Dr. Berry's Presentation to Design Certification Review
March 7, 1968

PHYSIOLOGICAL REQUIREMENTS OR CONSTRAINTS
FOR A SPACECRAFT ATMOSPHERE

As we repeatedly stated during the Congressional hearings after the accident, any atmosphere which has sufficient oxygen to support life also will support combustion. Our aim is to provide an adequate amount of oxygen to assure man's capability to perform is not compromised and still reduce the fire hazard to the greatest degree possible.

The principle physiological considerations in selecting an atmosphere are: (Chart 1)

Hypoxia - A reduced amount of oxygen available to the body's cells compared to that provided at sea level.

Hyperoxia - An increased amount of oxygen available to the body's cells compared to that provided at sea level.

Dysbarism - The symptoms resulting from a decrease in total atmospheric pressure.

Hypoxia Considerations:

Many factors involved in providing adequate O_2 at cellular level -

Adequate O_2 in atmosphere and our current problem
Adequate intake O_2 and transfer across alveolus
Adequate blood transportation of O_2 to cell
Adequate use by cell

Amount O_2 in alveolus (lung sac) depends on the total pressure and the partial pressure of O_2. It is a non-linear system with two variables. Remember alveolar equation from our paper. Important variable is the driving pressure of O_2 available at the cell. Depends on -

(1) Alveolar mix graph Chart 2
(2) O_2 dissociation curve Chart 3

Effects of reduced alveolar pO_2 vary with individuals but have been extensively studied.
Gross divisions of behavioral effects on Chart 4.

Attach. 3

Some effects noted at 4-5,000 altitude - night vision

Body starts series of adaptive changes to handle this stress and maintain homeostasis.

Inc. heart rate
Inc. respiration rate
Biochemical changes - pH and electrolytes
Inc. rbc production

People who live at high altitude like Andean Indians have inc. chest size, inc. hemo, and myo- globin etc. which allow them to function. They have an inborn adaptation by nature. - trouble at sea level. Sea level man starts series of changes and can produce physiological alterations such as inc. hemoglobin and some adaptation in 2-4 weeks. Germans tried this in WWII and Russians now doing much work in this area.

Our concern is not the traditional time of useful consciousness (TUC), but

(1) Peak performance - no alteration due to hypoxia
(2) No triggering of adaptive mechanisms

We want some safety margin or pad for the man so he isn't dipping into his physiological reserve.

The low 4-5,000 ft. altitude where these mechanisms may start activation should be noted. In spaceflight we are in a new area with many stresses active simultaneously. Weightlessness causes cardiovascular adaptive changes and we have no information on what a combination of weightlessness and hypoxia may produce in man. Thus our problem is different from the airlines, the USAF, and high altitude dwellers.

Ground Rules:

1. An acceptable mission cabin atmosphere must provide a sea level equivalent PAO_2 or higher.

2. If the spacecraft is launched with an oxygen/nitrogen mixture which results in a cabin atmosphere after orbital insertion that violates rule 1, the atmosphere must be enriched to provide a sea level equivalent PAO_2. The crew may remove helmets and gloves under the following conditions:

    a. The cabin atmosphere provides a PAO_2 of at least 82 mmHg*, and

b. Enrichment procedures are under way which will ensure a sea level equivalent atmosphere (73% O_2 at 4.8 psia) within 4 hours of first crew exposure to that atmosphere.

3. The suit loop oxygen concentration for planned or prolonged operations at 3.75 $\pm$ .25 psia (EVA or pressurized return) must be at least 95%. This will result in a PAO_2 of 82 mmHg* at 3.5 psia.

4. Oxygen prebreathing time prior to launch should be 4 hours. Time in the spacecraft may be counted if the loop O_2 percentage is kept above 95 percent and there is no significant break in the oxygen procedures.

Medical Requirements to be Met by Apollo Office

Agreement with Project Manager, Mr. Low, that

1. Test of 60/40 with purge, urine dump bleed, cabin seal off and oxygen make-up.

2. Test data to prove positive pressure in suit circuit with no nitrogen in-leak.

3. Accurate telemetered delta pressure information on suit loop.

4. Accurate and readable pO_2 sensor in suit and cabin.

Mission Rules:

Will have to develop rules covering use of ΔP and pO_2 sensors, drop in cabin pO_2, etc.

Special Cases:

Launch acceleration and pad or launch aborts considered.
Ideally require 100% O_2 - provided by suit.
If get double failure - 60/40 survivable.

Dysbarism:

Dysbarism family tree. Chart 5. Can prevent by denitrogenation preflight. Worst case sea level to 3.5 psi

* 4,000 ft. air altitude equivalent
62% O_2 at 4.8 psia, 52% at 5.6 psia

with failure of cabin seal off.
Two hours is not enough prebreathing.
Four hours is enough.
Trying to define period between.
Effects no worse with 60/40 atmosphere at 5 psi if properly denitrogenated. Chart 6
Require four hours prebreathing with planned 60/40.