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Alternate Apollo Atmosphere

As a result of the recent AS 204 accident, we have attempted to unilaterally review alternatives aimed at decreasing potential fire hazards by changing current atmosphere composition. The enclosed paper is a first cut at this. I propose to further discuss these approaches and our thinking with Chuck Berry. In the meantime, I am furnishing the document to you for your information.

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Enclosure

cc: MAT/Mr. Day
MO/Colonel McElmurry
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ALTERNATE APOLLO ATMOSPHERES

In view of the advanced stage of the Apollo hardware development, any review of Apollo atmosphere composition and associated operational procedures should be based on existing systems and facilities. This paper presents alternatives based primarily on fire hazard and physiological consideration without benifit of the analysis of the Spacecraft 204 accident.

1. Inflight Atmosphere:

During space flight, the present atmosphere for CM and LM is 5 psi pure oxygen. It is assumed that maintaining a maximum total pressure of 5 psi is highly desirable from an engineering point of view. Therefore, the following possible approaches which may be considered to reduce the fire hazard during flight are limited by this constraint:

a. Maintain the total pressure of 5 psi with a mixed gas atmosphere (31% nitrogen, 69% oxygen). Such an atmosphere is satisfactory from a physiological point of view; it decreases the fire hazard, but it does require engineering modifications to the spacecraft and service module. This atmosphere is compatible with the use of a pure oxygen atmosphere at 3.8 psi in the space suit (for EVA and emergency operation), provided the initial pressure in the suit was 5 psi and was lowered to 3.8 psi gradually as the nitrogen is flushed out of the system.

b. Maintain the pure oxygen atmosphere, but lower the pressure to 3.8 ± 0.1 psi. This again appears to be satisfactory from a physiological point of view. The fire protection obtained is less than a mixed gas atmosphere, however, engineering modifications required are minimal.

2. Pre-launch Atmosphere - General Principles:

During the pre-launch period the spacecraft pressure is raised temporarily to 20 psig to seal the hatch and check relief valves. Subsequently the pressure is lowered to 16 psig until launch. This supra-atmospheric pressure within the spacecraft is apparently necessary to maintain a tight seal of the hatches. Currently pure oxygen is used to pressurize the spacecraft.

3. Pre-launch Atmosphere - Space Suit:

In the space suit a pure oxygen atmosphere must be maintained during the pre-launch period to eliminate completely the possibility of bends which could occur in a mixed gas atmosphere as cabin pressure falls on ascent into space.

For operational reasons the pressure in the space suit must be slightly higher than the pressure in the cabin environment. This brings the pressure in the space suit at launch time to about 16 psig pure oxygen. In the space suit alone the fire hazard of such an atmosphere should be less than it would be in the spacecraft because of the lack of potential ignition sources in this closed system. Past operational and simulation experience fails to identify any fire originating in the space suit or with the associated space suit supporting system. Therefore, it would seem logical to retain the current space suit circuit but isolate it from the cabin atmosphere until a shirt-sleeve environment can be established following launch.

Soon after launch the suit pressure falls corresponding to the fall in cabin pressure. The normal operating pressure in the suit for pressurized suit operations (EVA or unpressurized spacecraft) is 3.8± 0.1 psi, i.e., the same as the pressure recommended earlier as one potential spacecraft atmosphere.

4. Pre-launch Spacecraft Atmosphere - 31% N_2 - 69% O_2:

If in view of the recent accident an atmosphere of pure oxygen at 16 psi is considered too hazardous, the previously suggested flight atmosphere of 31% nitrogen, 69% oxygen may be one alternative. This atmosphere at 16 psi provides a partial pressure of oxygen of 571 mm Hg compared to 158 mm Hg of the normal earth atmosphere. Although physiologically acceptable, this oxygen concentration may also be considered too much of a fire hazard, however, it does provide a liveable spacecraft atmosphere through the ascent period. All other approaches require that the pre-launch atmosphere be different from the suggested inflight atmospheres. The problems involved in selection of a suitable pre-launch atmosphere are discussed below.

5. Pre-launch Spacecraft Atmosphere - Air or Nitrogen (Isolated Space Suit Atmosphere Loop):

During the pre-launch period, when the pressure is above ambient atmospheric pressure the pure oxygen currently used in the spacecraft could be replaced with air (or 100% nitrogen) which would greatly decrease the fire hazard; however, this poses the problem of eliminating all or most of the nitrogen before the atmosphere could be made suitable for shirt-sleeve operation at low total pressures. Two approaches are possible:

a. During ascent, the spacecraft atmosphere is allowed to equilibrate with the outside. When all the entrapped spacecraft atmosphere has been eliminated, the spacecraft is repressurized to the designed atmosphere. If this approach is adopted, it imposes a condition of some impaired mobility (pressurized space suit 3.8 psi for O_2, 5 psi for 69% oxygen 31% nitrogen) on the astronaut during parts of the critical launch-insertion phase of the mission when the astronaut is confined to the space suit because of low oxygen concentrations.

b. During the ascent phase, the pressure in the spacecraft is lowered while simultaneously excess nitrogen is flushed out gradually by the introduction of oxygen. This approach provides a liveable atmosphere throughout the ascent phase, but it requires considerably more oxygen than the depressurization procedure.

c. If the inflight atmosphere be pure oxygen at 3.8 psi, it will be necessary to eliminate <u>all</u> the nitrogen present during the ascent period. This can be achieved fairly easily with depressurization, but it would be difficult and would require considerable amount of oxygen using the flushing method.

6. <u>Pre-launch Spacecraft Atmosphere - Carbon Dioxide:</u>

A carbon dioxide oxygen atmosphere for the spacecraft alone during the pre-launch period would practically eliminate any fire hazard. This technique would also offer the possibility of subsequent absorbing the carbon dioxide without the need of depressurization of flushing. However, carbon dioxide in high concentrations is toxic and absorption by on-board lithium hydroxide canisters or new techniques such as molecular sieves are not very efficient processes.

SUMMARY RECOMMENDATIONS

Pending completion of the accident review board deliberations or additional information which may uncover some current unknown condition not previously considered, the following recommendations are presented.

On the basis of the above analysis and the saftey of depressurized operations demonstrated in Gemini, it is suggested that:

1. The pure oxygen atmosphere during the Apollo flights be maintained, but if desired, consideration be given to lowering the pressure to 3.8 ± 0.1 psig.

2. The space suit be maintained in a pure oxygen atmosphere at all times with its attendent ECS isolated from the spacecraft atmosphere during launch and operate at a pressure slightly above that of the spacecraft.

3. During the pre-launch period the cabin atmosphere be dry air.

4. During ascent phase the cabin be permitted to depressurize to inflight pressure (3.8 or 5 psia) and be maintained at that level until orbit has been achieved.

5. As soon as flight operation is stabilized in orbit and suit integrity checked, the spacecraft be depressurized and repressurized with pure oxygen.

Advantages:

1. The fire hazard during preflight operations is reduced over currently used procedures.

2. Space suit operations during the critical launch and insertion

period can be conducted without differential pressurization and attendent mobility limitations.

3. Spacecraft atmosphere is always tolerable as long as oxygen flow by the nose-mouth area is not interrupted. (This should be confirmed by actual simulation).

4. Depressurization and subsequent repressurization is accomplished only after all systems have been checked and dynamic phases of the launch have passed.

5. Minimum expenditure of stored onboard oxygen supplies.

7. No instrumentation changes required. O V [illegible]

Disadvantages:

1. Requires orbital depressurization of spacecraft to achieve true shirt-sleeve operation in a truly nitrogen free environment.

2. Requires additional oxygen for repressurization.

3. Requires modification of ECS to lock out the spacecraft atmosphere and prevent nitrogen contamination of the suit until spacecraft has been repressurized with pure oxygen.

4. Requires alternate method of introducing atmosphere gases to the spacecraft and suit circuit during ground operations.