The "Manhigh" Sealed Cabin Atmosphere

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WHEN the *Manhigh* capsule system was being designed in the fall of 1955, the primary objective was a maximum performance system of minimum weight that could lift a man into a space equivalent environment for twenty-four hours. This objective had to be met safely and supply an answer to what the man could do if any specific component failed. Beyond this, an effort was made to provide him with as comfortable a "shirt sleeve" environment as possible.

The pressure and atmospheric composition of a sealed cabin designed for a space mission must be selected in terms of the peculiar needs of that specific mission. This paper shows how the atmosphere used on the *Manhigh* program was tailored to fit the needs of that flight. Many of the considerations apply directly to satellite missions and other high altitude balloon flights.

The sealed cabin atmosphere of the *Manhigh* program is here considered in three steps. First, the implications of the approach defined above are presented under basic decisions in terms of the fundamental design parameters resulting from that approach. Next, atmosphere selection shows how the capsule pressure and atmosphere composition were derived from the limits imposed by the basic decisions. The last section illustrates how the meaning of the various measurements in a sealed cabin environment may be derived citing data of the *Manhigh II* flight.

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BASIC DECISIONS

Four decisions profoundly influenced the final selection of an atmosphere for the capsule. The first was the form of the capsule structure itself. The final design provided for a capsule with a diameter of 3 feet having a cylindrical midsection with hemispherical ends above and below. This pressure shell stood 8 feet high. Four feet of the cylindrical section and both hemispheres were of aluminum 0.032 inch thick. The lower hemisphere was welded to this cylinder. This section and the upper hemisphere were clamped to a 1-foot long cylindrical casting which served as the load-bearing member and contained the windows. The sections were attached by quick-release Marmon clamps. This design was chosen to permit rapid opening for emergency egress from the capsule both in flight and after landing. The clamps could be released either by mechanical force through a mechanical rod that penetrated the turret casting or electrically.

As tests proceeded, the quick release, rapid exit feature revealed itself as a mixed blessing. Once, during a pressure test, the Marmon clamp opened unexpectedly for no apparent reason while the capsule was pressurized. Mechanical corrections were made to prevent a recurrence, but the possibility of a similar episode could not be completely discounted. A similar clamping arrangement, but without quick release features, was used in two other locations: the line joining the two halves of the air regeneration unit, and the point where the air regeneration hose attached to the capsule. These were also potential but very unlikely sources of rapid decompression during flight.

The second decision followed directly from the minimum weight objective of the flight. A sealed cabin would be essential. Previous balloon flight experience[10] had demonstrated the principles and revealed many practical problems encountered in providing this type of atmosphere for animals. By supplying an oxygen source which maintains a constant pressure within the cabin, and a scrubbing system to absorb carbon dioxide and excess water vapor,* the composition of the atmosphere should remain constant. In the operation of a true sealed space cabin, no gas can be obtained from outside the cabin and none should be vented from the cabin atmosphere to the outside.

The third decision concerned whether or not the pilot should be required to wear a partial pressure suit during flight. This involved the question: Which is more important to the ultimate success of the flight—a higher degree of comfort, initiative and alertness on the part of the pilot, or the possibility of emergency pressurization in an uncomfortable pressure suit should the capsule suffer catastrophic mechanical failure?

It was obvious that without a pressure suit, any form of decompression which occurred in less than 20 to 30 minutes at peak altitude would be fatal. A Marmon clamp failure or loss of one of the 5½-inch windows would cause very rapid decompression: In addition to the U. S. Air Force traditions of providing crew members with a possible alternative "if," there was the very real consideration of the unknown hazards that might arise owing to our incomplete knowledge of the problems to be faced living under space equivalent conditions for a prolonged period of time. The decision was made that the pressure suit would be worn.

Finally the question had to be resolved: Should a face plate be worn throughout the flight? Information then available[7] indicated 12 to 16 seconds of useful consciousness follow-

*The capsule atmosphere was circulated through an outboard unit containing beds of LiOH for CO_2 absorption and beds of LiCl, then $Mg(ClO_4)_2$ for moisture absorption.

ing rapid decompression. *Manhigh* pilots learned to don the face mask in 6 to 9 seconds, theoretically leaving a 3 to 7 second margin. Wearing the face plate constantly would require development of a much more difficult "personalized" closed system, precluding a capsule atmosphere system.

ATMOSPHERE SELECTION

As a result of the basic decisions, the questions of preflight pressure check and the necessity for bends protection arose.

Experience with the sealed animal capsules had repeatedly demonstrated the importance of checking the capsule immediately before flights to detect any leaks. The wisdom of this approach was confirmed when, on several ground tests, the capsule had to be pressure-checked two and three times before a satisfactory seal was obtained. If the operating pressure and altitude is about 6 or 7 pounds per square inch (psi), the capsule can be pressurized to its full operating pressure at ground level with a total pressure of approximately 21 pounds per square inch absolute (psia) or 6 pounds per square inch gauge (psig) sea level. Because the capsule structure was designed and tested at 15 psig, an operating pressure of 6 psig would provide a safety factor of better than 2.5. It would be a complicated and time-critical procedure to attempt to change the composition of the atmosphere during ascent. This approach was given no further consideration; however, the composition of the atmosphere when the pilot experienced the high 21 psia pressure during pressure check required careful consideration.

The second question was that of bends protection. It is well established[5] that bends appear in from 10 to 30 minutes after acute exposure to high altitude depending on the degree of denitrogenation and individual differences. Should rapid decompression occur at ceiling altitude it would take at least one hour, possibly several, to descend to less than 20,000 feet. Even with the emergency capsule parachute it would take nearly half an hour to reach this level from 100,000 feet. The flight was an effort to explore the problems of satellite flight. Because it is unlikely that a crew member could return this quickly in an orbiting satellite, the atmosphere was selected in terms of satellite requirements so that the crew member would not experience bends with sudden complete loss of cabin pressure. This should apply if depressurization occurred during ascent, or if he remained at altitude for several more hours.

To select an atmosphere, the interrelations and implications of the total pressure, the oxygen concentration, and the inert gas were considered in terms of the objectives defined above.

Total Pressure.—With the thin lightweight capsule shell selected, a total atmospheric pressure of approximately 5.5 psi, equivalent to 25,000 feet, would provide a little better than a 2.5 safety factor. A higher pressure with that safety factor would have required a heavier shell.

It is axiomatic among drivers that decompression which does not exceed a pressure ratio of 2 to 1 should not produce bends. The MC-3 pressure suit operated at an altitude equivalent of approximately 40,000 feet. Cabin pressurization corresponding to any altitude between 25,000 feet and 40,000 feet would result in a decompression that remained within the 2 to 1 ratio. Experiments have shown[1] that with a constant oxygen partial pressure the fire hazard steadily increases with decreasing total pressure. This encourages the selection of the highest total pressure consistent with other considerations.

To ensure that the pilot would not experience serious bends if a rapid decompression occurred when he first reached ceiling altitude, it would be necessary for him to denitrogenate on 100 per cent oxygen four hours before launch.[5] Inasmuch as the pilot was sealed into the capsule about 8 hours before launch, it was sufficient to provide an atmosphere low enough in nitrogen to permit effective denitrogenation through the prelaunch period. The lower the total capsule pressure at altitude, the higher the percentage of oxygen required and, therefore, the less inert gas would be in the capsule at ground level before launch. The composition of the capsule atmosphere was expected to change very little after launch, but if anything, would gradually increase in percentage of oxygen.

The physiologic effects of rapid decompression *per se* were also considered in selecting the cabin pressure. The lower the cabin altitude (the higher the pressure), obviously the greater the hazard of rapid decompression. Failure of one of the capsule shell Marmon clamps would instantaneously divide the capsule into two portions, creating the most severe decompression possible in this system. Assuming a total pressure of 5.5 psi and using the method of Haber and Clamann,[4] the time constant for decompression time of the capsule is approximately 0.005 second which gives a total decompression time of 7 to 10 milliseconds.

What this would mean in terms of lung damage and time of useful consciousness must be extrapolated from other data. Bancroft[2] has shown that decompression from 200 mm. Hg. to 50 mm. Hg., or less, causes an immediate and severe drop in systolic and diastolic blood pressure. With decompression to 35 mm. Hg., this occurs in a few seconds, and the dogs so exposed maintained only 10 mm. Hg. pulse pressure. This may reflect bubble formation in the left ventricle which would produce circulatory stasis. This lack of circulation should reduce significantly the time of useful consciousness below the 12 to 16 seconds observed with decompression to lower altitudes. In addition, a decompression this rapid could well cause considerable confusion and discomfort, if not more serious injury.

The time constant for the 5½-inch diameter window orifice is 0.22 second. This leads to an effective decompression time of 300 to 500 milliseconds from 25,000 to 80,000 feet, assuming the air volume of the capsule to be 40 cubic feet. Decompression times to altitudes beyond 80,000 feet are probably of little physiologic significance. Because the time-constant of human lungs is about 0.6 seconds, it is significantly greater than in either situation examined. In either case, a higher capsule pressure with more rapid decompression and greater changes in pressure would be distinctly undesirable. A total cabin pressure of 5.8 psi (300 mg. Hg. equivalent to an altitude of 23,500 feet) was selected.

Oxygen Concentration. — Having established the total pressure, it is necessary to select a percentage of oxygen that will provide a minimum alveolar oxygen partial pressure of 100 mm. Hg.[1] at a total pressure of 280 mm. Hg. This requires 60 per cent oxygen in the inspired air. On the *Manhigh II* flight a value of 160 millimeters of oxygen partial pressure was attained as the flight reached ceiling altitude. This provided 61 per cent oxygen. This high percentage of oxygen served as an advantage by helping the pilot to eliminate nitrogen before flight. It did require, however, that the pilot experience an oxygen partial pressure of 500 mm. Hg. during the process of establishing the atmosphere on the ground.

Inert Gas.—The remaining 40 per cent of the capsule atmosphere, representing 120 mm. Hg. partial pressure, must consist mostly of an inert gas. Roth[8] exhaustively examined the relative advantages and disadvantages of the various inert gases from a theoretical point of view. He concluded that the maximum bubble size and symptom frequency after decompression theoretically should be an inert gas factor expressed by:

$$(\text{solubility in oil})^2 \times \frac{\text{diffusion coefficient in oil}}{\text{solubility in water}}$$

Comparing helium, neon, argon, krypton and zenon with nitrogen, he concluded that helium should produce only one-fourth the symptoms and neon, five-sevenths of the symptoms that nitrogen would after rapid decompression. Theoretical values for nitrogen and helium correlated well with the frequency of symptoms observed after decompression.

Helium has four times the heat conductivity of nitrogen and, therefore, is preferable during the daytime when maximum transfer of heat from the pilot to the capsule atmosphere is desirable. This is a disadvantage at night when the capsule becomes cold and the pilot needs to conserve heat.

The increased vocal pitch produced by helium is temporarily annoying until the subject learns to lower the pitch of his voice to compensate for the helium effect. This increase in pitch is apparently due to the reduced impedance provided by helium to the vibration of vocal cords set to their normal length and tension. Helium has one-seventh the density of nitrogen. The fact that helium has 2.57 times the diffusion rate of nitrogen would make it correspondingly more difficult to retain in a sealed cabin; because it constitutes only a part of the total atmosphere this effect is reduced to a secondary consideration. This high diffusion rate permits its prompt elimination from the body during ascent.[9]

Helium appears to reduce significantly the likelihood of the pilot experiencing dysbarism in the event of emergency decompression. However, in addition to the increased leak rate which it would cause, the physiologic effects of applying helium as an inert gas were not well established at reduced total pressure for a long period of time. On this basis, an inert gas composition of half helium half nitrogen was selected[9] to reap some of the advantages of helium without blundering into unexpected problems if nitrogen was eliminated completely.

Archibald[1] has described in detail the procedure he devised to denitrogenate the pilot and establish an atmosphere of approximately 60 per cent oxygen, 20 per cent helium, and 20 per cent nitrogen. Helium was introduced by pressurizing the capsule to 20 psia with it, observing the capsule for leaks, and then releasing the pressure and discharging nitrogen with it. Oxygen was introduced into the capsule atmosphere, and the pilot denitrogenated by having him breathe 100 per cent oxygen through the pressure suit helmet.

FLIGHT EXPERIENCE

A primary purpose of the *Manhigh II* flight was to make observations of the new environment. To survive in space, a pilot must also constanly monitor any changes in his capsule atmosphere. The earlier an indication of malfunction is detected and properly interpreted, the better are the chances of coping with it. In solo space flight this becomes even more critical. In the absence of complicating factors, the percentage of oxygen and inert gases within any sealed cabin should remain constant throughout flight. During the *Manhigh II* flight the composition did change.

The *Manhigh* capsule atmosphere was established more than eight hours before flight at the ambient atmospheric pressure of 750 mm. Hg. The pressure of the capsule atmosphere was controlled by the Firewel regulator. This control device vented capsule atmosphere to the outside whenever the external pressure dropped below the internal pressure. It automatically stopped venting and maintained the internal pressure at the value selected for flight (300 mm. Hg. or 5.8 psig). The capsule pressure began to vent immediately after launch and stabilized at 300 mm. Hg. by 44,000 feet, 20 minutes after the capsule passed through 24,000 feet, the altitude of equivalent pressure.

The regulator was designed to maintain this internal pressure by releasing oxygen from the liquid oxygen system. Valves were provided to permit operation of the overboard vent and the oxygen converter by manual control only. Fundamentally, the sealed cabin atmosphere system would operate in the same manner whether it was on automatic or manual, except that under manual control the limits of excursion in capsule pressure would be up to the pilot. Also, the pilot would know when gas was vented overboard to relieve capsule pressure. This tended to occur because the rate at which oxygen vaporized from the converter due to heat leaking into it was slightly in excess of the pilot's metabolic needs.

The capsule atmosphere was measured on the *Manhigh II* flight in terms of total pressure, oxygen partial pressure and temperature. The total pressure was expected to indicate the function of the automatic regulator, or to guide the pilot in case the system was operated manually.

The Beckman oxygen analyzer was essential for monitoring and establishing the desired per cent of oxygen in the atmosphere. It served as a double check on the total pressure gauge insuring sufficient oxygen. Should the capsule develop a leak while on automatic regulator, it should first be detectable by an increased partial pressure of oxygen due to loss of irreplacable inert gas through the leak. The total pressure and temperature were recorded on the photo panel, but the oxygen partial pressure was reported only by the pilot so these readings are available only when included by the pilot in his semihourly pilot reports. The capsule air temperature was needed for evaluation of the temperature control and in the interpretation of changes in capsule pressure.

The oxygen quantity gauge had a course calibration that served to indicate roughly the status of the oxygen supply, but was considered too insensitive to reveal the loss of oxygen due to a leak unless it was an already critically large one.

The air regeneration blower was turned on throughout the flight so any changes in carbon dioxide or water vapor partial pressure should have occurred slowly.

The following abbreviations are used in the following discussion:

P_T Total pressure in capsule—mm. Hg
P_{O_2} Oxygen partial pressure—mm. Hg
P_{H_2O} Water vapor partial pressure—mm. Hg
P_{CO_2} CO_2 partial pressure—mm. Hg
P_I Inert gas partial pressure—mm. Hg
T Capsule air temperature—°R.
$O_2\%$ Per cent oxygen in capsule—%
I% Per cent inert gas in capsule—%

Before considering the changes observed in the capsule atmosphere during flight, the factors which tend to increase and decrease the capsule pressure (Table I) will be reviewed.

TABLE I. FACTOR WHICH CHANGE TOTAL PRESSURE IN CAPSULE

Reduce	*Increase*
A. Leak	1. Increase in T
B. Decrease in T	2. O_2 Released
C. No O_2 supply	3. Increased P_{H_2O} or P_{CO_2}
D. Metabolism	
E. Pressure bleed	
F. Decreased P_{H_2O} of P_{CO_2}	

The tendency for capsule pressure to decrease due to a leak, factor A (Table I), is masked if the regulator is on automatic maintaining a normal capsule pressure from the oxygen supply. The magnitude of pressure change with change in temperature, factor B, may be computed from

$$P_{T'} = \frac{P_T T'}{T}$$

where P_T' is the final pressure, P_T the initial pressure, T′ the final temperature, and T the initial temperature. Dryden, Han, Hitchcock and Zimmerman[3] measured metabolic rate, factor D, during flight obtaining 400 to 600 cc. per minute. Five hundred cc. per minute should be a maximum average figure during a balloon flight. Pressure bleed, factor E, refers to venting or dumping a part of the capsule atmosphere to the outside to prevent over-pressurization of the capsule. Inasmuch as the total pressure is the sum of all partial pressures, reduction of any one will reduce the total. Thus any reduction in P_{H_2O} or P_{CO_2} will reduce the P_T by the same value.

In the *Manhigh* system, change in the O_2 per cent was considered the most sensitive indicator of a capsule leak. The situations listed in Table II would tend to increase or decrease the O_2 per cent.

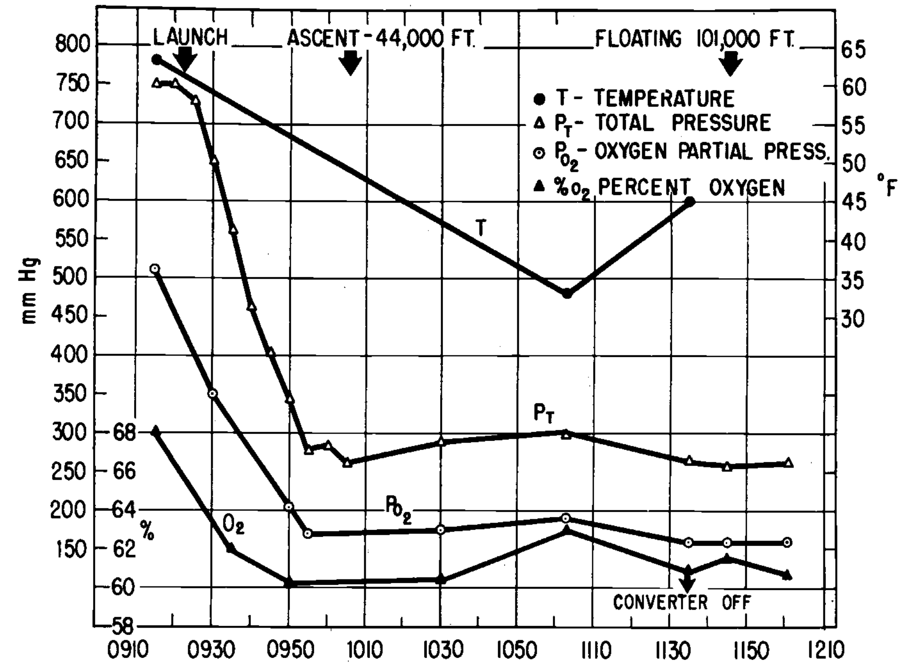

Fig. 1. Capsule atmosphere during ascent on the *Manhigh II* flight on August 19, 1957.

A leak, factor A in Table I, represents a permanent loss of irreplaceable inert gas resulting in a real increase in O_2 per cent if the pressure is maintained from the oxygen supply factor 2. The B + 2 combination would produce an increased per cent of oxygen as long as the temperature remained low. This can be considered an apparent increase in O_2 per cent because it returns to its original value if the increased pressure produced by rewarming the capsule is reduced by metabolic oxygen consumption rather than venting capsule atmosphere. P_T was read to the nearest 10 mm. Hg. and P_{O_2} to the nearest 5 mm. Hg. The combined error was ±7.5 mm. Hg. At operating pressures during flight, values for O_2 per cent are valid to ± 2 per cent.

Ascent.—The values obtained for the atmosphere parameters during ascent are presented graphically in Figure 1. The pressure dropped to slightly below the expected value of 300 mm. Hg and the P_{O_2} stabilized at a satisfactory 63 per cent. The 8 per

TABLE II. FACTORS WHICH CHANGE OXYGEN PER CENT

Increase	*Decrease*
A + 2	C + D
B + 2	D (ascent)
F	3
	1 + D

cent drop in O_2 per cent from launch to 0950 was unexpected.

Assuming no O_2 entered the capsule, at 300 P_T the calculated O_2 per cent would decrease from 64.3 per cent to 60.5 per cent, a change of nearly 4 per cent, due to metabolism over a 30-minute period. This calculated decrease in O_2 per cent based on a D mechanism is only half the observed value. The observed decrease in temperature and any O_2 converter boil off would have tended to increase the O_2 per cent. There is no information to indicate the liquid oxygen converter boiloff varies markedly with time. If it were storing heat through this period to be released as oxygen later it would give the effect during the storage period of a C + D situation. Part of the large drop in O_2 per cent during ascent may be accounted for by the low accuracy of the original data. Since several P_{O_2} readings before launch and after 0955 were consistent this discrepancy is probably not an observational error.

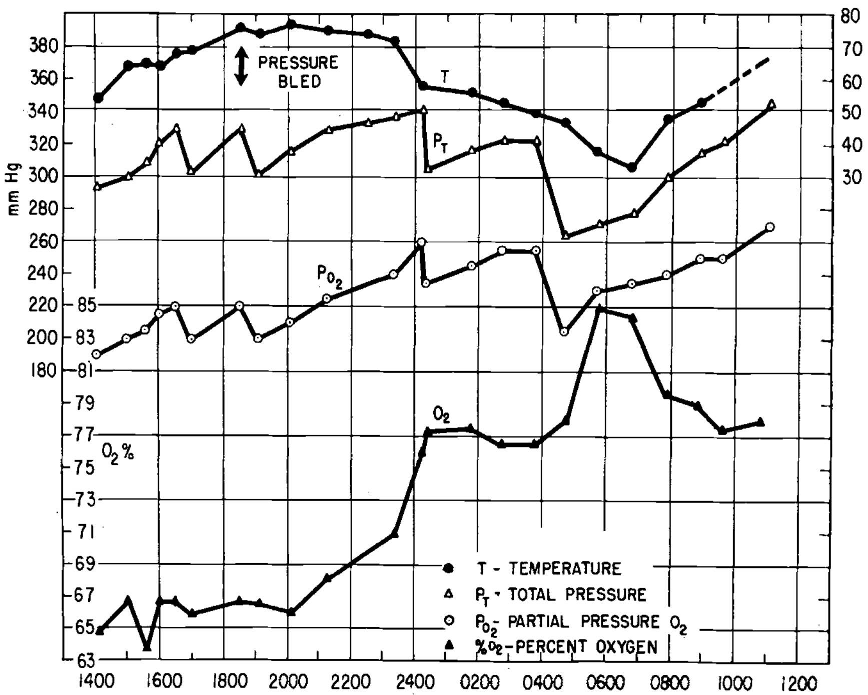

Fig. 2. Capsule atmosphere while at altitude during the *Manhigh II* flight on August 19-20, 1957.

A B+2 situation is illustrated between 1030 and 1100 hours in Figure 1. Not only was the temperature dropping, but the loss of capsule pressure which should have occurred was more than compensated for by O_2 from the converter. The magnitude of change in the O_2 per cent is larger than expected for the observed changes in P_T and T.

The Firewel regulator had shown

a tendency to hunt during ground tests and the oscillation of P_T between 0950 and 1135 hours suggested it was again hunting. The flight physiologist in the ground command van and the pilot agreed that the regulator and oxygen converter should be placed on manual operation. This was done for the remainder of the flight at 1135 hours of the first day.

At Altitude.—Throughout the period that the flight remained at altitude, whether the capsule became warmer or cooler, the P_T (Fig. 2) consistently showed a slow rise until the pilot bled capsule pressure to the outside reducing it to the desired 300 mm. Hg. This produced the four precipitous drops of P_T at 1630, 1830, 0015 and 0330. Inasmuch as the Firewel regulator was not operating on automatic, the increase in P_T must have been derived primarily from the fact that the boiloff of O_2 from the liquid O_2 converter exceeded the metabolic demands of the pilot.

The oscillation of the O_2 per cent between 1400 and 1600 illustrates the ±2 per cent variation one can expect from gage inaccuracies.

One would not expect any apparent change in O_2 per cent during the quickly executed manual pressure bleed since proportionate parts of all atmosphere components are lost. However, as the pressure builds up again, the O_2 per cent should increase slowly if the pressure increase is produced solely by accumulating O_2. Numerically this would amount to an increase of 3.1 per cent of oxygen between 1700 and 1800 hours (Fig. 2). This value was derived in terms of the per cent of inert gas lost by pressure bleed. A similar loss of inert gas occurred at 1900. When the total pressure returned to its initial value of 330 mm. Hg. at 2100 hours one would have expected the O_2 per cent to have increased approximately 6 per cent. Since the temperature increased less than 10 degrees through this period, this magnitude of equivalent reduction of O_2 per cent cannot be explained on the basis of a 1 + D mechanism as will be shown numerically later.

The 20 per cent increase in O_2 per cent between 1400 and 0600 hours can be accounted for by the pressure bled to maintain capsule pressure. The two indications of rapid increase in O_2 per cent at 2400 and 0600 hours (Fig. 2) do not have an obvious explanation. If the oxygen converter suddenly released sufficient oxygen to produce an increase of several per cent the total capsule pressure should have increased correspondingly. The 14° F. decrease in temperature through this period could account for approximately 2 per cent increase in oxygen per cent based on a B+2 mechanism. It is not reasonable to expect a shift in P_{H_2O} or P_{CO_2} so quickly. These indications of rapid changes must have been largely instrumental error.

Between 0700 and 1100 hours of the second day (Fig. 2) values of O_2 per cent calculated from the reported data indicate a 6 per cent decrease. This appears to be a 1 + D situation in which pressure increase due to increasing temperature was offset by metabolic oxygen demands producing a decreased O_2 per cent. However, the 35° F. increase in temperature during this period would account for an increase of capsule pressure from 280 mm. Hg. to only 300 mm. Hg. It actually increased to 340 mm. Hg. and the value of O_2 per cent decreased 6 per cent.

The P_{H_2O} increases 9.2 mm. Hg. when conditions change from 35° F. and 40 per cent relative humidity to 70° F. and 60 per cent relative humidity.[6] This would account for an increase of capsule pressure to 310 mm. Hg.

A 1 per cent increase of carbon dioxide would correspond to a P_{CO_2} of 3.0 mm. Hg. This would account for a total pressure of 340 mm. Hg. At 1100 hours, a 3 per cent carbon dioxide level was measured. If this accumulation of CO_2 occurred entirely after 0700, which is unlikely, 3 per cent of the capsule volume would have been displaced by CO_2, and could account for 3 per cent of the decreased O_2 per cent using a 1+D mechanism. The remaining 3 per cent of decrease in O_2 per cent may be accounted for at least partly by instrumental error.

DISCUSSION

In early space missions of several days' duration there will necessarily be a limited reserve of oxygen. The more closely the composition of the atmosphere is monitored, the better command the astronaut will have of its condition including the regeneration system, and the earlier he can detect a leak of the capsule or other difficulties.

An accurate sensitive oxygen-quantity gauge would be very helpful in the early detection of a leak, but not the whole answer because changes in other factors, such as temperature, can temporarily increase oxygen demand to give the appearance of excessive flow. Changes in the percentage of oxygen should be an even more sensitive indicator. The manual operation of the atmosphere controls during the period at altitude during the *Manhigh II* flight greatly facilitated interpreting changes in the atmosphere. If similar evaluation of a flight that used the automatic regulation was desired, measurement of the volume of gas vented *vs* time would be most helpful.

Considerable difficulty was encountered interpreting the excessive decrease in O_2 per cent during ascent, the rapid increase in O_2 per cent at 2400 and 0530 hours of the second day, and the excessive drop in $\overline{O_2}$ per cent the second morning. The interpretation of the data would have been greatly facilitated and ambiguities resolved if volume output of the oxygen converter (including boiloff) had been available. Rate of flow, alone, might not be sufficient because of the danger of not noticing the flow rate during a short period when it is high. This is particularly true of an automatic demand system. The importance of measuring the cumulative volume output of the converter would be even greater if there was no measurement of the volume of gas bled from the capsule. In any case, a much clearer picture of the factors influencing a sealed cabin atmosphere and their relative importance will emerge if the data obtained is three times more accurate.

In addition to the parameters previously measured, direct knowledge of the P_{H_2O} and P_{CO_2} will help. If full advantage is to be taken of all the information thus obtained during a flight it may well be necessary to feed it to a small computer which accounts for the interacting factors and than indicates to the pilot whether there is any malfunction. As an alternative, the data could be telemetered to the ground and the ground personnel return their interpretation of it to the astronaut.

SUMMARY

The factors involved in the selection of a sealed cabin atmosphere for space flight are so numerous and some of the trade-offs so close that the final decision must be based on the specific needs of the mission concerned. The needs of the *Manhigh* flights lead to the selection of a cabin total pressure of 300 mm. Hg., 60 per cent oxygen, 20 per cent helium, and 20 per cent nitrogen. The factors tending to decrease capsule pressure include a pressure leak, decrease in temperature, absence of oxygen supply, animal metabolism, pressure bleed, and decrease in P_{H_2O} or P_{CO_2}. Seven ways in which these factors can combine to change the oxygen per cent are related to its changes during the *Manhigh II* flight. The ambiguities and uncertainties arising from the attempt to interpret the available data would have been greatly reduced if: (1) accuracy of measurements had been increased by a factor of three; (2) the cumulative volume flow from the oxygen supply had been measured; and (3) the P_{H_2O} and P_{CO_2} had been measured directly. Instrumentation that permits the astronaut to know at all times what is happening to his atmosphere will be very important in extended space flight.

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