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AD856663

GEMINI B OXYGEN SAFETY STUDY

VOLUME VII

SIMPLIFIED TWO GAS SYSTEM

REPORT F415

COPY NO. 1

MCDONNELL ASTRONAUTICS COMPANY
DIVISION OF MCDONNELL DOUGLAS CORPORATION
LAMBERT - ST. LOUIS MUNICIPAL AIRPORT, BOX 516, ST. LOUIS, MO. 63166

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1. SUMMARY

A simplified two-gas system for the Gemini B is defined which provides a mixed gas atmosphere in the cabin and requires no diluent gas make up on board the spacecraft. The system approach is aimed primarily at the elimination of the hazard during ground operations when oxygen pressures are in the 15 to 20 psi range with the present system. Because of the short duration of the crew occupancy after lift-off and prior to crew transfer to the Laboratory, the system provides a mixed gas atmosphere as long as cabin repressurization is not required.

The mixed gas system employs helium as the diluent, requires limited modification to the existing Environmental Control System and uses present ground gas supplies. Modifications to ground support equipment consist primarily of the addition of a helium/oxygen flow control panel and helium and oxygen umbilicals, and modifications of the check-out console in the Launch Control Center.

During ground operations helium and oxygen are delivered to the cabin through umbilicals and a 3:1 partial pressure ratio of helium to oxygen is maintained. This is accomplished by introducing helium directly into the cabin at a flow rate of .079 pounds/minute while the oxygen is introduced into the ECS system in parallel with the on-board supply. The oxygen is fed into the suit loop at a constant rate of .218 pounds/minute, circulated through the suit circuit and vented into the cabin through the existing demand regulator. The cabin recirculation valve is closed, suit vents are closed and the crewmen breathe 100% oxygen. The mixed gas in the cabin is vented overboard through the cabin outflow valve.

At T-60 seconds ground supplied oxygen and helium are cut off, the cabin outflow valve is closed, and the mixed gas is trapped in the cabin. On-board oxygen continues to feed the suit circuit at the normal high rate flow. During ascent the cabin pressure is reduced through the normal cabin pressure relief valve.

On attaining orbit, the crew switches from high rate flow of O_2 to normal operations. At this time, the partial pressure oxygen is approximately 3.5 psi and total cabin pressure is approximately 5.8 psi, and the recirculation valve may be opened and the suit vented to the cabin. From this time on until preparation for transfer to the Laboratory, the crew breathes the mixed gas. At the end of the mission, the cabin is repressurized with the mixed gas from the Laboratory instead of 100% O_2 and the Gemini B system operation is the same as that prior to transfer to the Laboratory.

AVE system changes are limited to redesign of coolant umbilical disconnect, addition of helium and oxygen lines, redundant check valves, cabin filter for the helium line, guillotines to sever the helium line and partial pressure oxygen sensors.

AGE changes consist of a new H_e/O_2 Flow Control Panel, H_e and O_2 umbilical hoses, and a remote control and a monitoring panel added to the ECS checkout panel in the Launch Control Center.

Supporting technical analyses are presented including bio-medical considerations, gas flow rates, atmosphere changes during flight, monitoring requirements, and reliability evaluation. Additional testing required is identified.

It is recommended that the Gemini B baseline be changed to incorporate a simplified dual gas system similar to the system defined in this volume.

2. INTRODUCTION

In view of the recent accidents related to spacecraft oxygen systems, a re-evaluation of the Gemini B baseline for the Manned Orbiting Laboratory Program was undertaken to identify potential oxygen hazards and indicate what can be done to minimize these hazards. The study was conducted under CCN No. 1/P001 to Contract F04695-67-C-0023.

Included was a review of procedural/operational considerations, materials, and NASA Gemini data/experience, and identification of possible testing and desig changes. Primary emphasis was placed on changes which reduce or eliminate the hazards associated with manned ground operations, but also included consideration of the entire flight regime. The study resulted in recommendations which, when implemented, should provide increased safety without major program impact.

The results of the study are presented in a nine-volume report. The volumes are:

Volume I - Summary and Recommendations
Volume II - NASA Gemini Environmental Control System Data
Volume III - Materials Summary
Volume IV - Equipment Review
Volume V - Cabin Egress
Volume VI - Procedures - Ground Testing and Flight
Volume VII - Simplified Two-Gas System
Volume VIII - In-Flight Emergency Operations and Procedures
Volume IX - Testing

This volume defines a simplified two-gas system for the Gemini B which provides a mixed-gas atmosphere in the cabin in place of the existing pure oxygen atmosphere.

2. (Continued)

An approach is described which is based on a minimum modification of the Gemini B Environmental Control System; it does not require on-board supply of diluent gas; and it provides 100% oxygen to the crewmen through prelaunch and ascent phases of the mission. The impact of the mixed gas system on Gemini B AVE, AGE, and pad and flight operations are identified. Also included are discussions of biomedical considerations, monitoring and control requirements and a description of the testing required resulting from changes in the Gemini B baseline configuration.

3. SELECTED APPROACH

3.1 System Concept - The basis of the mixed gas system is to provide helium and oxygen to the cabin during all ground operations and to maintain a 3:1 partial pressure ratio of helium to oxygen. The crew members are breathing a 100% oxygen atmosphere by virtue of the fact that they are in unvented pressure suits and the cabin recirculation valve closed.

Helium has tentatively been selected as the diluent gas because it has already been selected as the diluent for the Laboratory mixed gas system. Since the Gemini B and Laboratory atmospheres mix during crew transfer operations it is undersirable to introduce a diluent different from that already being used in the Laboratory.

During ground operations, the existing cabin outflow (depressurization) valve is in the open position. Helium is fed directly into the cabin from a ground supply at a constant flow rate of .079 pounds/minute. Oxygen is fed into the suit loop at a rate of .218 pounds/minute, circulated through the suit circuit and vented into the cabin through the existing suit demand regulator at a rate of .215 pounds/minute (.003 pounds/minute metabolic usage).

During this time, the primary on-board oxygen supply is operational but is not delivering oxygen due to the higher pressure of the ground supply. If the ground supply pressure drops, oxygen will flow into the suit loop from the on-board supply.

3. (Continued)

Prior to launch, the mixed gas is trapped in the cabin by closing the cabin outflow valve. The ground supplied helium and oxygen are shut off but oxygen continues to feed to the suit circuit from the on-board supply at high rate. This prevents an excessive drop in oxygen partial pressure in the cabin during ascent as the cabin pressure is reduced through the normal cabin pressure relief valve. At this time the oxygen is fed into the closed suit loop at the rate of .16 pounds/minute and the crew continues to breathe the 100% oxygen atmosphere in the closed suit circuit.

With the flow rates quoted, the cabin pressure on attaining orbit is approximately 5.8 psi with an oxygen partial pressure of approximately 3.5 psi. The crew then switches off the O_2 high rate and the ECS reverts to normal operation where oxygen is added only in response to the cabin pressure regulator and demand regulators to make up for crew metabolic usage and cabin leakage. At this time the cabin recirculation valve may be opened, and the suit is vented to the cabin.

From this point on, until preparation for crew transfer to the Laboratory, the crew breathes the mixed gas. In the event of a loss of cabin pressure, the suit vent must be closed immediately by the crewman and the recirculation valve should be closed for safety. The suit pressure regulator then holds the total pressure in the suit at 3.5 psia, which means the O_2 partial pressure could drop to 2.03 psia. This is equivalent in terms of aveolar oxygen partial pressure to a normal atmosphere at approximately 15,000 ft. pressure altitude, and is acceptable for a short period of time during an emergency. The crew then turns the O_2 high rate on again for a period of about .6 minutes in order to bring the O_2 partial pressure in the suit back up to about 3 psia.

3. (Continued)

During crew transfer, O_2 is supplied at a rate of 10 lb/hr from the transfer umbilical. This has the effect of purging the suit of helium, and raising the O_2 partial pressure, so that no problem will be encountered even if transfer in pressurized suits is required.

Mixed gas operation can be achieved in the Gemini B at the end of the MOL mission by repressurizing the cabin with mixed gas from the Laboratory instead of 100% oxygen. After this is accomplished, system operation during the loiter period is identical to that at the beginning of the mission prior to transfer of the crew from the Gemini B to the Laboratory.

The schematic of the modified ECS system is shown in Figure 3.1-1.

3.2 AVE System Changes - The modifications to the existing Gemini B AVE to accommodate the simplified dual-gas system consist of:

A. redesign of the coolant umbilical disconnect mounted on the equipment section of the adapter to add two ports for the ground supplied oxygen and helium,

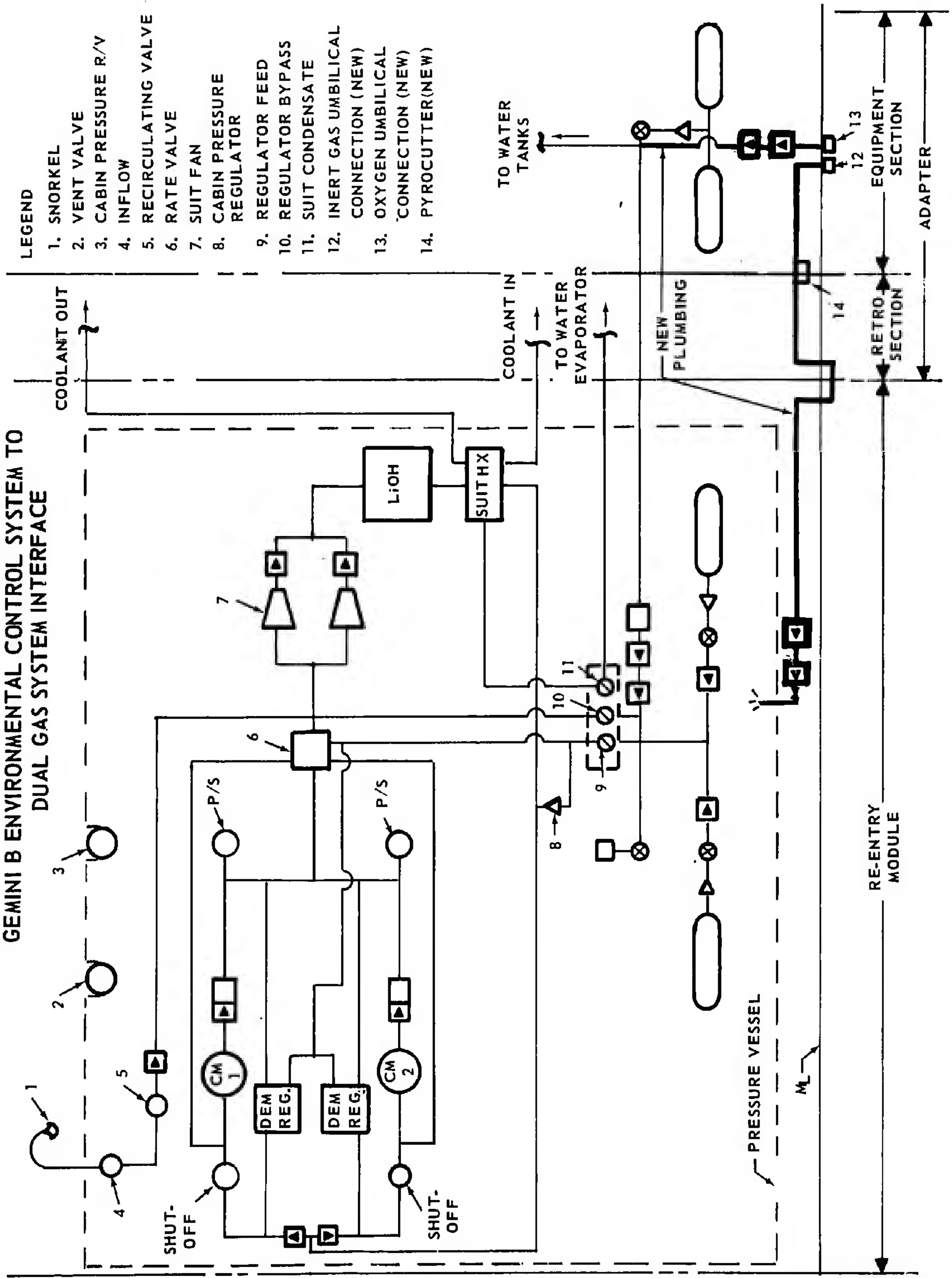
B. addition of one helium plumbing line in the adapter from the umbilical disconnect to the existing reentry module disconnect point,

C. addition of helium plumbing in the reentry module from the adapter disconnect point into the cabin,

D. addition of one oxygen plumbing line from the ground umbilical disconnect to the primary oxygen supply line in the equipment adapter,

E. addition of four check valves (two in the oxygen line and two in the helium line) to provide redundant closing of the ground supply lines after lift-off (The oxygen check valves are located in the adapter and the helium check valves are in the reentry module.),

GEMINI B ENVIRONMENTAL CONTROL SYSTEM TO DUAL GAS SYSTEM INTERFACE



LEGEND

1. SNORKEL
2. VENT VALVE
3. CABIN PRESSURE R/V
4. INFLOW
5. RECIRCULATING VALVE
6. RATE VALVE
7. SUIT FAN
8. CABIN PRESSURE REGULATOR
9. REGULATOR FEED
10. REGULATOR BYPASS
11. SUIT CONDENSATE
12. INERT GAS UMBILICAL CONNECTION (NEW)
13. OXYGEN UMBILICAL CONNECTION (NEW)
14. PYROCUTTER(NEW)

FIGURE 3.1-1

3.2 (Continued)

E. installation of a filter on the cabin outlet side of the helium line.

F. addition of two pyro operated guillotines to sever the helium line at the retro adapter interface.

G. installation of an oxygen partial pressure sensor in the Gemini B cabin.

The check valve to be used in the oxygen and helium lines is an existing qualified NASA Gemini part (McDonnell P/N 52-83700-15). It has a cracking pressure of 3 psi.

An alternative to the dual check valves in the helium line is to install a manual shut-off valve in place of one of the check valves to prevent cabin leakage.

The tube cutter guillotines are identical to the small wire bundle guillotines presently planned for use on Gemini B and identified as McDonnell part number 58A720072-1 and -2.

The NASA Gemini did not use an oxygen partial pressure sensor and the sensor used on the Mercury program was quite unreliable; therefore, a specific oxygen partial pressure sensor has not been selected for this application. A study will be made of existing approaches to determine which best satisfies the Gemini B requirements. These requirements are:

A. operate in a total pressure varying from 20 PSIA (on-pad pressure check) to 5 PSIA (on-orbit pressurization).

B. measure O_2 partial pressure quantities from 0.0 to 6.0 psia approximately. Nominal values are 5.0 psia partial prior to launch, and a minimum of 2.0 psia partial during ascent, and 3.5 psia partial on orbit.

C. operate in an oxygen-helium mixed gas atmosphere.

3.2 (Continued)

D. provide outputs to drive a PCM channel (5.0V or 0-20 mv) and a meter on the main instrument panel.

E. provide required ingestion of gas mixture (i.e., minimal flow available in atmosphere to be sampled).

F. provide an accuracy of ± 5% of full scale.

G. provide a rate of response equivalent to the maximum rate of change of cabin pressure during ascent.

H. withstand exposure to a vacuum.

I. qualify for manned space flight.

The most prominent categories of partial pressure sensors are polaragraphic, mass spectrometers, and gas chromatographs. Polaragraphic types utilize the variations in passage of electrical current through a solution in a cell caused by the variations in dissolved oxygen in the solution, which in turn is dependent on the amount of gaseous oxygen above the cell.

Mass spectrometers ionize a sample of gas into charged particles and separate the particles into their characteristic mass to charge ratio for detection.

A gas chromatograph column assembly physically separates the sample's constituents for detection.

Ultraviolet absorption and oxygen reduction are relatively newer techniques also under study and development.

Polaragraphic sensors were flown on the NASA Mercury and Biosatellite programs and are under consideration for the NASA Airlock program and the Laboratory segment of the USAF MOL program. Characteristics of this type of sensor which would have to be studied in more detail prior to their selection for the Gemini B spacecraft, include:

3.2 (Continued)

A. warm-up time - 30 minutes,

B. possible inflight sensor replacement due to life-limited components,

C. temperature sensitivity,

D. operation under humidity and pressure variations,

E. in-flight calibration requirements, and

F. response time and accuracy in low air flow regions (the Gemini B has no cabin fan).

The other oxygen sensor techniques detailed above generally require bulky and fragile hardware.

3.3 AGE Changes

3.3.1 Dual Gas Flow Control - The Dual Gas Flow Control System, shown in Figure 3.3-1, utilizes existing WTR Pad Complex He and O_2 sources. The system consists of a He/O_2 Flow Control Panel, He and O_2 Umbilical Hoses, and a remote control and monitoring panel to be added to the 52E180014 ECS Checkout Console located in the Launch Control Center (LCC). The system provides the following capabilities:

A. separate flow control of He and O_2,

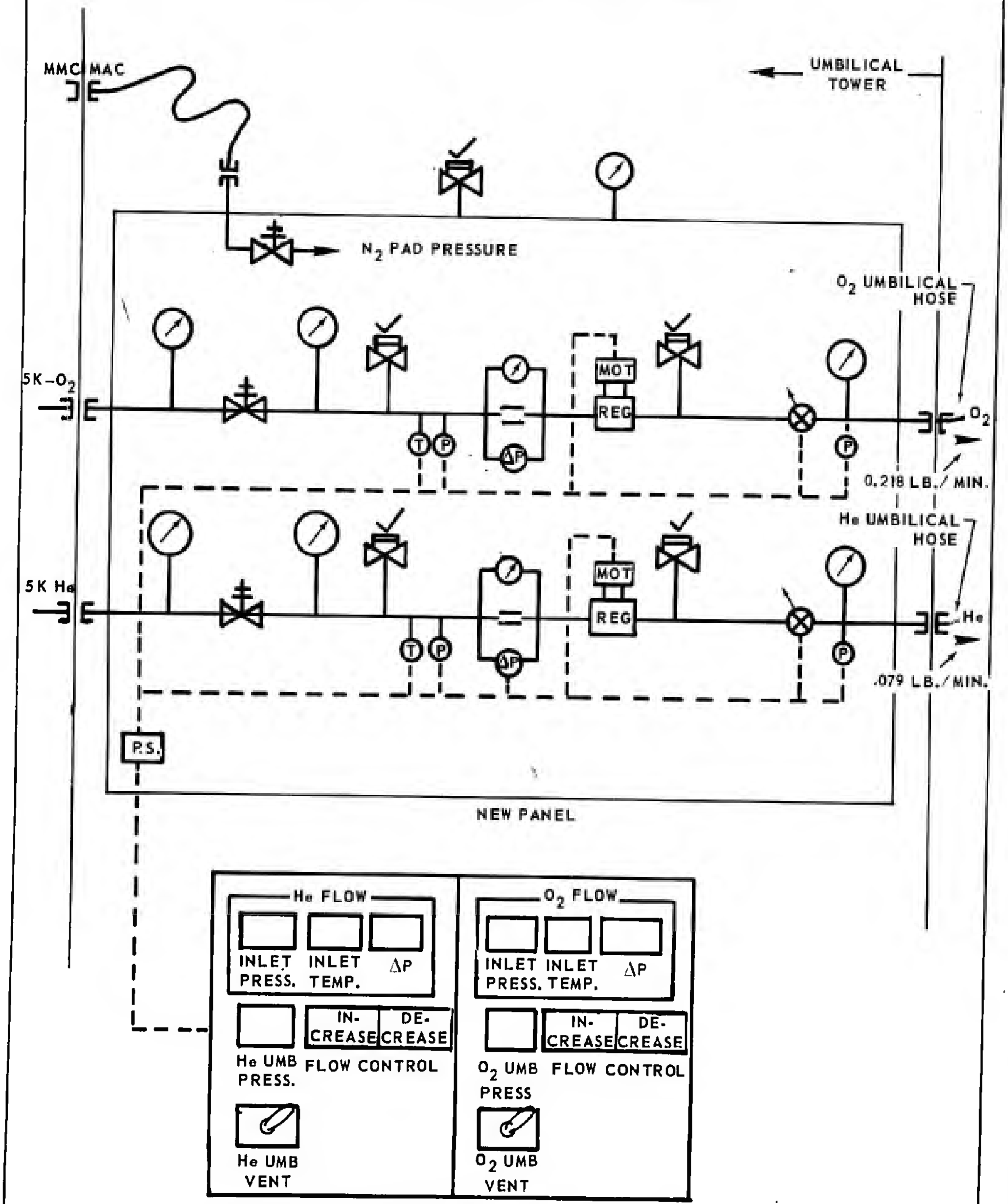
B. remote monitoring of all pertinent system parameters,

C. remote control of O_2 and He flow rates to provide a means of responding to system drift and/or malfunctions, and

D. remote cut-off of O_2 and He flow and bleed down of the umbilical hoses prior to severing the umbilical disconnects.

The described system meets the program requirements with minimum design impact.

ENVIRONMENTAL CONTROL SYSTEM DUAL GAS PANEL
(MOD. TO 52E180014 ECS CHECKOUT CONSOLE)



ENVIRONMENTAL CONTROL SYSTEM DUAL GAS PANEL
(MOD. TO 52E180014 ECS CHECKOUT CONSOLE)

FIGURE 3.3-1

3.3.2 Cabin Purge - Pre-launch O_2 purge of the S/C cabin is replaced by a Cabin He/O_2 purge. AGE utilized to perform the original O_2 purge of the cabin is compatible with the He/O_2 purge requirement. A premixed source of He/O_2 at the prescribed partial pressure ratios is made available through utilization of the 58E421217 High Pressure N_2 Carts which were designed for use on the Heat Shield Test (HST) Program. In this application, the He/O_2 mixture is used in place of N_2. Two such carts are required at WTR, located outside the Environmental Enclosure (EE) on the MST and connected to the 52E180030 O_2 regulation panel by a flex line which passes through the EE wall. The configuration is shown in Figure 3.3-2

3.4 Revised Operational Procedures - ECS operational procedures are revised for the condition when the crewmen are suited in the cabin with hatches closed. This involves the areas of cabin purge and cabin leak test.

3.4.1 Cabin Purge - This function is performed using the external supply of pre-mixed He/O_2 described in Paragraph 3.3. Procedural revisions are required to utilize this supply of mixed gases simultaneously with the dual gas system to prevent negative suit pressure in a partial helium atmosphere.

3.4.2 Cabin Leak Test - This function is performed generally as follows:

A. following determination of an acceptable cabin purge, the external purge of He/O_2 is shut off, the cabin vent valve is closed, and cabin pressure is increased by use of the dual-gas AGE system to 3 psig;

B. the dual-gas supply is closed, and a 3-minute monitor of cabin leakage is made. It is to be noted that at this time in the launch count, this test is only a gross check for any gross error in hatch closure. The acceptable decay rate with the dual-gas atmosphere is determined by tests during SST;

SPACECRAFT CABIN He/O_2 PURGE SYSTEM

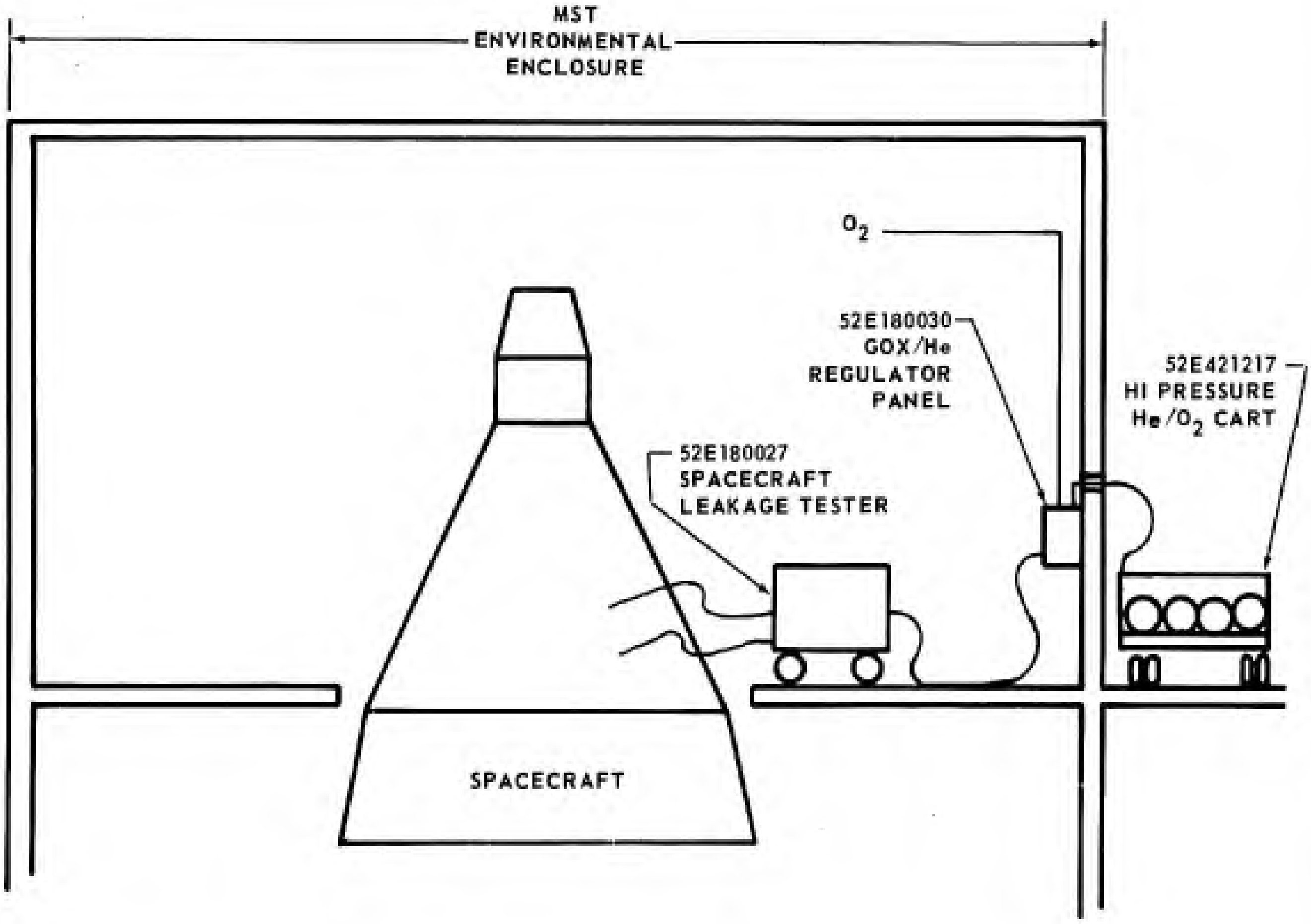


FIGURE 3.3-2

3.4.2 (Continued)

C. following the determination of an acceptable cabin leakage, the cabin is returned to normal dual-gas atmosphere for pre-launch conditions.

3.5 Laboratory System Changes - In order to achieve full dual-gas cabin atmosphere benefits at the end of the mission, the system in the Laboratory which repressurizes the Gemini B should be modified to accomplish this repressurization using a mixed gas instead of pure oxygen as in the present baseline.

4. SUPPORTING TECHNICAL ANALYSIS

4.1 Bio-Medical Considerations - The use of a spacecraft diluent on the pad to reduce the likelihool of fire is possible and at least three approaches are feasible:

A. a mixed gas atmosphere in both the suit and cabin circuits,

B. one-hundred percent inert diluent in the cabin and 100% O_2 in the suit,

C. a mixed gas atmosphere in the cabin and 100% O_2 in the suit circuit.

From the physiological viewpoint, as long as adequate oxygen partial pressure is maintained, the primary difficulty with a mixed-gas atmosphere throughout both suit and cabin is the problem associated with decompression sickness. Regardless of what gas is used as a diluent, the probability of the crew experiencing decompression sickness in going to altitude exists if no time is allowed for 100% oxygen pre-breathing.

Some differences can be expected in the time required for pre-breathing or equilibration depending upon diluent selection. The belief that helium is superior to nitrogen relative to protection against decompression sickness arises from its fat-water solubility ratio and consequent rapid elimination from fluids and tissues. The desaturation times are illustrated in Figure 4.1-1.

The major limitation of approach (B) above (that is, 100% inert gas in the cabin circuit and 100% oxygen in the suit) is the lack of a breathable atmosphere if the crew were for some reason required to open faceplates. This approach offers a high degree of fire protection, since everything external to the suit circuit would be devoid of oxygen. Physiologically, it makes little difference what inert gas is chosen for the cabin circuit.

DESATURATION RATE FOR MAN COMPARING NITROGEN TO HELIUM
BEHNKE, A.R. THE ABSORPTION AND ELIMINATING
OF GASES OF THE BODY IN RELATION TO ITS FAT
AND H_2O CONTENT, MEDICINE 24: 359–79 (1945).

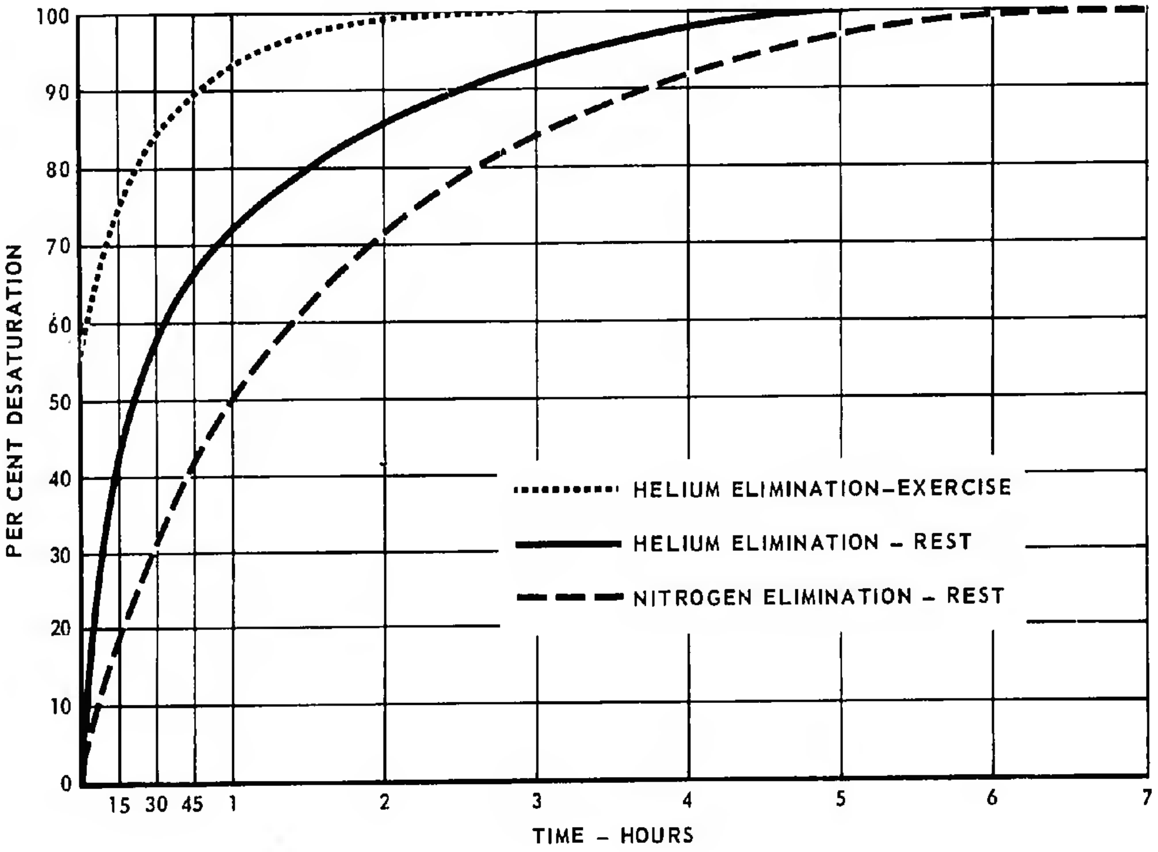


FIGURE 4.1-1

4.1 (Continued)

Approach (C), breathable mixed gas in cabin, 100% oxygen in suit, perhaps affords the best total atmosphere from the safety viewpoint. As long as the faceplate is kept closed, it matters little what inert diluent is used in the cabin. Either nitrogen or helium is satisfactory. An acceptable oxygen partial pressure in the cabin mixed-gas atmosphere is predicated on maintaining a physiologically acceptable alveolar oxygen partial pressure.

When helium is introduced into an oxygen breathing environment, there is an upward shift in the frequency spectrum of the speech waveform. The magnitude of the frequency shift, or speech distortion, depends upon the quantity of helium added and the pressure of the environment.

Tests performed in a 50-percent helium, 47-percent oxygen mixture, at 7 psia, indicate that speech distortion can be detected by the listeners. Even though the distortion was present, it was determined that it was not indicative of a lack of voice intelligibility. Isolated word, words in sentence, and digit intelligibility percentages were found to be comparable to that acquired during tests in a 3.5 psia pure oxygen environment. It should be noted that successful spacecraft to ground voice communications were accomplished, in a 3.5 psia oxygen environment, during NASA Gemini EVA operations.

4.2 <u>Flow Rates</u> - The Gemini B Environmental Control System contains an orifice by-passing the primary oxygen shut-off valve for the purpose of pressurizing the closed portion of the ECS in the event of a decompressed transfer. This orifice is sized nominally to flow .16 pounds/minute oxygen at 70°F with 110 psia upstream. The same line is utilized to introduce oxygen into the ECS circuit from the AGE source during ground operations. The nominal oxygen pressure that

4.2 (Continued)

the AGE umbilical provides at the connection to the primary system is 135 psig; therefore, the nominal oxygen flow on the launch pad into the ECS will be .218 pounds/minute. The nominal .218 pounds/minute flows into the suit circuit; a small portion (.003 lb/min) provides the metabolic requirements of the crewmen, and the remainder is discharged into the cabin through the relief port of the demand regulator. In the cabin, CO_2 and water vapor carried into the cabin with the excess O_2 mixes with helium introduced directly into the cabin and are vented overboard through the outflow valve. The nominal helium flow is 0.0787 pounds/minute and, when mixed, results in 25% oxygen by weight (3.75 psia oxygen) in the cabin. This initial oxygen partial pressure is adequate to provide a breathable atmosphere during ascent, as discussed in Paragraph 4.3.

4.3 Atmosphere Change During Flight - Figure 4.3-1 illustrates how the cabin gas total pressure and major constituent gas partial pressures (oxygen, helium, and water vapor) vary during the last minute of launch, during ascent, and early orbit. At T-60 seconds, the cabin outflow valve is closed, the ground supplied oxygen and helium flows are discontinued, and the constant nominal oxygen high-flow rate of 0.181 pounds/minute (on ground) is initiated and ducted into the suit-loop from the on-board primary oxygen supply maintaining 100% oxygen in the suit circuit. This rate is higher than the normal orbit high-rate oxygen flow of .16 lb/min., because the primary O_2 regulator regulates to 110 psig, or 124.7 psia on the ground. The oxygen then flows into the cabin through the relief portion of the demand regulator. The cabin pressure increases until 33 seconds into ascent, at which point the cabin pressure-relief valve automatically begins to dump cabin gas overboard and relieves the cabin pressure. The constant oxygen flow rate into

GEMINI B CABIN PRESSURE DURING LAUNCH, ASCENT AND EARLY ORBIT

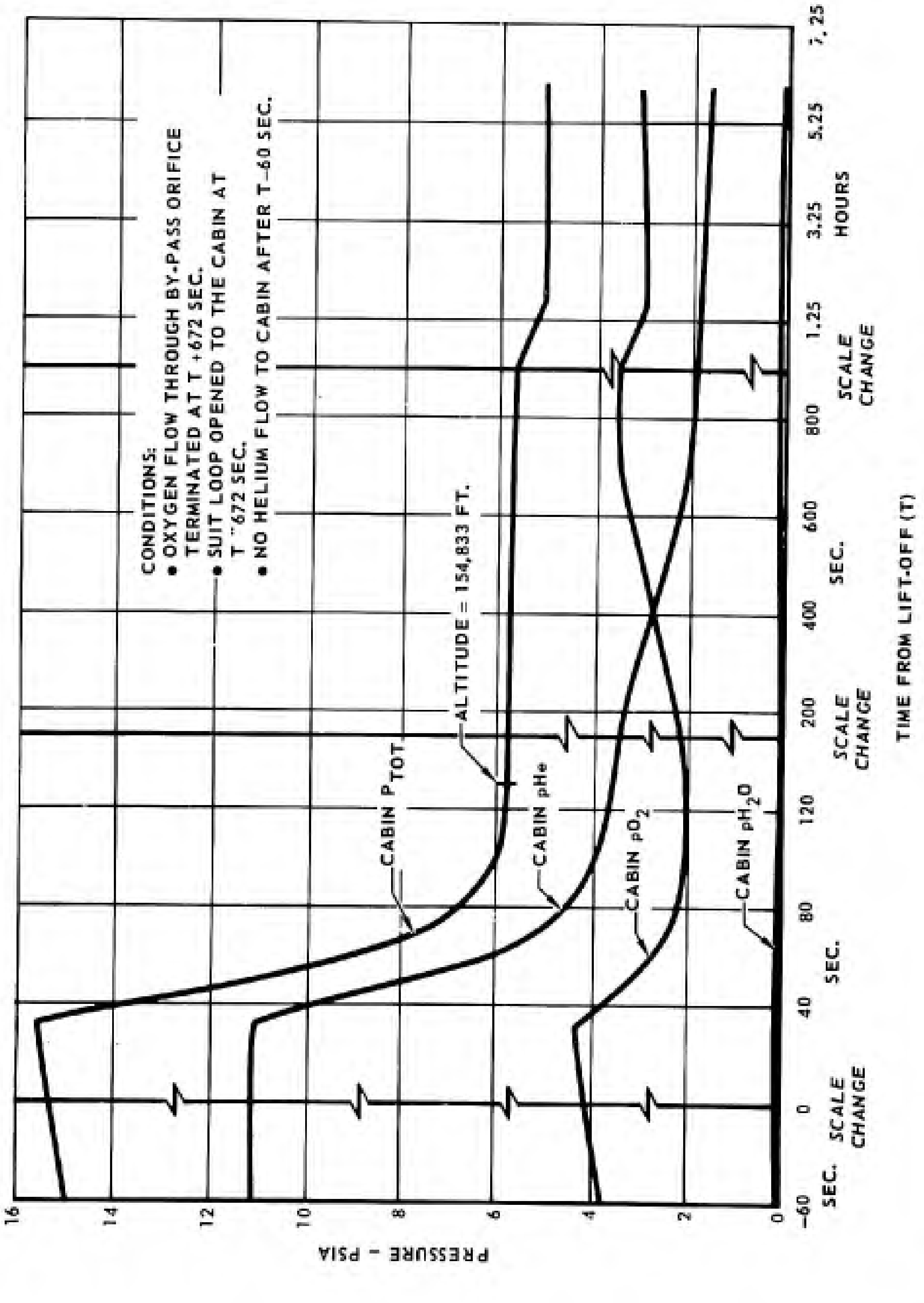
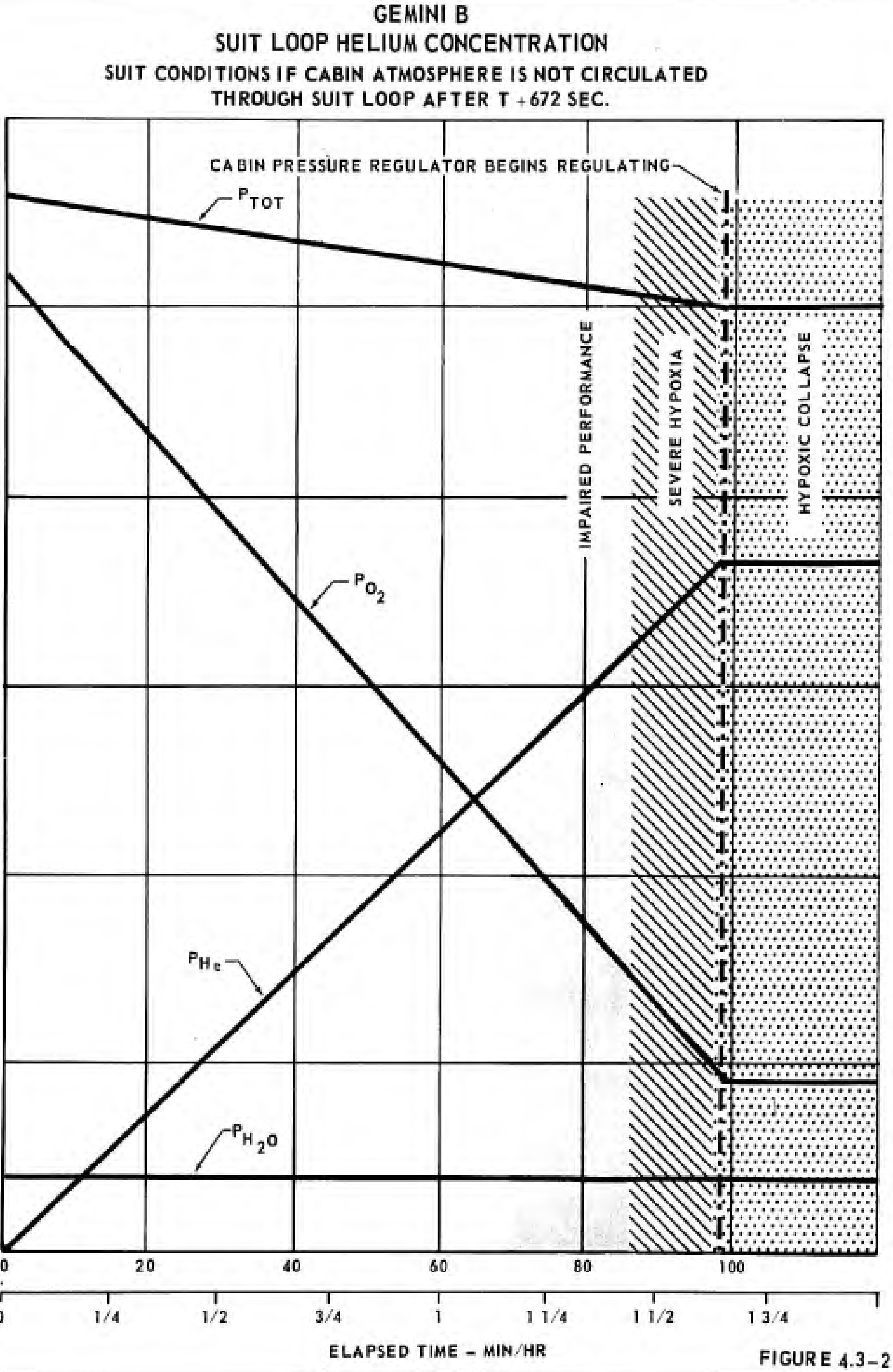


FIGURE 4.3-1

4.3 (Continued)

the suit loop is maintained until T +672 seconds during ascent and early orbit, at which time the cabin oxygen partial pressure will be 3.5 psia. A minimum oxygen partial pressure in the cabin of 2 psia occurs during ascent, a level that is considered physiologically acceptable for the time involved. At 672 seconds when the cabin oxygen partial pressure of 3.5 psia is reached, the constant flow of 0.16 pounds oxygen/hour (in orbit) into the suit circuit is terminated by shutting off the oxygen by-pass valve. At this point, the suit loop is opened to the cabin atmosphere, and the cabin atmosphere is circulated through the suit loop to prevent, a concentration of helium in the suit loop. Figure 4.3-2 illustrates helium concentration in the suit loop, if the suit-loop recirculation valve is opened without venting the suit or if the suit loop is operated closed and there is leakage into the suit loop. Therefore, to be assured there is no helium concentration in the suit, the cabin atmosphere is continuously circulated through the suit loop. This could be accomplished if the MOL pressure suit is designed with a helmet visor that could be opened in conjunction with the recirculation valve. If the MOL suit helmet has no such visor, then another opening into the cabin must be provided in the suit loop (possibly a shut-off valve in the suit outlet hose) to allow flow of the cabin atmosphere into the suit loop, through the suit, and out again into the cabin.

4.4 Monitoring Requirements - The dual-gas system discussed in this report is configured to minimize the necessity of on-board atmospheric control, since the flow of gas into the cabin both on the pad and in flight is not controlled by sensing the partial pressures of the cabin atmosphere constituents.



GEMINI B
SUIT LOOP HELIUM CONCENTRATION
SUIT CONDITIONS IF CABIN ATMOSPHERE IS NOT CIRCULATED
THROUGH SUIT LOOP AFTER T +672 SEC.
CABIN PRESSURE REGULATOR BEGINS REGULATING
P TOT
P O2
P He
P H2O
IMPAIRED PERFORMANCE
SEVERE HYPOXIA
HYPOXIC COLLAPSE
SUIT PRESSURE - PSIA
0
1
2
3
4
5
6
MIN → 0
20
40
60
80
100
HR → 0
1/4
1/2
3/4
1
1 1/4
1 1/2
1 3/4
ELAPSED TIME - MIN/HR

FIGURE 4.3-2

4.4 (Continued)

Monitoring is required only as a means of notifying the crew members or the ground of an excessive concentration of oxygen or diluent gas in the cabin to permit initiation of corrective action.

The basic monitoring of the atmosphere during on-pad operations is through the AGE flow control panel. Assuming perfect mixing of the oxygen and diluent in the cabin, the atmosphere in the cabin remains within the proper proportions as long as the flow from the ground supply is held within specified limits.

Ground system malfunctions between the supply and the control panel are reflected in the flow control monitoring. Malfunctions downstream of the flow control panel, such as leaks, imperfect mixing, etc. which cause a concentration of either oxygen or diluent in the cabin are not detected at the AGE flow control panel; therefore, some type of on-board monitoring is required to provide an indication of the amount of oxygen in the atmosphere. This type of monitoring is also required during the ascent phase of the mission to detect variation in predicted atmosphere content as the cabin pressure reduces.

4.4.1 Response to Monitoring Indications - During the on-pad and ascent phases of the mission, the crew is breathing pure oxygen in the closed suit loop; therefore, there is no immediate hazard if the concentration of diluent gas in the cabin becomes excessive. If this occurs on the pad, the flow of diluent and oxygen is varied from the control panel to bring the levels back into proper proportion. If it occurs in flight, the crew simply remain in the closed suit loop until sufficient oxygen can be fed into the cabin from the on-board supply.

Excessive concentration of oxygen in the cabin also presents no immediate danger to the crew except insofar as it defeats the purpose of the two-gas system in reducing the fire hazard. If this occurs on the pad, the action is the same as

4.4.1 (Continued)

with excess diluent - simply vary the flows until the proportion returns to normal. There is no corrective action required for excessive oxygen in flight, since the system inherently tends toward a pure oxygen atmosphere as a limit after lift-off. Again, the advantage of the two-gas system in reducing fire hazard is lost. However, since the O_2 pressure in this case reaches a limit of 5.5 psia in orbit versus 15 psia on the pad, the fire hazard is less critical.

4.5 Reliability Evaluation - A failure mode and effect analysis of the proposed AVE changes was performed to determine their effect on ECS reliability. The analysis revealed that two additional single-point failure modes for the primary oxygen supply result from intersecting the existing spacecraft oxygen supply line with the AGE oxygen supply line. The portion of this added line downstream of the check valves is pressurized by the primary oxygen supply to a nominal 110 psi throughout the entire mission, including the orbital storage period. Either external line or fitting leakage or external leakage of the pressurized check valve results in loss of the primary oxygen supply.

Since portions of the existing spacecraft oxygen supply system are used to deliver AGE oxygen during pre-launch activity, revisions to the normal pre-launch ECS operations and checkout procedures result. A final check of the manual by-pass valve (a single-point failure mode for the primary oxygen supply) in the normal flight position (closed) is precluded. Operation of the two-gas system requires that this valve be open from T-115 minutes to T + 672 seconds, after which the valve is closed, and it must seal to prevent loss of primary oxygen.

Occurrence of the failure modes discussed above could cause total loss of the primary oxygen supply. Since such a loss is not in itself considered cause for immediate mission termination, the overall effect of the added failure on crew

4.5 (Continued)

safety is not significant. However, this area requires more detailed investigation with respect to probability of mission success.

The outflow vent valve is also affected by revised procedures. This valve is opened after the pre-launch cabin leak check and is not closed until T-1 minute, too late for a final leak test in its flight position. However, the valve has a redundant sealing capability and is not considered a single-point failure mode.

In the proposed concept, the composition of the cabin atmosphere is determined by the flow rates at which oxygen and helium are delivered to the cabin. Specific inlet pressures for the on-board flow controlling orifices have been calculated corresponding to the individual flow rates necessary to provide the desired oxygen/helium ratio. The proposed AGE provides the capability for automatically maintaining these specified orifice inlet pressures. In the event of moderate but significant line leakage or restriction, adjustment is made from the AGE console to maintain the correct oxygen/helium flow ratio. It is evident that, to be assured that correct orifice inlet pressures are being maintained either automatically or by manual setting, it is imperative that no interruption or loss of any of the AGE parameter displays occur. Therefore, to prevent a countdown hold due to a single-point failure of a portion of the AGE instrumentation, the AGE is equipped with a dual monitoring capability.

5. TESTING

5.1 AVE Component Qualification

5.1.1 Umbilical Disconnect - Due to the configuration of the Gemini B adapter and its relationship to the launch complex, the coolant umbilical disconnect presently planned for Gemini B is a new design from that used on NASA Gemini, and a qualification program is to be accomplished. It is assumed that the simplified dual-gas system, if approved, will be authorized at an early enough time to permit incorporation of the provisions in the basic coolant umbilical disconnect; therefore, no additional testing will be required.

5.1.2 Check Valves - The 4 check valves, added as a part of the simplified dual-gas system, are existing NASA Gemini qualified parts (52-83700-15) and no additional qualification is required.

5.1.3 Tube Cutter Guillotines - Several of these devices are already being used on Gemini B to sever wire bundles , and no additional qualification testing is required.

5.1.4 Oxygen Partial Pressure Sensor - The selected oxygen partial pressure sensor will require complete qualification testing for Gemini B.

5.1.5 Requalification of Existing Equipment - Since the proposed AVE configuration utilizes the existing primary O_2 supply line to deliver AGE O_2 to the suit subsystem, it is necessary to supply AGE O_2 at a pressure higher than the primary O_2 regulator lock-up pressure to prevent expenditure of the primary O_2 supply. It is presently planned to deliver AGE O_2 at 25 psi over nominal design operating pressure. Check valves in the O_2 line to each water tank trap this higher pressure on the O_2 side of the tank bladder. If no transfer of water is required prior to entering the Lab, the tanks could be exposed to this pressure for the entire orbital storage period. The qualification and acceptance testing criteria of the ECS water tanks, upstream check valves, and downstream components to (and

5.1.5 (Continued)

including), the H_2O solenoid valves should reflect the higher pressure level (110 psi vs 135 psi, nominal).

5.2 AGE Testing - Development testing of the dual gas flow control and cabin purge systems is required. These tests are extended duration tests to verify the operational performance of the systems when integrated with either an actual or simulated S/C ECS. Consideration will be given to working the required testing into the Thermal Vacuum Test Plan.

5.3 Combined System Test - A preliminary study of combined system testing for the propsed two-gas system has led to two possible approaches toward verification of system operation. One approach is to verify the system during first-article demonstration tests; the other is to conduct total system (AVE and AGE) development tests.

Points in favor of the first article demonstration are the simplicity of the system, qualification of equipment at the component level, and the lower cost of a first-article demonstration as opposed to a development-test program. The purpose of the test is to verify that the equipment actually provides proper flow rates and pressure, accurate monitoring, and a habitable cabin atmosphere. The test is performed on the first flight article, and the two-gas system operation is verified on typical equipment operating within the range of system specifications.

The purpose of a complete system development test is to verify the interaction of the two-gas system equipment. This test, occuring earlier than a first-article test, allows time for any unanticipated system modifications.

5.3 (Continued)

The test involves manned and unmanned operations in a representative spacecraft (S/C 3A, schedule permitting, or a boilerplate reentry module if one were obtained for fire hazard studies). AGE and AVE are utilized and modified as required to demonstrate that system errors due to worst-case tolerance accumulations do not precipitate a hazardous condition in the spacecraft. These development tests will validate that the proposed closed-loop circuit operation does in fact prevent accumulation of inert gas. The test also enables responsible personnel to gain operational experience as early as possible. Parameters of interest are flow and leakage rates, pressures, monitoring errors, and partial pressures in the spacecraft. These tests simulate pre-launch, launch, and ascent phases to assure that the two-gas system provides a habitable atmosphere in the event of a suit-loop malfunction.

Both the first article demonstration and the total system (AVE and AGE) development test approaches to the combined system test should be considered at this time. The two gas system should be studied in greater detail, to compare the advantages and disadvantages of these approaches. The results obtained from a costly development program must be weighed against the uncertainty of a satisfactory first-article demonstration and subsequent system modifications.