

AMRL-TDR-63-82

FOREWORD

The design concepts reported herein were developed by Henry W. Seeler, M.E., Chief, Design and Fabrication Branch of the Biotechnology Division, Biomedical Laboratory. The work was performed in support of 6570th Aerospace Medical Research Laboratories Project No. 6373, "Equipment for Life Support in Aerospace," Task No. 637305, "Analysis and Integration of Life Support Systems."

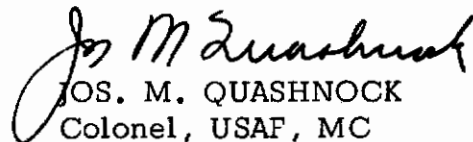
# *Contrails*

## ABSTRACT

A concept for a complete emergency life sustaining system for use during failure of the normal pressurization system in a spacecraft is advanced. The system includes four components: (1) an astronaut's uniform with a built-in mechanical pressurization system, (2) a pressure-breathing demand-regulator, (3) an automatically actuated system of solid chemical oxygen candles, and (4) a one-man compression tube. This system has been partially fabricated and appears worthy of further development.

## PUBLICATION REVIEW

This technical documentary report is approved.

  
JOS. M. QUASHNOCK  
Colonel, USAF, MC  
Chief, Biomedical Laboratory

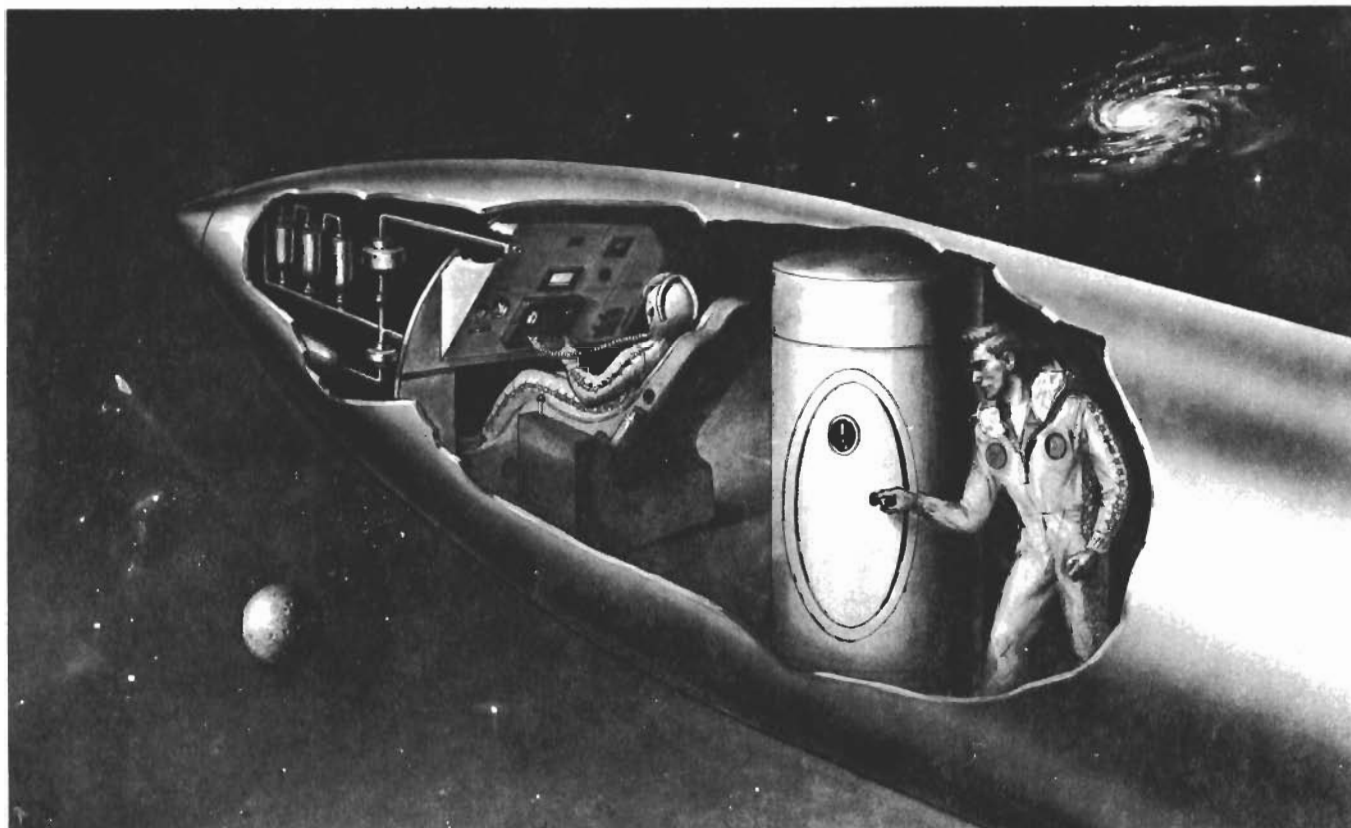


Figure 1. Artist's Concept of the Emergency Life Sustaining System for Spacecraft

## **EMERGENCY LIFE SUSTAINING SYSTEM FOR SPACECRAFT**

**Henry W. Seeler, M.E.**

### **INTRODUCTION**

This report presents a concept for a complete emergency life sustaining system for use during failure of the normal pressurization system in a spacecraft. The emergency system would operate automatically if the life support system were to fail, e.g., as the result of cabin structural damage. The emergency system would be completely separate from the main life support system and would make reentry of the earth's atmosphere possible.

The artist's conception, figure 1, shows the four major parts of the emergency life support system. Other life support equipment and instruments necessary for normal space flight are not shown. The first component of the system is the astronaut's uniform with a built-in mechanical pressurization system. The helmet

or hood of the uniform normally would be worn folded around the neck like a collar. Upon cabin decompression, the hood would inflate and automatically enclose the head. The uniform has been conceived as a compromise between the full pressure suit and the "shirtsleeves" idea. To require the astronaut to wear a full pressure suit for protection during an entire mission lasting for days or weeks would place a great demand upon his ability and strength. Conversely, while traveling on space missions in shirtsleeves may sound fascinating, what would occur in case of sudden decompression? Although the shirtsleeve space mission may eventually become a reality after we gain more knowledge of outer space, a safer, more conservative approach must be made in the meantime. The second part of the system is a pressure-breathing demand-regulator with a built-in forced breathing device. In event of physical weakness of the astronaut, the regulator would control his breathing as long as oxygen is available. The third component is an automatically actuated system of solid chemical oxygen candles. These are commercially available chlorate candle oxygen generators that have an indefinite shelf-life (ref. 1). Since this system is not under pressure until it is used, oxygen cannot leak from porous pipes or faulty connections. The fourth emergency item is the one-man compression tube. During normal flight, this tube could be used as a toilet, but after or during decompression of the spacecraft, it can be used for multiple compressions. Its uses include an area where the astronaut can change from his uniform into a full pressure suit, a toilet, a place to rest without the burden of a full pressure suit, and possibly as an airlock.

## **DESIGN AND OPERATION OF THE FOUR EMERGENCY ITEMS**

### The Uniform and Helmet

The basic idea for the proposed astronaut's suit was taken from the partial pressure suit, MC-4, (ref. 2), except that the astronaut's suit has no capstans and is tailored more like a uniform. The capstans were omitted because of the possibility of leakage and loss of irreplaceable oxygen. In addition, for a stylish looking uniform the capstans would be out of place. Pressure is evenly applied against most areas of the body by pulling mechanically on self-adjusting lacings, subdivided around the torso, arms, and legs. A preliminary design of the suit and details of the pressurization lacings are shown in figure 2. The lacings glide through ball-bearing-based rollers having as little friction as possible. The pull action of the lacings is altitude- or cabin-pressure controlled and is actuated by springs, or other means of tension, located in housings on the uniform. The uniform material must be inelastic in the transverse plane, e.g., around the leg. The first handmade model of the leg lacings with ball-bearing-based rollers is shown in figure 3. On the left, the model is shown without tension, and on the right, with the lacings pulled tight. This model has proved the feasibility of the basic idea, but is, of course, open for improvements.

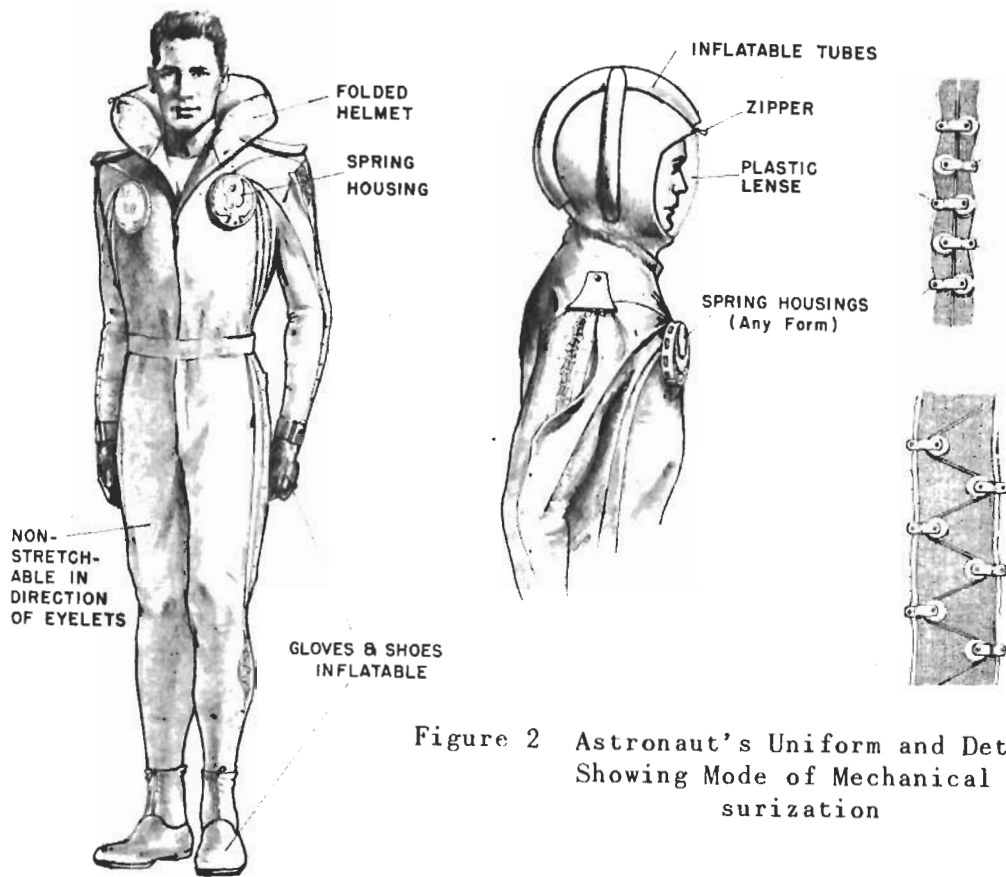
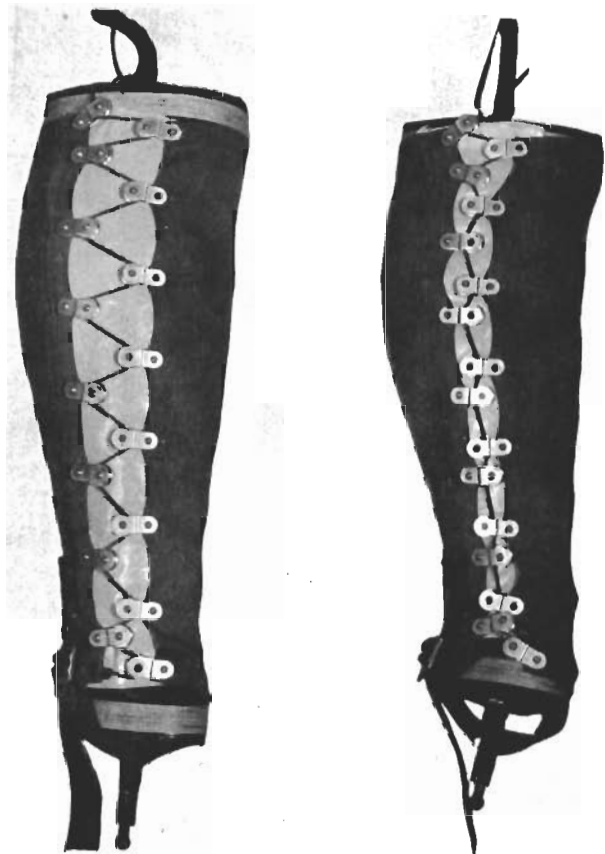


Figure 2 Astronaut's Uniform and Details Showing Mode of Mechanical Pressurization

Figure 3

Prototype of Mechanical Lacings

The model on the left is shown without tension, and on the right, with the lacings tightened.



Mechanical pressurization of all parts of the body not fully protected by the suit tension—depressions of the arms, legs, etc.—is provided by specially shaped foam rubber with closed cells or closed bags with foam rubber inserts for volume control. This method has been used successfully in oxygen mask tension devices (ref. 3) as shown in figure 4. In the oxygen mask, pads are inserted between the occipital area of the pilot's head and helmet where the decreasing ambient air pressure allows the trapped air in the cells to expand, thus increasing mask tension (figure 5). To maintain efficient ventilation between the suit inserts and the body, the inserts should be placed between the outer uniform material and the lining. The lining must be fabricated from porous material in order to ventilate the man without special ventilating equipment.

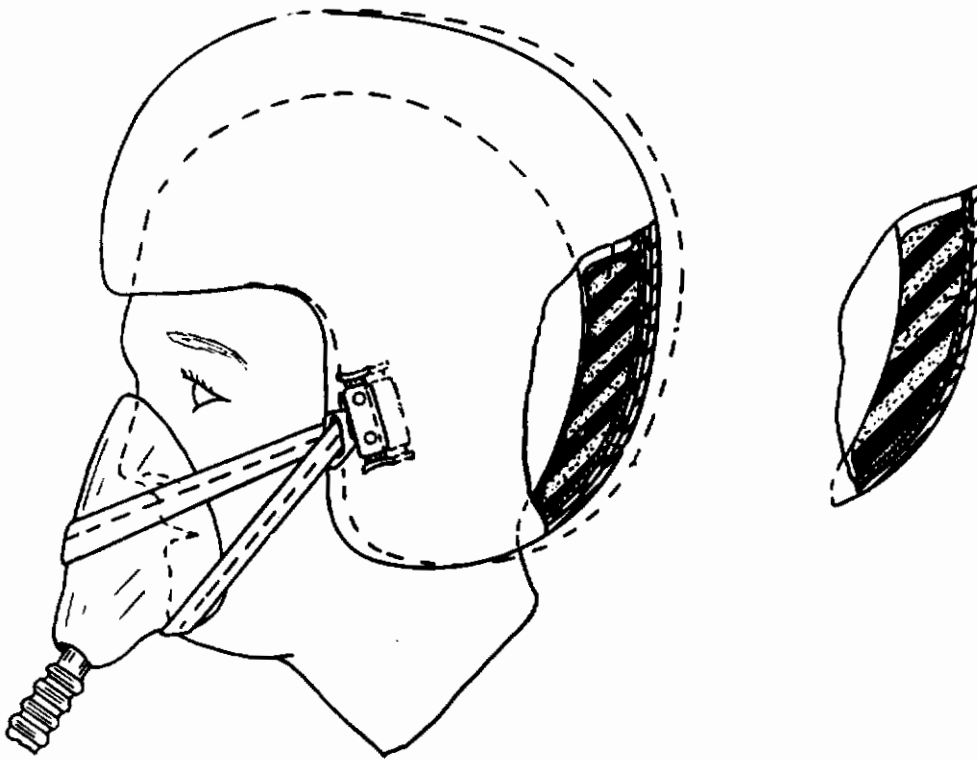


Figure 4. Mask-Harness Tension Compensating Device

The astronaut's head will be pressurized by an inflatable helmet. Normally this helmet would be worn folded around the neck. In event of decompression, pre-formed tubes in the helmet would inflate and enclose the head. The flexible lenses would be closed with a leakproof zipper. For safety reasons, a pressure-sensitive zipper is planned to eliminate the manual operation. Figure 6 shows a prototype of the pressure hood.



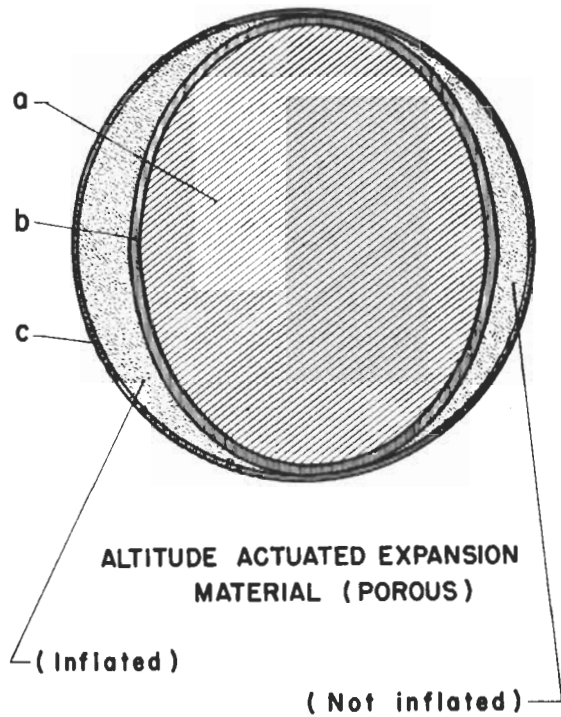


Figure 5. Cross-Section Through Arm Illustrating Principle of Pressure Protection for Depressed Areas of the Body

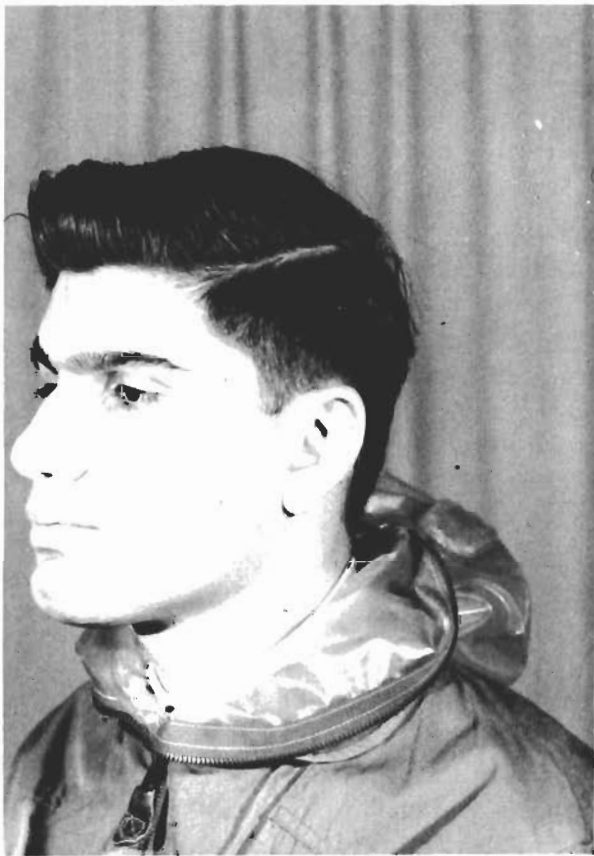


Figure 6. Prototype of the Inflatable Helmet

The subject on the left is shown wearing the hood uninflated and on the right, inflated.

### Combined Pressure-Breathing Demand and Intermittent-Forced Breathing and Pressure Suit Oxygen Regulator

For maximum use of oxygen during an emergency reentry, a special oxygen regulator must be designed for use with the combined uniform/pressure suit. It should be a pressure-breathing demand-regulator with counterpressure balance to the torso bladder. It should deliver sufficient pressure, connect to all suit bladders, and, possibly, should be designed to connect with the full pressure suit, A/P 22 S-2. It should also change automatically from pressure-demand to forced, automatically controlled, intermittent positive pressure with counterpressure balance to the torso bladders if the astronaut's breathing should fail. This means that during inhalation, less pressure would be applied on the torso bladder than in the helmet; during exhalation, vice versa. Further, the regulator should control the breathing demand for either normal or accidental conditions, as well as the compensated pressure for the uniform/pressure suit bladders. It should work with both open and closed-circuit demand-breathing systems.

### Emergency Chlorate Oxygen Generating System

The emergency oxygen generating system must be wholly independent of any life support system planned for use within the pressurized spacecraft. This is especially true, since all conventional systems are designed to operate while the cabin is pressurized and would be insufficient or would not operate in case of cabin decompression. Upon decompression, the chlorate candle installation would immediately start generating oxygen automatically.

Figure 7 is a diagram of the emergency oxygen system. The decompressed cabin pressure is sensed through the tube opening (a), the tube (b), and the sensor or igniter mechanism (c). Here, the first chlorate candle (d) with a large diameter for fast reaction will regenerate oxygen after ignition by the firing mechanism. Oxygen pressure will build up and flow through the tube (e), the check valve (f), into the line system (g), to the oxygen regulator (h). The two-way pressure control valve (i) prevents oxygen from flowing into the storage cylinder (j) before approximately 60 psi is built up within the line system. Sixty psi pressure should be developed to be fed into the pressure breathing- and suit-bladder regulator. After the pressure builds up to 60 psi, the additional oxygen may flow into the storage cylinder for further use. Simultaneously with the pressure build-up in the line system, the oxygen pressure will flow to the ignition or firing valve (k) on top of the next chemical oxygen candle (s) and preload it for the next ignition. This will occur as soon as the oxygen pressure within the system is used up to a predetermined lower pressure value. After the second candle is ignited by the valve (k), oxygen will generate and flow through the check valve (l) and the pressure within the system will build up again and simultaneously preload the next ignition valve (n) by flowing through the tube (m). The cycle may be repeated and repeated until all candles, which may be numerous, are used up. By adding more, or exchanging used oxygen candles during flight, the oxygen generation can be prolonged.

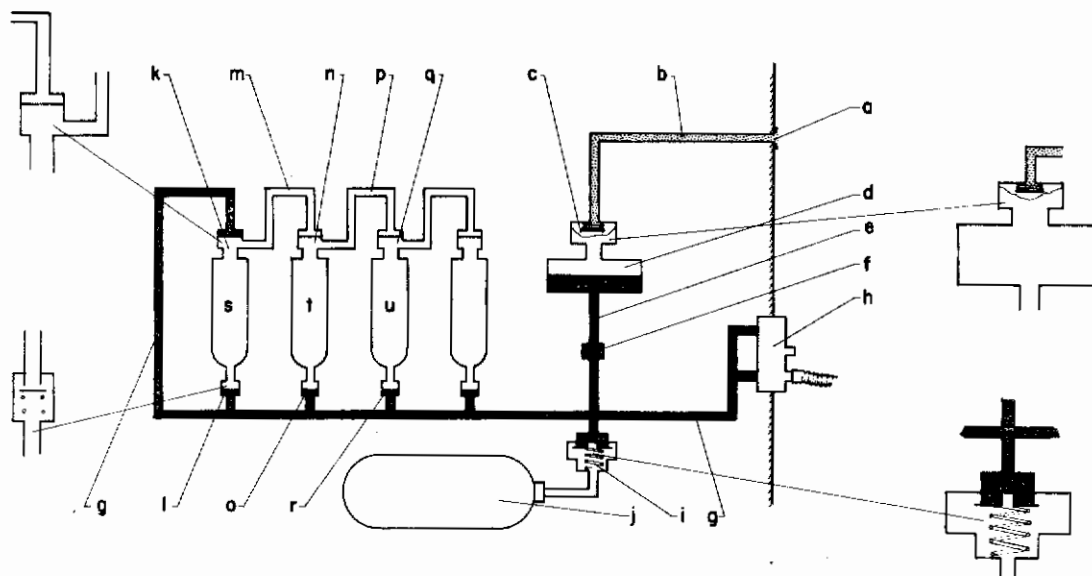


Figure 7. Emergency Chlorate Oxygen Candle System  
(Pneumatically Controlled)

In addition to pressure-controlled ignition valves, the oxygen candles could also be ignited electrically or by a combination of both. For safety reasons, electrical ignition, alone is not recommended for use in a space vehicle.

### Emergency Compression Tube

A small one-man compression tube is proposed for long range spacecraft (figure 8). During normal operation, this tube could be used as a toilet. After cabin decompression, it could be pressurized repeatedly and used for the same purpose. In addition, the astronaut could use it while changing or removing his uniform and donning a full pressure suit.

In an emergency, the astronaut would enter the compression tube (x) through the opening (a) connect his helmet tube to one of the chlorate oxygen candles (e) and then push the firing button (d) of the same candle. He would then close the sliding door (b) from inside the compression tube. In the meantime, oxygen would generate and pressure develop to 5 psi by means of one fast acting oxygen generation candle within the candle housing (e) to pressurize the helmet or hood of the astronaut's combination uniform/pressure suit. Rapidly rising pressure, exceeding 5 psi, would flow through the 5 psi adjusted relief valve (r) into the compression tube (x) and build up 5 psi pressure within the compression tube in 4-5 minutes. After equalization of the pressure within the helmet and compression tube, the astronaut could remove his suit, use the rest facilities, put on a full pressure suit, etc. Each single used chlorate candle within the battery (e) could be exchanged for a new one by turning the bayonet candle holder (f) a quarter to the left, taking out the used candle, and putting in a new one. Each candle would be independent from the others.

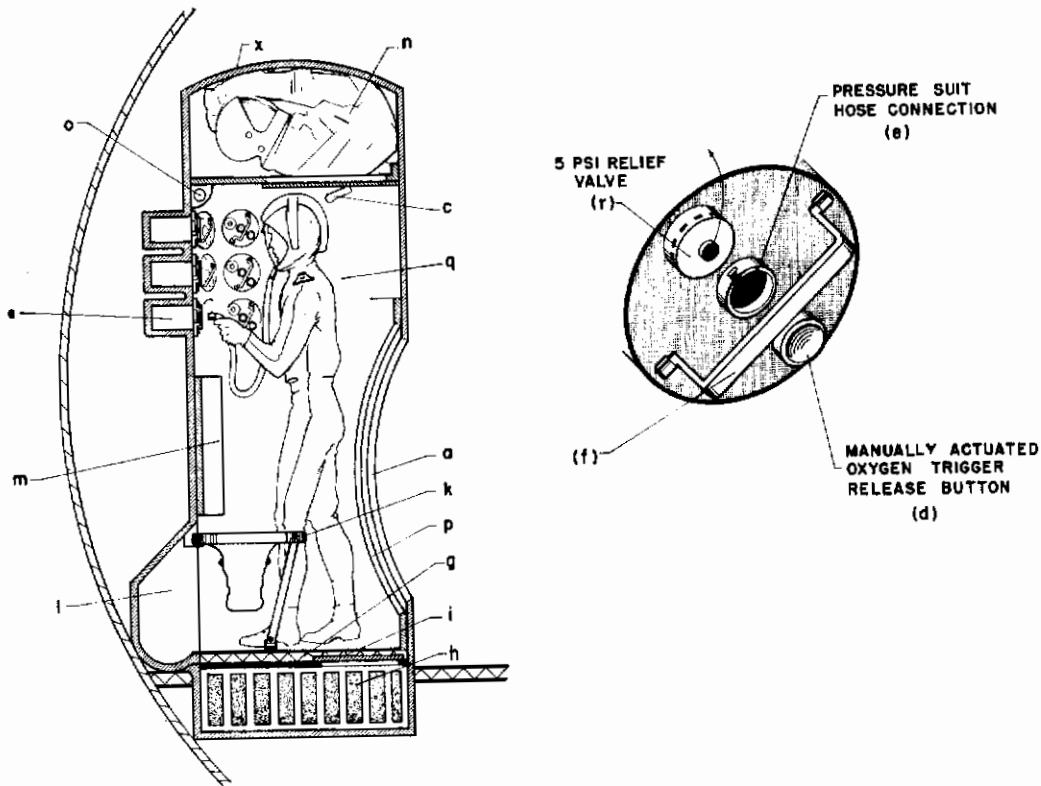


Figure 8. One-Man Compression Tube

One part of the compression tube, for instance, below the floor (g), could be filled with a carbon dioxide absorbent agent (h), or even better, with an agent such as potassium superoxide, which absorbs carbon dioxide and releases oxygen. When the main compression tube door is closed, a small compartment door (i) opens simultaneously into the carbon dioxide absorption chamber (h). The reverse occurs when the main door is reopened. Exposure of carbon dioxide absorption material can, of course, be accomplished by other means.

So that the astronaut's movement in the tube would not be restricted, the space toilet (k) could be lowered and pushed into a compartment (l) of the tube, and the compartment closed by a sliding door (m). A storage chamber (n) could be used for storing a full pressure suit, etc. A small battery-powered bulb (o), which could be turned on automatically as the astronaut enters the tube would supply enough light for changing suits, etc.

The one-man compression tube could also be designed for use as an airlock for leaving and entering the spacecraft while in space. As previously described, each compression could be accomplished with one chemical oxygen candle. The same action would be attained if the tube were used as an airlock without disturbing the interior life support pressure system. The airlock could accommodate a

second door for leaving and entering the ship or the whole unit could utilize one door and be turned approximately 60 degrees between entering the tube and leaving the spacecraft or vice versa. This tube is only in the initial design stage and may be modified to include many more functions or used as a solution for other problems.

### **SUMMARY AND CONCLUSIONS**

The proposed independent four-part emergency life sustaining system for spacecraft consists of (1) an astronaut's uniform with a built-in pressure protective system; (2) a controlled pressure breathing rescue regulator; (3) a separate chlorate oxygen generating system; and (4) a one-man combined compression tube and air-lock. This system has been designed, partially fabricated, and appears worthy of further development.

### **LIST OF REFERENCES**

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