SPACE SUITS FOR PROJECT APOLLO

Technological exploration brings man in contact with new and often hostile conditions. Sometimes these conditions are only exaggerations of the "normal" earth environment; however, man's exploration of space brings him in contact with environments so hostile and so different from those on earth that new protective clothing concepts must be developed to allow him to function effectively. This significant aspect of the lunar investigation of Project Apollo is the problem ILC Industries, Inc. of Dover, Delaware, was assigned as a prime member of the N.A.S.A. team.

Traveling to the moon represents a tremendous technical challenge and one of the outstanding achievements in modern history. To accomplish the objectives of Project Apollo man must leave the spacecraft and set foot on the moon. This is no routine task. When he enters that environment the simple is suddenly complex: ordinary physical movements require well engineered mechanisms to permit him to do such things as walk, breathe, climb a ladder, etc. Since the moon cannot sustain life he must take his "earth environment" with him. To accomplish this and yet allow him to walk about on the lunar surface and perform useful exploration he needs more than just a pressure suit; he needs a complete life support system which can be rapidly donned, is light in weight, is easily stored, and is extremely reliable.

The Apollo space suit with its associated "portable life support system" is more than a pressure suit; it is a manpowered vehicle with a self-contained environment. It is his only means of life support, protection, and communications during operations on the lunar surface. The space suit must protect the astronaut from the effects of lunar vacuum which would cause the body's fluids to "boil"; it must isolate him from temperatures which could vary from - 250°F. to +325°F.; it must protect him from high velocity micrometeoroids; and it must provide mobility for the performance of useful tasks during scientific excursions in a hostile environment.

In addition to lunar exploration capabilities the space suits must be used by the astronauts to perform free space extravehicular transfer from the Command Module to the Lunar Module should the docking system malfunction. The suit must also be used in event of unscheduled loss of cabin pressure and it must be capable of being donned before cabin pressure can no longer sustain life. This rapid donning capability permits the crew to remove the suits for a good portion of the flight if they desire.

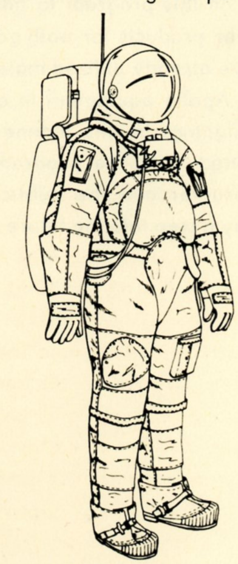

Figure 1
Extra-Vehicular Suit

Because crew members have different tasks to perform two space suit configurations will be used: one for the two astronauts who will travel to the lunar surface, and one for the third member of the crew who will remain in the Command Module. His suit includes an Intravehicular Cover Layer (IVCL) for fire protection. The Pressure Garment Assemblies (PGA) for the two astronauts who will perform the lunar landing and excursion have Integrated Thermal Micrometeoroid (ITMG) protection assemblies which perform the same fire protection function but which also provide protection against the extreme temperature range and micrometeoroid impacts (see Figure 1). The PGA, when coupled with a life support system carried on the astronaut's back, will provide the necessary ventilation, pressurization, and communications for operations independent of the spacecraft. Figure 1 shows the PGA with "backpack" attached.

A suit, helmet, and a pair of pressure gloves form the gas retaining envelope. The pressurization and ventilation system supplies the astronaut with a habitable atmosphere within the space suit. This ventilation system has ducts (See Figure 2) which distribute the pressurization and ventilation gas flow from either of two inlet gas connectors to the helmet and torso. The gas then passes to either of two exhaust gas connectors and is conveyed through hoses to the environmental control system of the spacecraft or portable life support system. (Figure 3 is a schematic of the system. The arrows in the illustration indicate direction of flow). The two sets of connectors are provided so the astronaut may check his portable "back-pack" while he is still connected to the oxygen supply in the Lunar Module. The gas flows into the helmet and passes over the inside of its surface to help keep the helmet from fogging and is then directed to the face area of the helmet for proper breathing and efficient removal of exhaled breath. As the flow of gas passes down through the neck opening and over the body it helps remove body

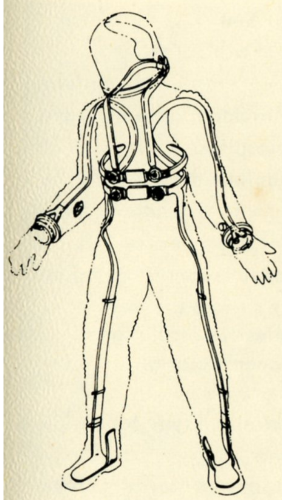

Figure 2
Ventilation System

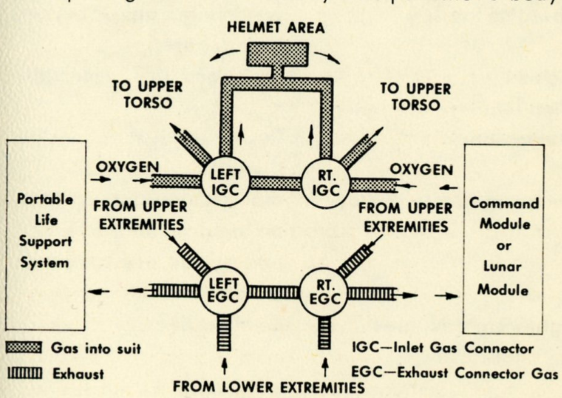

Figure 3. - Pressurization and Ventilation System

heat and moisture. The normal inlet oxygen temperature will be about 40 degrees Fahrenheit at a pressure of 3.75 psi.

During the intravehicular phases of an Apollo mission, a cotton constant wear garment is worn under the pressure garment. In place of the constant wear garment, the Lunar Module crewmen will wear a liquid cooling garment consisting of an outer layer of nylon Spandex material which supports a network of tubing through which cool water will flow to help keep the astronaut cool and comfortable.

This system does not rely upon circulating oxygen for cooling as in the Command Module environmental control system. (Much less physical work is accomplished in the Command Module therefore liquid cooling is not required). Cool water is circulated through tubes in direct contact with the skin so that the body heat is conducted away. Without the water cooling, problems such as astronaut dehydration, sweat in the eyes, etc. would occur at high work levels. The ventilation system is still required to replenish oxygen, remove carbon dioxide and moisture, and control total pressure.

The torso limb suit (See Figure 4) consists of an inner Nomex (high temperature nylon) fabric comfort liner, a neoprene-coated nylon bladder, and an outer nylon restraint structure. Specially designed joints at the shoulders, elbows, wrists, thighs, knees, and ankles provide the necessary suit flexibility to accommodate body movements. Unlike the earlier Mercury and Gemini suits the Apollo suits incorporate convoluted bellows of a patented ILC Industries' design which reduce the effort required to move the joints.

The Intravehicular Cover Layer is designed to protect the torso limb suit and the crewman in the event of an accidental fire dur-

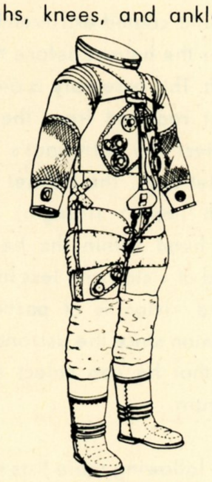

Figure 4
Torso-Limb Suit

ing the mission as well as on the launch pad. (See Figure 5). The assembly consists of three layers of fabric: an inner layer of Nomex cloth, and two layers of Beta (glass) cloth woven from Teflon-coated yarn.

The Integrated Thermal Micrometeoroid Garment (Figure 1) will insulate the space suit from the extreme heat and cold on the lunar surface. This thermal protection reduces the work required for the portable life support system. The ITMG employs an inner layer of neoprene-coated nylon, alternate layers of perforated aluminized film separated by a low heat conducting spacer fabric and an outer layer of fire resistant cloth. This insulation works very much like a common "Thermos" bottle. A special pair of thermal gloves and boots are used to protect those areas of the space suit which come in contact with the hot or cold lunar surface.

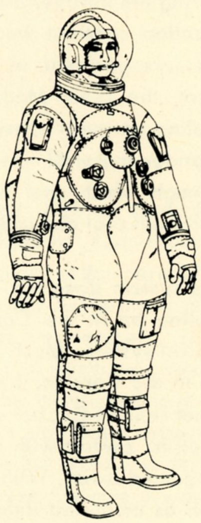

Figure 5
Intra-Vehicular Suit

A gold coated extravehicular visor assembly is placed over the helmet before the astronaut leaves the spacecraft. This assembly is designed to reduce the heat and light radiated from the sun and lunar surfaces and protect the astronaut's eyes from the harmful ultraviolet rays. The helmet (made from polycarbonate for high impact strength) allows the astronaut to turn his head within the helmet. This provides a greater field of vision and less fatigue for the crewman. Downward vision is of particular importance to the lunar mission since the astronaut must be able to see his feet so that he can select each step in the rough lunar terrain.

The following table lists the various materials or layers which make up the Apollo space suit. They are listed in the sequence from the exterior surface of the suit.

THE APOLLO SPACE SUIT MATERIALS

Extra-Vehicular Suit	
MATERIAL	FUNCTION
Teflon-coated yarn Beta fiberglas fabric	Fire protection (Completely nonflammable in oxygen atmosphere.)
Aluminized Kapton/Beta marquisette (Super-insulation)	Aluminized Kapton for reflective insulation. Beta fiberglas serves as a spacer separating reflective surfaces.
Aluminized Mylar film	Reflective insulation
Non-woven Dacron	Spacer material
Neoprene-coated nylon	Inter liner
Nylon fabric	Restraint layer for inside layer.
Neoprene-coated nylon	Bladder material serves as an impermeable layer containing suit pressurization oxygen.
Light-weight Nomex fabric	Comfort liner.
Liquid Cooled Garment	
Nylon Spandex	Retains tubing close to skin.
Vinyl tubing	Water distribution for cooling.
Porous lightweight nylon	Comfort layer

Intra-Vehicular Suit	
MATERIAL	FUNCTION
Teflon-coated yarn/Beta fiberglas fabric	Fire protection (Completely nonflammable in oxygen atmosphere.)
Nomex (high temperature nylon)	Snag and fire protection.
Nylon fabric	Restraint layer for inside layer.
Neoprene-coated nylon	Bladder material serves as an impermeable layer containing suit pressurization oxygen.
Light-weight Nomex fabric	Comfort liner.
Constant-Wear Garment	
Cotton	Comfort layer

ILC Industries, Inc. is proud of its role in the space program and vigorously supports the ever-expanding field of aerospace technology. We have more than eighteen years experience in research, development, and manufacture of air-inflated assemblies, pressure vessels and life support systems. This experience has provided a sound base for our continuing research, development and design of aerospace life support equipment, and has given ILC its place in the U.S. industrial complex as a leader in this growing field.

Although the Apollo program represents a tremendous challenge and a great step forward in aerospace technology, we at ILC Industries see it as the beginning rather than the end of a long line of successful efforts. We plan to utilize our experience and knowledge gained on this program to advance the state-of-the art in other products for both government and industry. We have already utilized materials applications developed for Apollo equipment in other products which we are designing. In this manner the results of technology gained on space programs are passed along to the consumer and the public. The walk on the moon is truly a step into the future.

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