Papers on the Lunar Settlement

Engineering 6 : Pressure Suits

0. Introduction A man cannot survive unprotected in the vacuum of space. There are dangers other than asphyxiation to be protected against, and there are tasks to be performed other than mere survival. These considerations require a carefully-designed appliance to enable extraterrestrial living.

1. Fundamentals Without air in his lungs, a man will die rapidly. Without pressure against his midriff to allow him to deflate his lungs, he will be unable to breathe. Without pressure against his skin, subcutaneous moisture may boil, including blood, lymph, and even the contents of cells. Without insulation against heat gain and loss, he may be frozen or roasted. Without some kind of protection, he may even be hit by a meteorite. What is generically termed a pressure suit is intended to guard against some combination of these issues.

2. Current Art The earliest pressure suits were developed in the course the evolution of high-altitude flight. At first, to counteract the thinness of the air, aviators were supplied with bottled oxygen, increasing the quality of their breathing mixture. At higher altitudes, this became less satisfactory. Before cabin pressurization became practicable, and later on in military aircraft and others which might suffer damage, a different approach was taken. Possibly referring to the diver's "hard-hat suit", the aviator was encased in a kind of man-shaped balloon with a glazed helmet, immersing him in a heavier atmosphere.

For the aviator sitting in his cockpit, with some residual air pressure around him, this approach has proven satisfactory. Such is not the case for space travel. Balloon-type pressure suits proved unsuitable from the very beginning, and it is astonishing that they are still in use today.

The very first man to venture into naked space, Aleksei Leonov, discovered that the air pressure within his suit caused it to expand in the vacuum and become unpleasantly rigid. This "starfish effect" nearly kept him from returning from returning to his capsule, because he could not bend his limbs or trunk. American astronauts, using a lower pressure in their cabins and suits, had less of a problem, but even so the Apollo astronauts found themselves unable to properly bend down to pick up rocks. The NASA Space Shuttle astronauts have the worst of both worlds ; using a Russian-style heavy atmosphere in the orbiter and a light atmosphere in the suits, they require hours of decompression before and after going outdoors, in order to avoid caisson sickness.

3. Other Approaches The need for a new method is clear, but it has not yet been filled. Some parties have suggested "hard suits", metal shells yet more like divers' suits, using bellows joints to keep the volume from changing when the occupant moves about. While such suits would be able to hold any desired atmosphere, their mass would be even greater than that of today's pressurized fabric suits, and they would still greatly impede motion.

What is needed is a concept which would permit the wearer to do heavy work for extended periods without adding to his fatigue more than the unavoidable degree. Wernher von Braun once proposed a thing like a diving bell, studded with remote manipulators, less worn than operated or occupied. Such a device would certainly be useful for some situations, but it can hardly be described as convenient, much less light weight or easily produced and transported.

A suitable method is, however, known, and considerable research has been done on it. This is the elastic counterpressure garment, which relies on the observation that the pressure against the wearer's skin need not be air pressure.

4. The Counterpressure Suit It may be stated, generally, that pressure is pressure. Human skin is tough, and not extremely permeable, and it is capable of resisting vacuum to some degree, for some time. If it can be reinforced, its resistance can be increased. What is needed is the application of pressure, which can be done by mechanical means.

In its simplest form, the counterpressure garment is an elastic body stocking which squeezes the wearer's body with a pressure equal to that of the breathing atmosphere he is supplied. Of course, considerable elaboration is required to turn this cursory description into something usable.

First, without air pressure, volatile materials such as water and oil can still be drawn out through the pores into space, even if the overall pressure on the skin is sufficient. This calls for the incorporation of an impermeable layer in the suit. The same step seems called for to solve the problem of air leaking out from underneath the helmet, through the porous fabric. The head, we may say, will be immersed in air to protect the eardrums and eyes, and facilitate the use of the senses, even though something like a SCUBA mask could handle the air supply. The helmet, then, may require some kind of neck-seal to sit against the skin, which will meet the impermeable layer of the suit. Since this layer would be quite unpleasant against the skin, an inner comfort liner seems called for.

Even with the proposed Luna City atmosphere of only 30 kPa, a suit to apply this kind of pressure would be very constricting. In fact, however, no such thing is required. Water boils at 40° Centigrade under 7.5 kPa of pressure, and this is all that is required against the skin for safety, except in the area of the midriff where atmospheric pressure is needed to reinforce the diaphragm and permit normal breathing. Accordingly, the suit can be designed for an overall 10 or 15 kPa, with a cummerbund to apply the necessary addition.

Bunching and wadding of the suit will require careful tailoring and probably new methods of assembly, and fitting the hollow places of the body properly may require innovative undergarments as well. Since no amount of tailoring can compensate for the various changes the body undergoes continuously, adjustment must be provided, probably in the form of a system of cinches for best fit and tension. Of course, adjusting these each time the suit is worn would be awkward and imprecise, and a set of buckles or snaps to act as "quick-releases" for easy donning and doffing is certainly called for.

5. Auxiliary Equipment The pressure suit itself is not the whole story.

There is the portable life-support system which must be carried to supply the breathing air. There is the need for communication equipment, for tool storage, for thermal management. For all these purposes, additional facilities are needed.

A coverall garment, perhaps aluminized, would shield the suit and its wearer from the rays of the sun, from dust, and from the smallest of meteorites. This jumper or smock could be fitted with any variety of pockets, loops, snap fittings, Velcro, and other carrying facilities. It has become conventional to carry the portable life-support system as a backpack incorporating oxygen bottles and carbon-dioxide scrubbers, water, and the required thermal and sanitary appliances, along with power supplies and various equipment. While this seems as good an arrangement as any, some of these functions (batteries, for example) could be distributed to a harness worn over the pressure suit, or incorporated in the coverall.

The problem of heat and cold is not merely one of the sun, but also one of metabolism. Beyond the coverall, some cooling system is needed if the spaceman is not to be drenched in sweat. The solution adopted for balloon suits, running water through tubes either in an undergarment or in the suit itself, remains plausible, although some work with thermoelectric elements might be rewarding. A bigger problem is getting rid of the heat. The cycle used in the Apollo suits, which relied on boiling the cooling water off to space, can hardly be used. A phase-change material with a high latent heat, such as water ice, can be used as a "reservoir of cold", but the period of activity for the wearer will be limited by the capacity of this reservoir. He will need instruments to show how much margin he has left before the pack requires thermal, as well as electric, oxygen, and scrubber recharge. Packs or parts of packs can, however, be made demountable and interchangeable for more rapid turnaround.

Boots should probably not be relied upon for pressure, socks or the like being called for instead. Gloves, however, must be as thin as possible to allow satisfactory sensation and manual dexterity for performing tasks.

6. Emergencies Since the counterpressure suit will probably require individual fitting, reliance on it poses a danger when an area far from the suit storage area becomes depressurized, or rapid response is required. For this purpose, balloon suits in "one size fits all" or a small assortment of standard sizes may serve as a backup, kept folded in lockers, each with its oxygen bottle and a transparent hood instead of a helmet. Such devices require only a minimal capability.

7. Conclusion The problem of space garments has been examined, and a promising avenue of work identified. There is every reason to believe that practical examples of such a suit, so necessary for the success of the settlement, can be produced in short order.

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