid transfer will be accomplished by pressurizing storage tanks with gaseous nitrogen.

Liquid Oxygen (LOX) Storage Tank (Figures 3 and 4)

The LOX storage tank is used to store liquid oxygen in the silo during standby. GN_2 is used to transfer the LOX to the missile during the rapid and fine load portions of the countdown. This tank is a double-walled, vacuum-insulated, cylindrical vessel of 25,000 gallon capacity, but is filled with only 21,850 gallons.

The outside dimensions are 45 feet tall x 12 feet diameter. The approximate weight of the tank, including externally connected hardware (lugs; pipe fittings, ETC.) is 101,000 LBS.

The tank has its own vacuum system to maintain the low pressure in the vacuum jacket. Maximum liquid oxygen boiloff which shall not be greater than 1/4% per day is allowed to escape, and losses are resupplied normally every ten to twelve days. The tank is provided with support rings for vertical mounting and is located on the eighth level of the crib structure.

LOX Topping Tank (Figures 3 and 4)

The LOX topping tank is also used to store liquid oxygen in the silo during standby. Like the LOX storage tank, GN_2 is used to transfer the LOX to the missile during the rapid and fine load portions of the countdown and to maintain liquid oxygen level in the missile tank while holding at the commit ready. The tank is a double-walled, vacuum-insulated cylindrical vessel with a 3600 gallon capacity and filled with 3420 gallons. The outside dimensions are approximately 29 feet tall x 7 feet diameter. The approximate weight of the tank, including externally connected hardward (lugs, pipe fittings, ETC.) is 23,000 pounds.

The topping tank, like the storage tank, has its own vacuum system to maintain the low pressure in the vacuum jacket. Maximum liquid oxygen boiloff and replenishment of the topping tank and storage tank are the

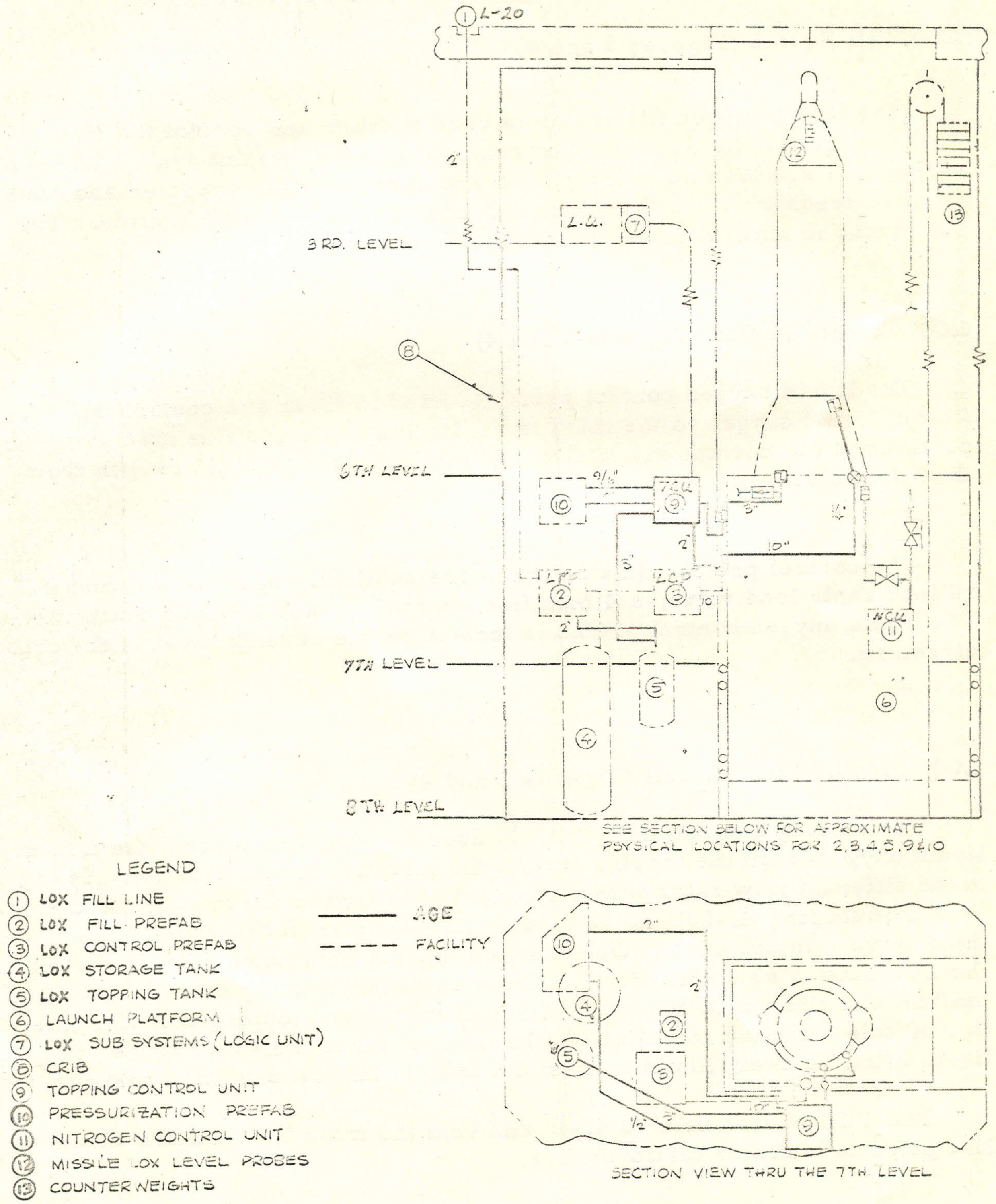


Figure 3 - LOX Transfer System

same. The topping tank is also provided with support rings for vertical mounting and is located on the eighth level of the crib structure.

LOX Fill Prefab (Figures 3 and 4)

The liquid oxygen fill prefab is used to filter and control the flow of liquid oxygen to the liquid oxygen storage tank and topping tank. The two valves that are located in the prefab are pneumatically operated and have position feedback switches on the full open and full closed position. The fill prefab is located on the seventh level of the crib.

LOX Control Prefab (Figures 3 and 4)

The liquid oxygen control prefab is used to filter and control the flow of liquid oxygen to the missile during the rapid and fine load portions of the countdown. It also controls the flow of liquid oxygen from the missile during a missile drain sequence.

The control prefab contains three pneumatically operated valves; a 10 inch rapid load valve, a 4 inch fine load valve, and a 4 inch drain valve. The liquid oxygen control prefab is located on the seventh level of the crib structure.

LOX Topping Control Unit (Figures 3 and 4)

The topping control unit (TCU) is used to filter and control the flow of liquid oxygen from the topping tank to the missile. It will also provide three different flow rates with a constant pressure in the topping tank. With fine topping (L-60), rapid topping (L-50), and bleed orifice open, the flow rate is 250 GPM. Opening fine topping with rapid topping closed, the flow rate is 50 GPM. With both fine and rapid topping closed, the bleed orifice will allow 6 GPM to pass through the ground topping transfer line to maintain a chilled condition and be dumped through L-52 into the liquid nitrogen over flow line from the inflight helium shrouded spheres.

The TCU is also used to drain and vent the main LOX fill and drain line prior to launcher platform rise.

N-5 2.4 PSI UNSEATS
2.2 PSI RESEATS

Pressurization Prefab (Figure 4)

The pressurization prefab is used to filter and control the flow of gaseous nitrogen for resupplying the gaseous nitrogen storage vessels. It is also used to control the pressure in the LOX storage and topping tanks which is the function to be described here.

The pressurization prefab is provided with a graphic control panel on which are located the liquid oxygen storage and topping tank liquid level indicators. Also, there are pressure controllers and gauges which control and indicate the storage tank ullage pressures. The prefab also contains vent valves N-4 and N-5 and pressurizing valves N-1, N-2, and N-3 for AND N-50 controlling pressures in the two liquid oxygen storage vessels. The pressurization prefab is located on the seventh level of the crib.

Vacuum Pump

Liquid oxygen must be stored at a very low temperature; therefore, their storage tanks must be insulated from the outside surroundings. As mentioned in their description, the LOX storage and topping tanks have a vacuum jacket, the construction of which is a tank within a tank. Vacuum pumps are used to evacuate the outer jacket on these tanks and thereby provide insulating space around the inner tank which holds the LOX.

Initial evacuation of the vacuum jacket is achieved with a portable pump which has water cooling and a large capacity. Installed type pumps then maintain the vacuum automatically at 150 microns of Hg absolute.

LOX Resupply

Under normal conditions the system will store LOX for 10 days without resupply. At each resupply period, the liquid oxygen vessels in the silo are refilled to make up boiloff losses suffered since the preceding resupply. If required operationally, a second countdown may be performed after one loading to commit, an hour hold, and then a drain before topping off the liquid oxygen vessels.

LOX System Data Flow

An explanation of the LOX system data flow appears under the launch control operation of this study guide.

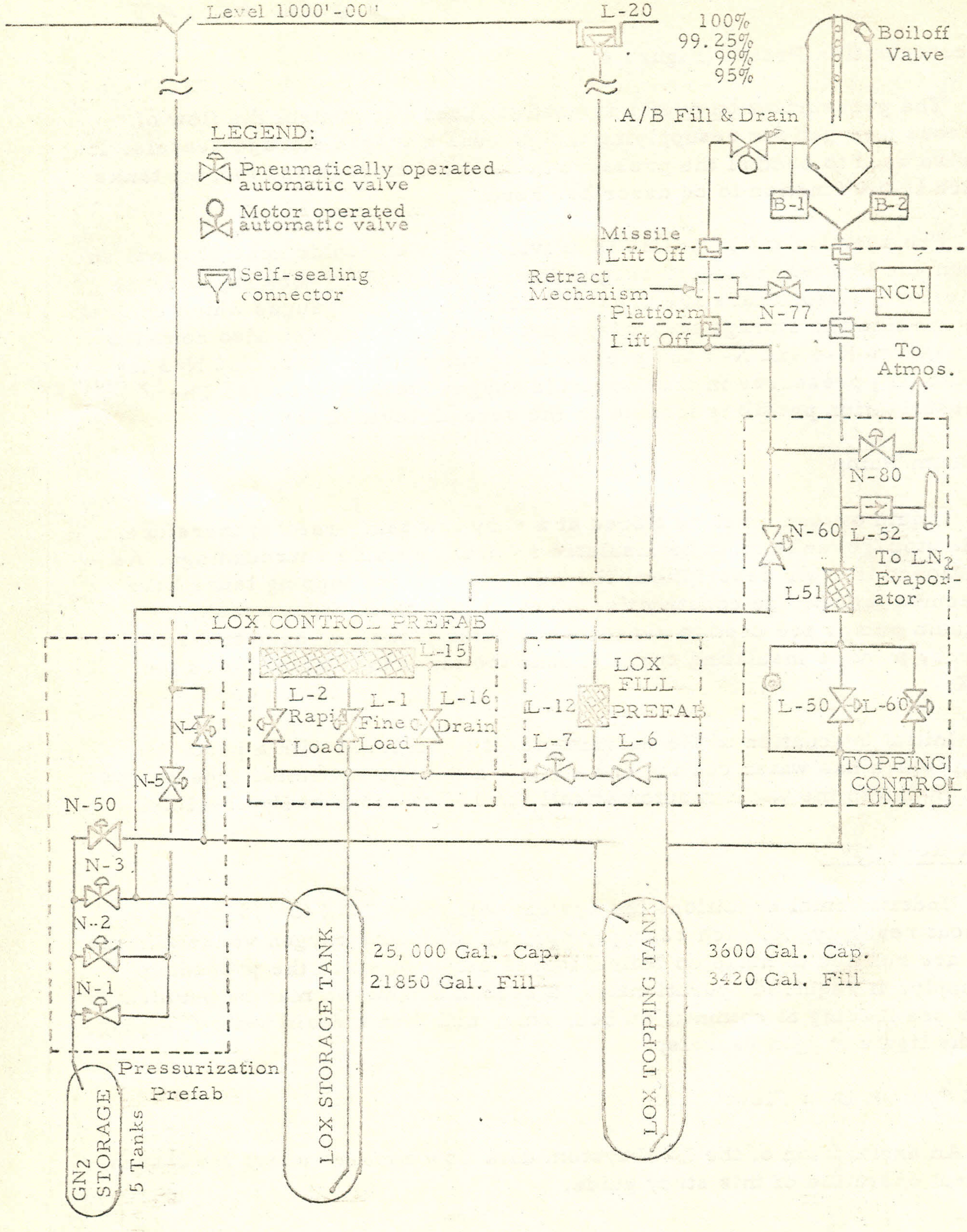


Figure 4 - Simplified Flow Diagram LOX Transfer System SM65F

LN_2/HE TRANSFER SUBSYSTEM

The liquid nitrogen/helium transfer system is designed to load rapidly, safely, and accurately the missile spheres and shrouds with helium and liquid nitrogen during countdown.

The LN2/He transfer system consists of He storage tanks, LN2 storage tank, LN_2/He heat exchanger tank, and LN_2 prefab. The LN_2/He system is located on the 7th and 8th levels of the crib structure. (Figure 6)

Economy of weight and space required within the missile dictated that the gas be stored at low temperatures and then heated before used. Liquid nitrogen (chemical symbol: LN_2) was selected as a refrigerant for the helium because of its very low boiling point (-320F). In addition, liquid nitrogen is plentiful, relatively inexpensive, and chemically stable enough to be transported and handled without danger.

Helium (chemical symbol: He) was selected as the gas medium for the airborne pressurization system for three of its advantageous characteristics:

1. Low specific weight

2. Chemical stability (Inert)

3. Good thermodynamic properties

To conserve space aboard the missile, the helium is refrigerated by LN_2 during loading of the spheres.

The space saved within the missile by refrigerating the helium can be illustrated by comparing gas densities at +70°F and at -320°F.

Helium at 70°F @ 3000 PSIG = 1.9 LBS/FT^3

Helium at -320°F @ 3000 PSIG = 5.9 LBS/FT^3

Within the missile the heating of the gas before use expands it greatly thereby permitting the pressurization of a volume. An illustration of the advantage gained by heating to an average of +250°F can also be made by again comparing gas densities:

Helium @ -320°F @ 3000 PSIG = 5.9 LBS/FT^3

Helium @ +250°F @ 3000 PSIG = 1.45 LBS/FT^3

Helium @ +32°F atmosphereic pressure = .01114 LBS/FT^3

LN2/He Subsystem Components

Helium Storage Tanks (Figure 5)

Two tanks, Number 1 helium inflight storage and Number 2 helium inflight storage have a capacity of 250 CU FT each and are filled with helium to a nominal working pressure of 6000 PSIG. These tanks are cylindrical with spherical ends.

The helium is routed through the pneumatic distribution unit (PDU) wherein 25 LB/MIN at 3000 PSIG is routed to the missile airborne helium bottles: a total of 14 LB/MIN at 6000 PSIG is routed to the pressure control unit (PCU) for subsequent pressure regulation and flow to the missile fuel and LOX tanks during countdown and emergency purposes. The helium storage tanks are located on the 8th level of the crib structure.

Gaseous Nitrogen Supply (Figure 5)

There is one gaseous nitrogen storage tank which supplies the PCU during standby for missile tank pressurization. This is the ground pressure supply. 6000 PSI

Another supply consists of ~~two~~ ONE gaseous nitrogen cylinder~~s~~ ~~manifolded together~~ to provide pressure for transferring liquid nitrogen. ~~These~~ This cylinder~~s~~ ~~are~~ IS pressurized at 4000 PSI and ~~are~~ IS located ~~in a stack of seven bottles~~ at level 8 of the crib. The other ~~five~~ TWO cylinders are for liquid oxygen transfer.

Liquid Nitrogen Storage Tank (Figure 6)

The liquid nitrogen storage tank consists of two concentric chambers. The inner chamber has an internal volume of 4000 gallons and a full capacity capability of 3600 gallons of liquid nitrogen. The tank system contains a relief valve, rupture disc and manual vent system. In addition, piping is provided for connection to a liquid level indicator mounted on the liquid nitrogen prefab control panel described later.

The outer chamber provides support for the inner shell and a structural frame for the entire storage tank-heat exchanger assembly. The annular volume between the tanks is maintained at a pressure of 10^{0} microns of mercury absolute (for effective prevention of heat leakage) by means of an external vacuum pumping system mounted on the underside of the storage tank.

The liquid nitrogen storage tank stores liquid nitrogen at atmospheric pressure in standby and delivers liquid nitrogen under pressure to the missile during countdown. The LN_2 storage tank is approximately 23 feet tall and 8.5 feet in diameter and weighs approximately 32000 pounds.

Liquid Nitrogen/Helium Heat Exchanger Tank (Figure 6)

The liquid nitrogen/helium heat exchanger tank consists of an inner and outer concentric shell. The inner chamber is made of stainless steel and has an internal volume of approximately 1600 gallons with a fill capacity of 1200 gallon. The tank system is piped to the relief valve and venting system of the liquid nitrogen storage tank to vent nitrogen vapor during standby and countdown. Additional piping is provided for connection to a liquid level indicator mounted on the liquid nitrogen prefab control panel described later.

The outer chamber provides support for the inner shell and a structural frame for attachment on top of the liquid nitrogen storage tank. The annular volume between the tanks is maintained at a pressure of 10^{0} microns of mercury absolute, using the same vacuum pumping system as used for the liquid nitrogen storage tank.

The main function of the heat exchanger is to cool down ambient helium gas (60° to $80^{\circ}F$) at a flow rate of 25 LB/MIN and a pressure of 3000 PSIG to an outlet temperature of $-300^{\circ}F$ during countdown. The liquid nitrogen/helium heat exchanger is approximately 6.5 feet tall x 8.5 feet diameter and weighs approximately 14000 pounds. The LN_2/He heat exchanger is located on top of the LN_2 tank on the 8th level of the crib structure.

Liquid Nitrogen Prefab (Figure 6)

The liquid nitrogen prefab is a separate cabinet located on the 7th level of the crib structure directly above the liquid nitrogen tank-heat exchanger assembly. The main function of this unit is to control liquid nitrogen flow from the storage tank through the coaxial LN_2/He line to the missile helium bottle shrouds.

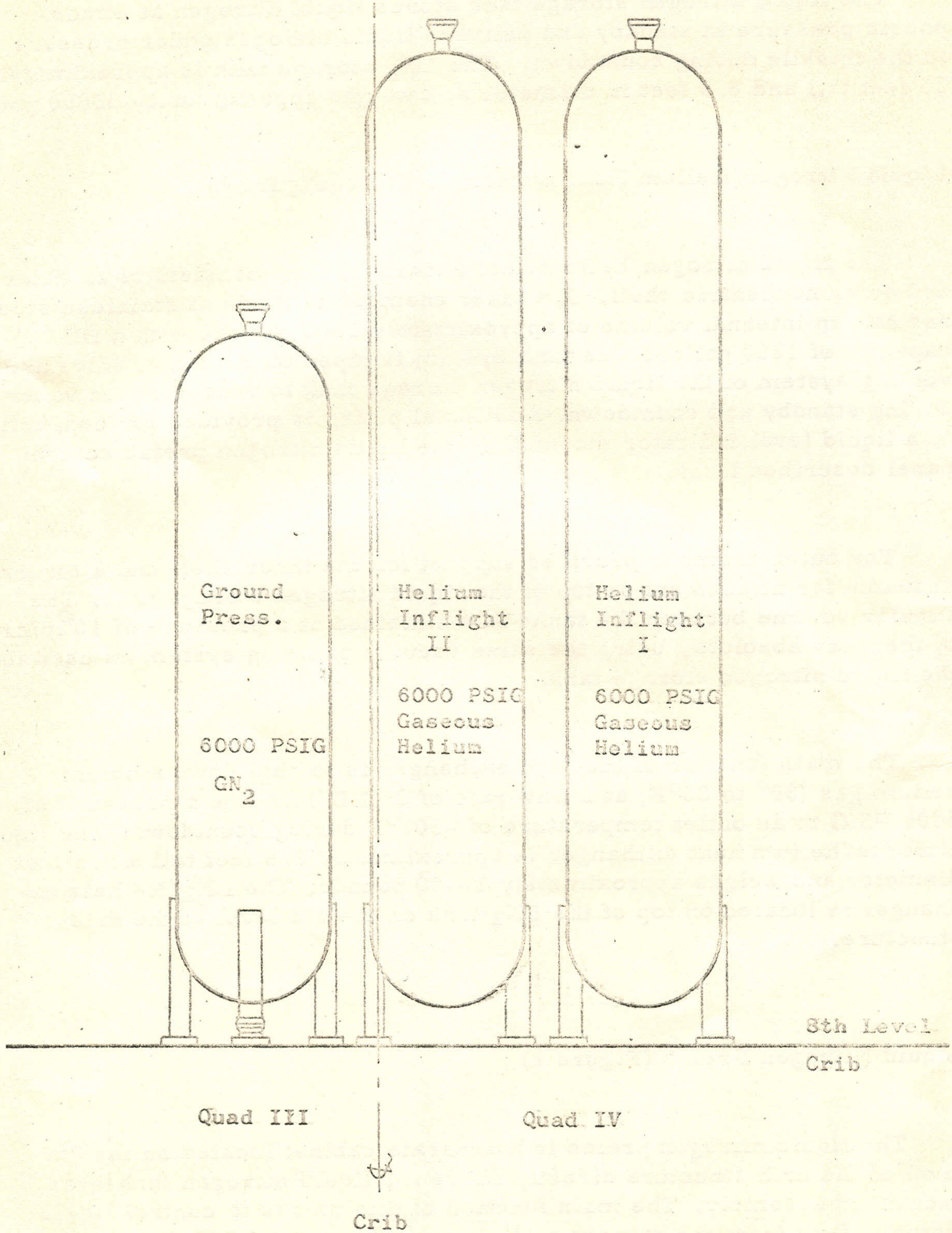


Figure 5 - Gaseous Helium and Nitrogen Storage

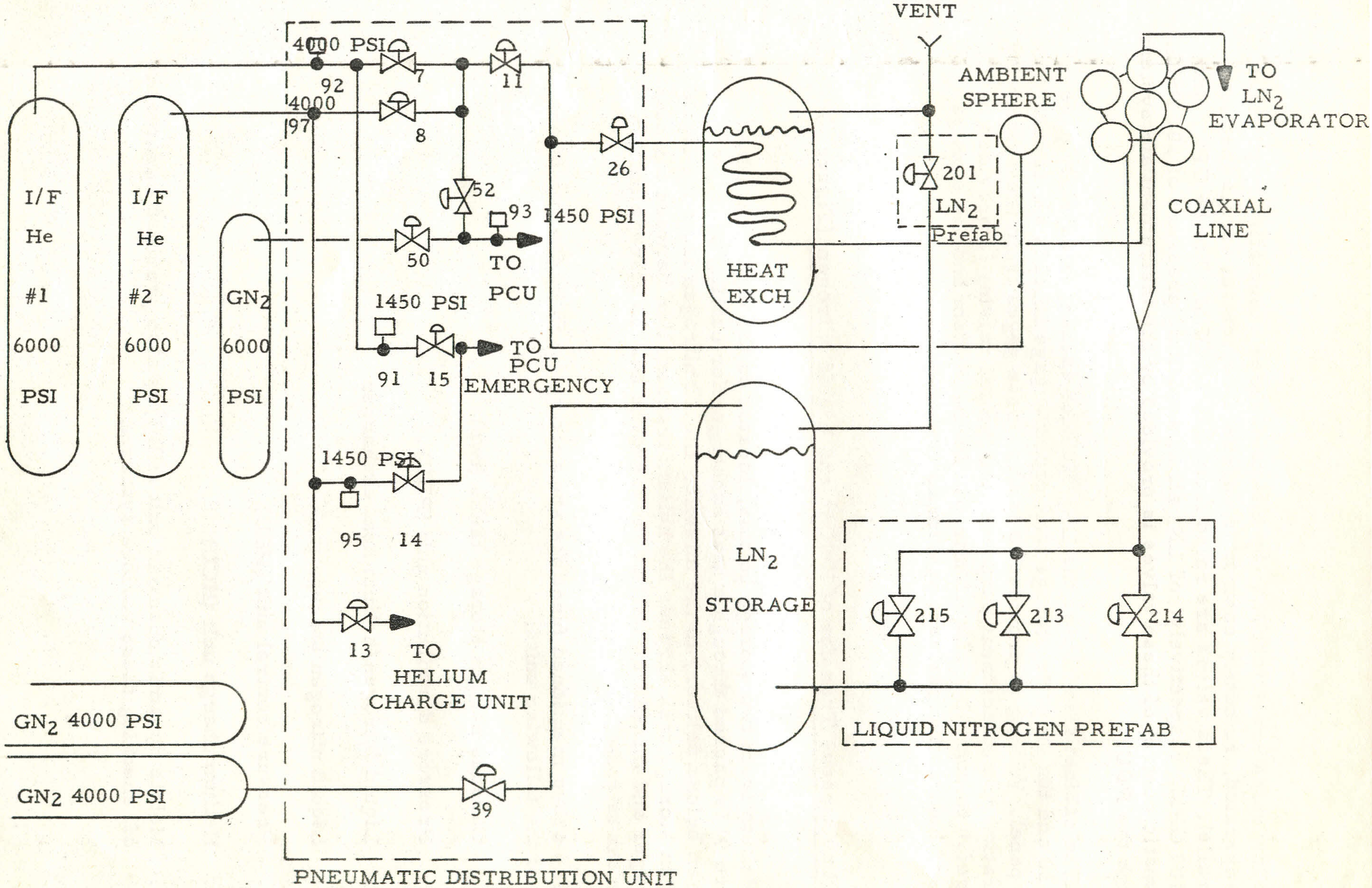


Figure 6 - Simplified Flow Diagram Liquid Nitrogen/Helium Transfer

Flow rates are established by means of three pneumatically powered, pilot-operated, remotely controlled, preset flow control valves installed in parallel. These valves are rated from 0 to 10 GPM, 0 to ~~25~~ 15 GPM, and 0 to 100 GPM, respectively, of LN_2 all at a working pressure of 100 PSIG. Pneumatic control of these valves is provided by the instrument air system through the PDU.

This cabinet also houses the LN_2/He heat exchanger capacity gage LL1220 and the LN_2/He storage tank capacity gage LL1221 on its instrument panel. Valving is provided to isolate these gages from the system for calibration or replacement purposes. Additional valving is provided in the prefab to control the liquid nitrogen filling system and the storage tank and heat exchanger vent system as required.

The Simultaneous Transfer of Helium and Liquid Nitrogen (Figure 6)

Helium from two storage bottles, located on the eight silo level (Figure 9) is passed through a heat exchanger for cooling by liquid nitrogen before delivery to the missile. Liquid nitrogen from the liquid nitrogen storage tank shrouds the helium transfer line between the heat exchanger and missile as well as the airborne helium storage bottles within the missile.

The above mentioned functions are accomplished by the use of one or more of the following units:

1. Gaseous helium storage tanks (two)
2. Pressure distribution unit (PDU)
3. Liquid nitrogen/helium heat exchanger
4. Liquid nitrogen storage tank
5. Pressure control unit (PCU)
6. Helium charge unit (HCU)
7. Mobile dynamic checkout unit (MDU) is also provided as a means of checking these various systems.

The output of the inflight helium tanks is routed to the PDU wherein the following is accomplished:

1. 8 LBS/MIN at 6000 PSIG is routed through the PDU to the PCU for subsequence pressure regulation and flow to the missile fuel and oxidizer tanks during countdown (HNS line).

2. 25 LBS/MIN at 3000 PSIG is routed through the PDU to the LN_2/He heat exchanger where it is cooled and routed to the missile airborne helium bottles (HRS line).

3. 6 LBS/MIN at 6000 PSIG is routed through the PDU to the PCU in parallel with item (1) and is used for emergency purposes only (HES line).

4. 9 LBS/MIN of gaseous nitrogen at 6000 PSIG from the nitrogen ground pressurization tank is routed through the PDU to the PCU (HNS line) for subsequent pressure regulation and flow to the missile fuel and oxidizer tanks during standby.

GASEOUS NITROGEN SUBSYSTEM

Gaseous nitrogen is stored in the missile silo (8th level) for LOX transfer, LN2 transfer, and fuel tank pressurization. There are 1250 cubic feet at 4000 PSIG for LOX transfer, 500 cubic feet at 4000 PSIG for LN2 transfer, and 4 cubic feet at 4000 PSIG for fuel leveling tank pressurization.

The GN2 is routed, monitored, and controlled by the pressurization prefab panel during all resupply operations.

Gaseous Nitrogen Subsystem Components

GN_2 Storage Vessels

A bank of ~~seven~~ THREE bottles of GN_2 makes up the main gaseous nitrogen storage facility. ~~Five~~ TWO bottles are manifolded together and used for LOX transfer. ~~Two~~ ONE ~~bottles~~ bottle ~~are manifolded together and~~ IS used for liquid nitrogen transfer and in the nitrogen control unit. The additional smaller bottle that requires recharging is located in the fuel-leveling prefab (4000 PSIG).

Pressurization Prefab

The pressurization prefab is used to filter and control the flow of gaseous nitrogen for resupplying the gaseous nitrogen storage vessels. It is also used to control the pressure in the ullage of the LOX storage and topping tanks.

The pressurization prefab is provided with a graphic control panel for performing manual gaseous nitrogen resupply operations.

Two resupply lines are routed from fill connections at grade level. Shutoff valves are provided to program flow to the various banks of storage vessels. Also provided are shutoff valves between the vessels and the users and a valve to allow the vessels to be blown down through the main liquid oxygen vent line.

The pressurization prefab contains the following valves for controlling the ullage pressure in the LOX storage tank:

1. Vent valve N-5

2. Relief valves SV-6A and SV-6B

3. Pressurizing valves N-1, N-2 and N-3

The pressurization prefab contains the following valves for controlling the ullage pressure in the LOX topping tank:

1. Vent valve N-4

2. Relief valve SV-5

3. Pressurizing valve N-50

LAUNCH CONTROL AND CHECKOUT OF FUEL, LOX, LN_2/HE SYSTEMS

The launch control system uses a simplified operational technique called the "unitary concept". Unitary concept launch control equipment makes it possible for a single operator (the Launch Control Officer) to conduct the countdown and to launch the missile.

A launch control console presents a summary display to indicate the standby status of the missile and/or the progress of countdown. A malfunction of any subsystem will immediately identify itself on the launch control console, either in the standby patch of the countdown patch or the power and sensing ~~path~~ PATCH (malfunction patch).

Fuel tanking and leveling are completed prior to countdown; therefore, the fuel transfer system plays a small part in launch control operations. The only operation that is sequenced during countdown in the fuel subsystem is fuel line drainage. It is important to note, however, that the proper fuel level must be attained before countdown can be completed.

Launch Control Console

The standby status patch for LOX and fuel is located in the middle sections of the launch control console panel. This patch consists of a group of five green/red indicators which display the status of all subsystems during both standby and countdown. During standby, these indicators reflect the readiness for countdown state of their respective subsystems. During countdown, each indicator displays the status of its respective system at all times by each system modifying its inputs to the indicators if any included condition monitored during standby is modified during countdown. This means that each subsystem provides an input which represents its best information as to its overall condition at any time, whether in standby, countdown, commit or abort.

A subsystem, such as fuel, not being in its proper operating condition during any of the above mentioned phases will cause its indicator to illuminate red and also sound an audible alarm. A red indication reflects either a subsystem malfunction, or the possibility that the subsystem is in its local-control mode, or power has been removed from the subsystem. In as much as the status of several subsystems is reflected in an indicator, the launch crew must go to the logic units to observe the system in standby indicators of the subsystems. These indicators are located in the upper left hand corner of the first panel of the logic unit subsystems. They will be illuminated green if their subsystem is operating properly. If this is not the case, the indicator will not be illuminated. Therefore, the launch crew can immediately observe which system is at fault.

The logic unit may be observed only if the entire system is reverted back to the standby status. The logic unit for propellant transfer is located in the silo and no one normally is permitted to enter the silo during countdown.

A red indication during standby will prevent the initiation of the countdown as all indicators in this patch must been green to start the countdown.

It should be noted that a red illumination of an indicator in the malfunction patch will cause a standby status indicator to illuminate red.

The following presents the logic conditions that will cause the standby status indicators to illuminate green.

The LOX and FUEL indicator on the standby status patch reflects the status of the LOX, fuel and propellant level control (PLCU) subsystems. This indicator is green for the following conditions, otherwise it is red.

1. Logic unit standby bus energized, and

2. LOCAL/REMOTE switch in REMOTE position, and

3. Fuel airborne fill and drain valve closed, or

4. Start countdown command present

The malfunction patch is at the middle of the left edge of the panel. This is a group of thirteen amber/red indicators used to supply additional fault location. The faults indicated are either a critical NO/GO function that demands immediate correction because of a hazard to the site, or a fault of a marginal nature which, though it could have an effect on the site or weapon mission, does not represent an immediate danger or a mandatory NO-GO condition. The amber color in this patch is used to indicate a marginal fault, whereas the red is used for a NO-GO fault. Any of the malfunction lights turning red also cause a status indicator to the right in the status patch to turn red. In this manner, the malfunction lights do provide some detail of the summary status displays; however, in no case do they provide the full detail. The malfunction indicators are normally off unless a fault exists.

EXCEPT RESPONDER MODE AMBER

The illumination of any indicator in this section (whether amber or red) will also cause an audible alarm to sound. The alarm may be silenced by the ALARM RESET button on the console, but the indicator will remain illuminated until the malfunction has been corrected. The following presents the logic conditions that will cause the malfunction indicators to illuminate amber or red.

The FUEL LEVEL indicator in the malfunction patch displays the level of fuel within the missile. The indicator will illuminate red if either fuel "low" probes indicate dry, or both the fuel "high" probes indicate wet. According to the design of the PLCU, the unit is not activated until the countdown is started. Then, after a 2 second warmup period, a 3 second check is made of the fuel level. If a malfunction occurs during this period, the signal is locked up. Only 3 seconds are allowed for checking the fuel level.

Two fuel sensors are provided at both the high and low fuel levels to improve reliability. Inasmuch as a sensor failure produces a "wet" indication, both sensors must indicate "wet" (or failed) to actuate the FUEL LEVEL indicator.

The countdown status patch contains a group of amber/green indicators which depict the status of subsystem processes as they are activated and completed during the countdown sequence. An amber indication signifies the start of a subsystem process (such as valves properly positioned in LOX system for chilldown process), and a green indication signifies the completion of a process.

The following details the logic conditions that cause illumination of the FUEL and LOX READY indicator in the countdown status patch.

The LOX and FUEL READY indicator will illuminate green providing the following conditions are met.

1. Fuel level <u>not</u> too high, and

2. Fuel level <u>not</u> too low

a mandatory NO-GO condition. The amber color in this patch is used to indicate a marginal fault, whereas the red is used for a NO-GO fault. Any of the malfunction lights turning red also cause a status indicator to the right in the status patch to turn red. In this manner, the malfunction lights do provide some detail of the summary status displays; however, in no case do they provide the full detail. The malfunction indicators are normally off unless a fault exists.

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The following details the logic conditions that cause illumination of the FUEL and LOX READY indicator in the countdown status patch.

The LOX and FUEL READY indicator will illuminate green providing the following conditions are met.

1. Fuel level <u>not</u> too high, and

2. Fuel level <u>not</u> too low

3. LOX level greater than 99.25%

4. Abort signal not present

5. A 40 SEC TDDU timer, (commit delay timer) has run out.

The indicator must illuminate green before commit sequence can be started.

Launch Control of Fuel Subsystem

Standby Conditions

1. Fuel tanking panel number 1 in "REMOTE".

2. Propellant level panel number 2 in "REMOTE".

3. System power switch "ON" Fuel tanking panel number 1.

4. System power switch "ON" Propellant level panel number 2.

5. Airborne fill and drain valve closed.

Countdown Functions

The only automatic function by the fuel system during countdown is to drain the fuel fill line to the prefab (FFP) and the fuel fill to the missile (FFM). This is accomplished by opening F-2, NF-2, and NF-4, permitting the fuel to drain from lines FFP and FFM into the fuel leveling tank. At the same time the propellant level control unit (PLCU) will monitor the missile tank fuel level, (2 second warm-up with a 3-second monitor period for 5 seconds total), for a level between 99.4 percent and 100.4 percent. After this 5 second period the fuel portion of the PLCU is disabled.

Commit Sequence

At commit start valves F-2, F-3, NF-2, and NF-4 are closed, these valves not closing will not stop or enganger the countdown.

Start Abort

The abort signal will cause valves F-2, F-3, NF-2 and NF-4 to open.

Launch Control of LOX Subsystem

System Operation

At the start of countdown, the LOX fill operation begins. The LOX system operates through the following sequence automatically.

During a normal countdown (countdown start to missile ready for commit), system operation is controlled by the launch control logic units. While the missile is still in the silo and is being filled with LOX, any LOX which boils off is vented out of the silo by a vent mechanism (Figure 7)which draws the gases out of the missile shaft.

The gaseous oxygen vent mechanism consists of a length of ducting bent through a 90° angle. It is part rigid, and part flexible. It pivots about an axis which passes through the duct at the right angle bend. Also attached to this assembly are limit switches, brakes and counterweight system.

Prior to launcher platform rise, the missile boiloff valve is closed. Within the first two feet of rise the pipe with its end against the boiloff valve swings to a vertical position to clear missile. The gaseous-oxygen vent mechanism assembly is unique to the silo and is located on the second level of the crib structure.

Prior to countdown the system is in standby.

Standby is established by monitoring of:

1. L-7 main storage fill valve closed
2. Not on local power
3. N-60 main line drain pressure valves closed
4. ~~N-5 LOX storage tank vent open~~
5. L-16 missile drain valve closed
6. L-1 LOX fine load valve closed
7. L-2 LOX rapid load valve closed
8. N-4 topping vent valve open
9. System power on

1. At countdown start, missile fuel tank flight pressurization is initiated.

2. When the fuel tank pressure has reached 53 PSI and the missile LOX tank pressure is less than 17 PSI (boiloff valve open), the LOX logic unit receives a signal, "Pneumatics Ready for LOX Childown".

3. This signal causes the following to take place: (Figure 4)

   a. Storage tank vent valve, N-5, is closed.

   b. Topping tank vent valve, N4, is closed.

   c. Airborne fill and drain valve is opened.

   d. Fine load valve, L-1, is opened.

   AFTER D

   e. Childown timer (~~20~~ 40-SEC TDPU) is started.

   f. Rapid load chilldown timer, ~~10~~ 1 SEC TDPU, is started.

   g. Rapid load valve, L-2, is opened following the 1-second delay.

   h. Fine topping valve, L-60, is opened along with the rapid load valve. ~~At this time,~~ with missile tank pressures normal, storage tank vent closed, and ~~60~~ 40-second chilldown timer not complete, the LOX LINE FILLED indicator on the launch console illuminates amber.

4. When storage tank vent is closed pressurization valve, N-1, in pressurization prefab is opened and storage tank pressure is controlled to 18-25 PSI. When topping tank vent is closed pressurization valve, N-50, in pressurization prefab is opened and topping tank pressure is controlled to 160 PSI. Liquid oxygen now circulates up through the lines and into missile tank.

5. When the ~~60~~ 40-second chilldown timer is complete:

   a. Pressurization valve, N-2, is opened and storage tank pressure is controlled at 135 PSI.

   b. LOX LINE FILLED indicator turns green.

c. RAPID LOX LOAD indicator illuminates amber.

6. When the missile tank 95% sensor is reached:

   a. Rapid load valve, L-2, is closed.

   b. Rapid topping valve, L-50, is opened.

   c. RAPID LOX LOAD indicator turns green.

   d. FINE LOX LOAD indicator illuminates amber.

7. When the 99% sensor is reached:

   a. Fine load valve, L-1, is closed.

   b. Pressurization valves, N-1 and N-2 are closed.

   c. Airborne fill and drain valve is closed.

   d. Drain valve, L-16, is opened.

   e. Line drain pressurization valve, N-60, is opened. 135 PSI of nitrogen enters the line .

   f. Line drain timer, ~~50~~ 90 SEC. TDPU, is started.

   g. Commit delay timer, ~~40~~ 60 SEC. TDPU is started.

   h. FINE LOX LOAD indicator turns green.

8. When line drain timer is complete:

   a. Drain valve, L-16, is closed.

   b. Line drain pressurization valve, N-60, is closed.

   c. Line vent valve, N-80, is opened.

   d. Line vent timer, 40-SEC. TDPU, is started.

   e. Storage tank vent valve, N-5, is opened.

9. When line vent timer is complete: the line vent valve, N-80, is closed.

10. The topping operation has continued to fill the missile to 99.25%. When this sensor is reached:

a. Rapid topping valve, L-50, is closed.

b. Stop topping timer, 15 SEC. TDPU, is started.

11. When the stop topping timer is complete:

a. Fine topping valve, L-60, is closed.

b. The 6 GPM orifice continues to maintain topping line chill. Excess LOX flow goes through check valve, L-52, into LN_2 drain to LN_2 evaporator tank on Level 8.

12. The LOX system is ready for commit when:

a. Commit delay timer, 60 ~~40~~ SEC. TDPU, has run out.

b. Missile 99.25% sensor is wet. At this time the LOX AND FUEL READY indicator illuminates green. It has no amber color.

13. If the missile is held at this time and not committed, the liquid oxygen in the tank will boil away until the 99.25% sensor is uncovered. When the sensor is dry the fine topping valve, L-60, is opened. When the sensor is wet again the stop topping timer, 15 SEC. TDPU, is started and when run out, L-60 is closed again. This cycle is repeated throughout the hold, up to one hour.

Commit

1. When the commit sequence is started:

a. Fine topping valve, L-60, is opened if closed.

b. Rapid topping valve, L-50, is opened.

c. A not 100% LOX topping timer, 15 ~~50~~ SEC. TDPU, is started. (100% sensor failure timer).

d. A missile lift commit delay timer, 70 ~~54~~ SEC. TDPU, is started.

2. When the 100% sensor is reached and the 100% sensor failure timer has run out:

a. Fine topping valve, L-60, is closed.

b. Rapid topping valve, L-50, is closed.

c. Topping tank pressurization valve, N-50, is closed.

d. Topping tank vent valve, N-4, is opened.

3. The LOX COMMIT indicator illuminates amber almost immediately after the commit sequence is started. The conditions are:

a. Start LOX commit relay energized.

b. Missile lift commit delay timer not run out.

4. The LOX COMMIT indicator illuminates green when:

a. Missile lift commit delay timer has run out.

b. Commit internal relay energized.

Abort

1. Abort signal is received from countdown sequencer.

2. Topping and storage tank vents are opened.

3. A drain signal is generated when the LOX tank is ~~less than 8 PSI.~~ NOT LESS THAN 1.65 PSI & L/P IS DOWN AND LOCKED AND ABORT EX GREEN

4. All loading valves close.

5. The airborne fill and drain valve opens.

6. When storage tank pressure reaches 25 PSI the drain valve is opened controlled by a ~~1500 second~~ 45 MIN timer.

7. At expiration of timer, the drain valve is closed and the airborne fill and drain valve is closed.

8. System is returned to standby.

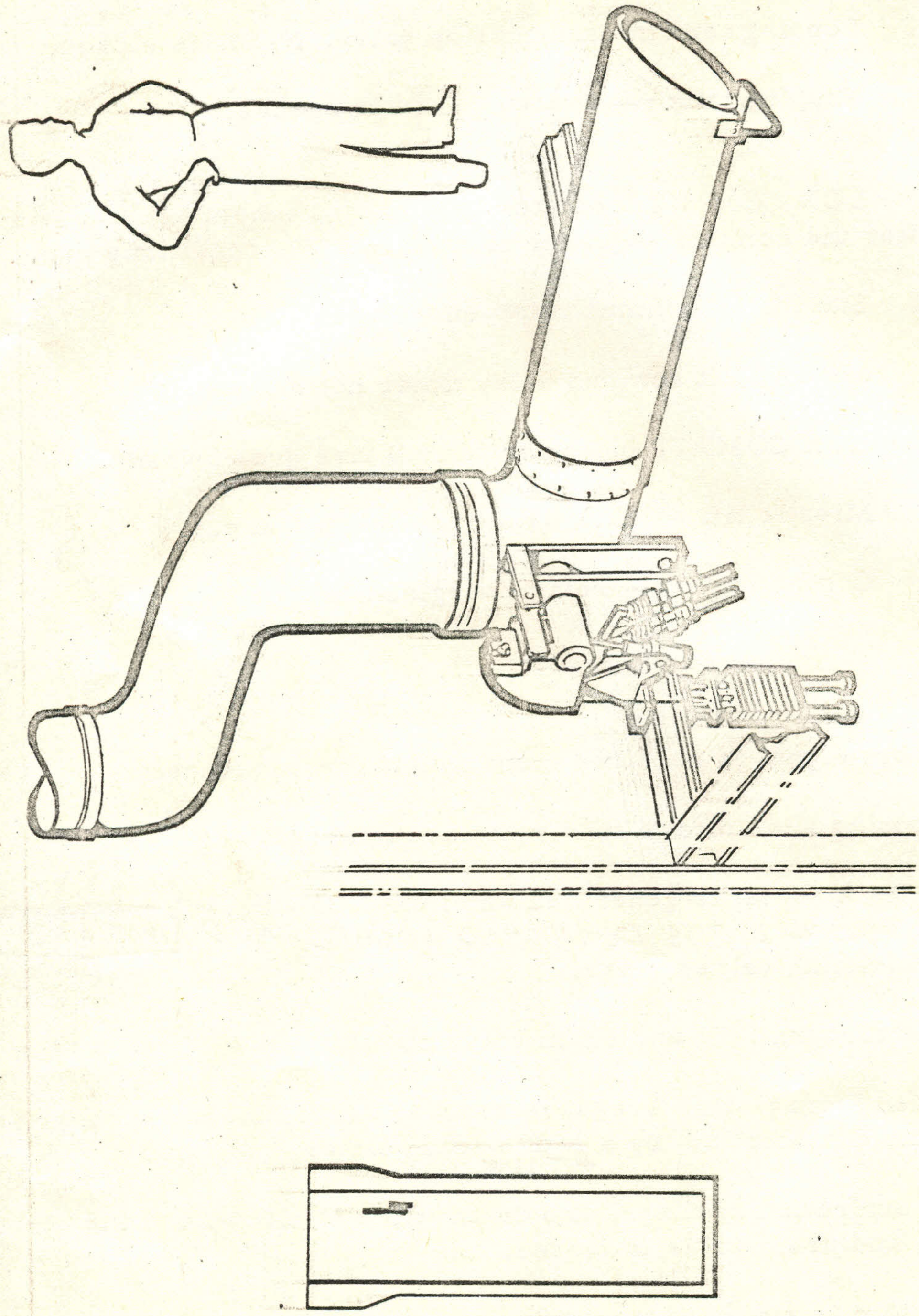

Figure 7 Oxygen Boiloff Vent

LAUNCH CONTROL OF LN_2/He SUBSYSTEM

Standby Conditions (Figure 6)

In standby, GN_2 is furnished to the pressurization control unit (PCU) for pressurization of the airborne LOX and fuel tanks from the tank designated ground pressurization. Helium is supplied from the helium bottle number 2 (normally) to the PCU for an emergency supply. Helium bottle number 1 in standby for helium load to inflight bottles. Helium supplies number 1 and number 2 must be above 4000 PSI. The automatic valves of the LN_2 and He systems must be properly set.

Countdown Functions

1. When the start countdown button is depressed the liquid nitrogen relay is energized. At this time:

   a. Liquid nitrogen storage tank vent valve, 201, on the liquid nitrogen prefab is closed.

   b. LN_2 tank pressurization valve 39 is opened and tank pressure is controlled at 100 PSI.

   c. LN2 transfer valves 213, 214, and 215 in the liquid nitrogen prefab are opened. These are medium load, rapid load, and fine load valves, respectively.

   d. Inflight helium cylinder Number 1 is selected and a normally open valve in the pressurization distribution unit allows helium to fill the ambient missile sphere.

   e. A liquid nitrogen rapid load timer, ~~360~~ 180 SEC. TDDO, is started.

   f. A LN_2 medium load timer, 390 SEC. TDDO, is started.

   g. A helium load timer, 120 SEC. TDPU is started.

   The LN_2 LOAD indicator illuminates amber at this time.

2. When the helium load 120 SEC. TDPU is completed valve 26 in the pressurization distribution unit is opened to allow helium flow through the LN_2 heat exchanger to the missile spheres. This flow is modulated by valve 11 to control flow at 25 LBS/MIN @ 3000 PSI.

At this time the HE LOAD indicator illuminates amber.

3. When the rapid load ~~360~~ 180 SEC. TDDO is complete the LN_2 Load indicator turns green. The rapid load valve, 214 is then closed.

4. When the medium load 390 SEC. TDDO is complete the medium load valve 213 is closed.

5. When the helium pressure in the inflight spheres reaches 3000 $\pm$ 50 PSI valve 11 is closed. At this time HE LOAD indicator turns green.

Commit Internal

At commit internal all nitrogen and helium supplied, with the exception of the helium supplied to the PCU for emergency use and GN_2 supplied to the hydraulic reservoir, are stopped.

Abort External

The inflight helium bottles are vented through the HCU. The normal helium supply is returned to the PCU. When the IFH bottles are vented, the countdown signal is removed and the system is returned to standby.

Vent Ambient Helium Bottle

The engine control (ambient control) bottle is vented through the VIA PDU HCU THROUGH via the helium heat exchanger, after a 2 hour time delay.

CHECKOUT

The subsystem checkout is performed by the mobile checkout and maintenance team (MOCAM) and is done by the Liquid Fuel System Specialist Technician (LFSST) under the direction of the Ballistic Missile Analyst Technician (BMAT). Once each month the logic unit panels are put in local operation. The checks consist of manually operating each of the automatic valves from the panels and a man observing that it strokes within the proper time limit. This check is called a "dry check". Once every six months, just after recycle, the transfer lines are filled with fluids and visually checked for propellant systems leaks. The gas lines are soap checked for nitrogen leaks. This is known as a "wet check". The systems are then returned to the standby conditions.

To check out the launch control console and logic units, the launch signal responders are used by the launch crew. This will be performed under the direction of the BMAT. This check will be performed as often as required to maintain the launch control equipment.

SAFETY PRECAUTIONS

General

Avoid direct contact with storage tanks. Do not lean on or otherwise contact storage tanks with hands or any part of the body. Never allow tools or other objects to strike the tanks.

Observe NO SMOKING rules. Smoke only in designated areas. In storage areas smoking is strictly prohibited at all times. Do not carry or strike matches anywhere.

Petroleum base liquids will burn or explode violently in the presence of liquid or gaseous oxygen. Approved petroleum base liquids having a low flash point; such as RP-1 fuel, hydraulic oil, and lubricants.

Most missile systems are interconnected or interrelated. An unscheduled operation of any one system can create hazardous conditions for another system. Always coordinate all activities.

Inspect all fuel storage and fuel transfer areas for general cleanliness and presence of unnecessary tools or equipment.

Fuel (RP-1)

RP-1 Fuel is toxic if inhaled, and can be fatal if taken internally. It is insensitive to shock but will explode when heated or vaporized. Mixed with liquid oxygen or other strong oxidizer, the residue, or gel will detonate on impact. Maintain adequate ventilation in any area where RP-1 is being handled. Wear protective clothing as may be required to prevent the fuel from contacting the skin.

Liquid Oxygen

Liquid oxygen is a pale blue, clear liquid with a temperature of -297°F. It is not toxic, but will cause burning of tissue on contact with the skin. Liquid oxygen is a fire hazard because it supports and accelerates combustion. Liquid oxygen is stable against detonation and mechanical shock, but becomes explosive when contaminated with organic materials. It reacts violently with grease and oil. When combined with RP fuels or alcohol, it forms a gel which can be exploded by shock or readily set off by a spark. The explosive potential of well-mixed gel is nearly twice that of nitroglycerine.

If quantities of gel are formed near you, report it to your safety representative and evacuate the area until it is declared safe.

Handle "thermos bottle" flasks of liquid oxygen with care; the vacuum insulating walls are easily broken. Do not shake flasks. The upper inside of the flask is warm compared to the portion of the flask in contact with the liquid oxygen, and any liquid oxygen will splatter violently.

When pouring liquid oxygen from one container to another, take extreme care to avoid contact between the two vessels as the inner container lip can be easily broken. The vapor visible when liquid oxygen is exposed to air is condensed moisture, not gaseous oxygen.

When piping or pumping liquid oxygen from one container to another, clean all vessels or piping carefully before use. Take precautions to prevent contact between liquid oxygen and organic material.

Do not restrain liquid oxygen piping from axial movement; allow for expansion and contraction. Liquid oxygen cannot be contained in a closed system; there must be pressure relief valves in the lines. The expansion of liquid oxygen into gaseous oxygen causes sufficient pressure to blow up an entire system. Do not touch liquid oxygen transfer lines or equipment during, or immediately after, transfer. Skin will stick to the equipment, and flesh will become badly burned or torn.

Do not use petroleum lubricant or organic packing materials as they can cause explosion or fire danger.

Clean all liquid oxygen transfer equipment with trichlor to remove grease, oil, and organic material. Purge pipelines and valves with dry, oil-free nitrogen before using them or making repairs.

Liquid oxygen is stored in vented, stainless steel contains protected with burst-diaphragm devices and relief valves. Interior insulation usually consists of a vacuum jacket filled with a suitable powdered insulation. Handle the containers with great care to avoid damage to the vacuum bottle. The containers will continuously vent gaseous oxygen into the storage area. As oxygen is heavier than air and tends to accumulate in pockets, good ventilation is necessary.

Do not drain or blow liquid oxygen into closed areas as this will create an extremely serious explosion hazards.

Vented gases must be directed away from personnel or flammable materials. Do not vent liquid oxygen into asphalt, macadam, or other organic surfacing material. These substances become potentially explosive in contact with liquid oxygen. The storage area must be cool, well ventilated, and away from fire hazard, open flame, or spark source. Never store liquid oxygen in the same area with fuels such as alcohol, RP, oils, or any other hydrocarbons. Liquid oxygen should be stored alone or with other oxidizers. Storage in the same area with liquid nitrogen, gaseous oxygen is permissible.

All personnel who work with liquid oxygen must wear the following protective items to prevent contact with the skin in case of spillage; loose asbestos gloves, a face shield, a loose plastic apron, and rubber boots. Care should be taken to prevent contamination of the clothing. Any clothing that is splashed or soaked with liquid oxygen should be removed and aired immediately as it will remain dangerously flammable for about two hours. Such clothing burns so fiercely when ignited that it is impossible to prevent serious burns. Before entering liquid oxygen areas be sure shoes are free from grease or metal filings. If liquid oxygen contacts the skin or eyes, it is likely to freeze these tissues and result in blindness or permanent disfigurement. Wash affected areas immediately with large quantities of water in order to remove the liquid oxygen and to heat the skin. Safety showers are provided for this purpose. Fires in which liquid oxygen is involved cannot be smothered as liquid oxygen furnishes the required oxygen to support combustion. Water (solid stream or fog), chemical (powder) foam, carbon dioxide, and inert gas are suitable fire fighting agents for liquid oxygen fires.

Helium

Helium is an odorless, tasteless, colorless gas. It is chemically inert and is not combustible, explosive, or corrosive. As with GN_2, the only possible hazards connected with the use of helium are those caused by the high pressures used and the shortage of breathing oxygen because of extremely high concentrations of gas in the air.

Use the same precautions as are observed in the handling of compressed gases.

Liquid Nitrogen

Liquid nitrogen is clear, colorless, and cooler than liquid oxygen. It has a temperature of -320°F and is chemically inactive. It presents no hazards other than those caused by its low temperature or the shortage of breathing oxygen because of extremely high concentrations of nitrogen in the air. Take the same precautions with liquid nitrogen as with liquid oxygen to prevent "burn" and damage to skin and eyes.

Do not expose quantities of liquid nitrogen to the air for any length of time. Exposure of liquid nitrogen to air will condense the oxygen in the air to form liquid oxygen on the surface of the liquid nitrogen and on the outside of the container. Liquid oxygen is present if the surface of the liquid nitrogen is bluish in color. If liquid oxygen has formed on the liquid nitrogen, the liquid nitrogen must be handled with all the precautions required for liquid oxygen.

Take the same precautions for the handling and transfer of liquid nitrogen as for liquid oxygen. Always treat equipment used alternately for liquid nitrogen and for liquid oxygen as if it contained liquid oxygen.

Containers for storing liquid nitrogen must conform to the standards established for liquid oxygen containers. Liquid nitrogen has an extremely high vapor pressure. Be sure that liquid nitrogen storage containers are vented to atmosphere at all times. The constant boiloff, if not dissipated, would quickly build up tremendous pressures and rupture the container.

To prevent liquid nitrogen from contacting the skin or eyes in case of spillage, wear loose asbestos gloves and face shields. If liquid nitrogen contacts your body, immediately flood the affected area with quantities of water to remove the cold liquid and to heat the area. Safety showers are provided for this purpose.

If liquid nitrogen is spilled, the primary hazard is that the material contacted may be frozen. No cleanup procedure is necessary; most of the liquid nitrogen will boiloff almost immediately, and the residue is not hazardous.

Safety Rules for High Pressure Gases

1. Do not disconnect internal tubing or electrical wiring, or attempt to replace components until the nitrogen supply has been cut off and the system bled, the control box is drained, and the electrical current is off. If the equipment is not depressurized, escaping gas can injure personnel.

2. All high pressure air hoses must be sand-bagged at intervals not to exceed 6 feet.

3. All hose fittings must be inspected for tightness before and after use. When caps are removed from hose sections, inspect hose interior.

4. All new hose must be cleaned prior to its use, and hydrostated to a pressure of 1 1/2 times the working pressure.

5. Do not break hose connections without first bleeding off all pressure.

6. All hose not in use should be plugged and stored in a designated area.

7. All hose in use shall be replaced if condition of the hose is doubtful.

8. Do not tighten hose or line connections if the system or hose is under pressure.

9. Do not use lines, fittings or other high pressure equipment at pressures exceeding the maximum work pressure.

10. Only qualified personnel should install stainless steel lines.

11. All new stainless steel lines must be cleaned and hydrostated before use.

12. All high pressure air receivers should have identification plates, stating date of manufacture, when last tested, and maximum working pressure.

13. All receivers should have shutoff and safety relief provisions (valves). Shutoff valves should not be located adjacent to receivers.

14. A DANGER sign should be displayed in all areas containing high pressure gases.

15. High pressure bottled gas must be plainly marked.

16. Do not operate high pressure gas equipment unless two or more operators are present.

17. Operator will be responsible for keeping all gases free from dirt, oil and other contaminants.

18. Use only approved lubricants for high pressure gas compressors.

19. Learn the markings and threads (right or left hand thread) on all gas cylinders and bottles.

20. Always know the working pressure of any fittings, valves, gages, etc., in the system.

21. All high pressure systems should have at least a gage, hand valve, and a relief valve.

22. All gages should be run through a drying system before being used.

23. Compressed gas cylinders should be clearly labeled.

24. Regulators and pressure gages must be used only with gages for which they are designed and intended.

25. All high pressure gas cylinders are provided with "rupture discs" as a safety device. Do not attempt to change or replace these discs while pressure remains in container.

SUMMARY

The Atlas Weapon System is so designed that a single operator may launch the missile. This is accomplished with the use of the launch control console (LCC), which will show the operator the status before and during countdown. It will also give indication of progression through out the countdown.

Because fuel is stored aboard the missile, there is only one thing that must be done to the fuel system at start of countdown, the missile fuel tank level is monitored. If it is between 99.6 percent and 100.4 percent from 3 to 5 seconds after start of countdown, the LOX system will be sequenced to begin LOX load. At the same time the LN_2/He system starts to load LN_2 to chill the shrouded spheres, then after a short delay He load will be started.

These actions plus others must be completed before the "Ready for Commit" indicator on the LCC will illuminate green. During propellant transfer, GN_2 is used as the pressurization medium to transfer propellants to the missile.

When commit is started, the LOX system tops the missile LOX tank between 99.25 percent and 100 percent full and LN_2 transfer stops. If there has been any drop of pressure in the He spheres, the helium charge unit will resupply and maintain them until the missile is away.

The major checkout and maintenance will be performed by the MOCAM crew under the direction of the BMAT The daily inspections and minor checkout is performed by the launch crew under the direction of the BMAT.

QUESTIONS

1. What is meant by the standby condition for the fuel subsystem?

2. What automatic function is performed in the fuel system during countdown?

3. What conditions are necessary in the fuel system before LOX loading sequence can start?

4. When does the gaseous oxygen vent mechanism swing away from the missile?

5. What is the maximum time topping will last during the commit sequence?

6. What is the desired pressure for the helium in the missile spheres?

7. How long does it take to load LN_2 aboard the missile?

8. What is GN_2 used for during countdown?

9. How often is a "Wet Check" performed?

10. What is the purpose of topping?

11. What is the medium used to transfer LOX?

12. How often will the storage and topping tanks be resupplied?

13. What are the five major components of the LOX system?

a.

b.

c.

d.

e.

14. What is the purpose of the heat exchanger?

15. Why is the liquid nitrogen put on board the missile?

16. What is the main function of the liquid nitrogen prefab?

17. What is the advantage of having a vacuum chamber between the two concentric tanks on the liquid nitrogen storage tank?

18. What is the primary purpose of the fuel leveling tank?

19. What are the dangers of handling RP-1 fuel?

20. What is the purpose of the fuel catchment tank?

21. How is the RP-1 fuel kept free from contamination?

22. What is the GN_2 pressure used for LOX transfer?

23. What are the functions of the pressurization prefab control panel?

24. How is GN_2 used to transfer LOX and LN_2?

25. At what pressure is GN_2 normally stored in the silo?