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26

AN EMERGENCY SURVIVAL SUIT

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INTRODUCTION

This paper describes a thermally insulative garment designed specifically as a lightweight, low stowage volume emergency suit for subzero weather survival. The insulating principal employed can be applied to many other thermal applications.

The primary design objective was to construct a minimum weight, insulative garment capable of providing thermal protection for sedentary metabolic rates of 450 Btu/hr, with an environmental temperature of -40° F. It was intended that the garment be stored as a part of a survival kit, or as a piece of emergency cold weather gear for motorists in the northern portions of the country.

DESIGN CONFIGURATION

Testing confirmed that the inflating suit design satisfies the objectives for a subject standing at rest with environmental temperatures down to -45° F. The garment weighs 11 oz excluding the weight of the inflating-gas source. Initially, the use of lung power or a small hand pump was planned for filling the suit walls. This would have resulted in an 11 ounce system with a stored voluem of approximately 30 cu in. However, a small, compressed-gas source was introduced to provide for rapid inflation. This addition increased the total system weight to about 2-1/2 lb.

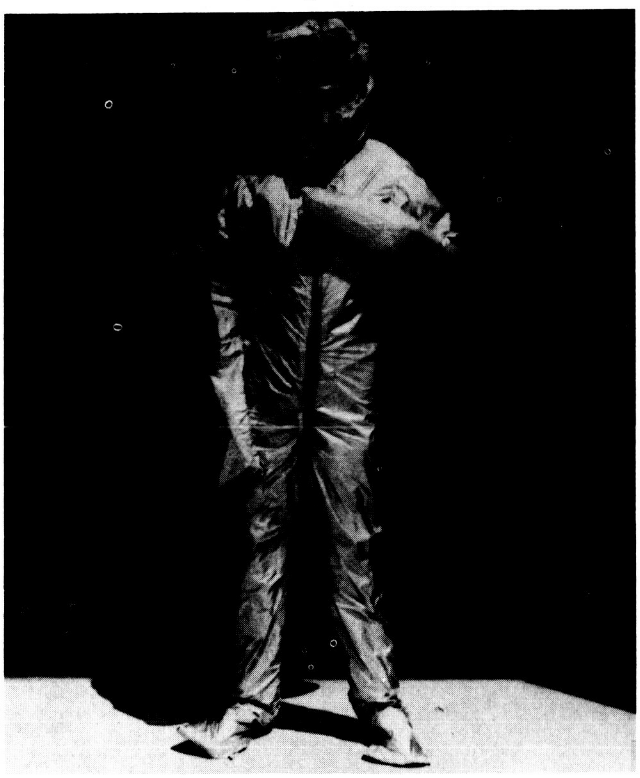

Figure 26.1 *Emergency survival suit.*

Figure 26.1 shows a photograph of the suit being worn for the cold room test. As shown, the garment is a form of superinsulator composed of multilayer, aluminized plastic. Specifically, the suit is constructed of three layers of aluminized polyethelyne with the edges sealed for suit-wall inflation. It is donned in the same manner as coveralls with a zipper down the front. The zipper serves both as the suit closure device and as the means of adjusting suit heat loss. The wearer simply opens the zipper if he becomes too warm.

The suit completely covers the body, including the hands and the head. For simplicity, an extension of the sleeves surrounds the hands. A head covering and viewing visor are also included. However, for future models, the visor will probably be replaced with an open slit in the covering to prevent internal fogging.

DESIGN CALCULATIONS

Figure 26.2 shows the suit wall model used for radiation and conduction calculations. Boundary condition temperatures were -40° F for the exterior surface and 80° F for the interior surface.

Radiation heat transfer was computed using an emittance value of 0.2, characteristic of polyethylene aluminized on only one surface. The surface area of the garment was estimated to be 20 ft^2. For these conditions, the heat loss by radiation is approximately 210 Btu/hr. A lower value could be obtained by introducing double surface aluminization of the polyethylene. A single surface was used for the prototype suit, because this was the only material available at that time.

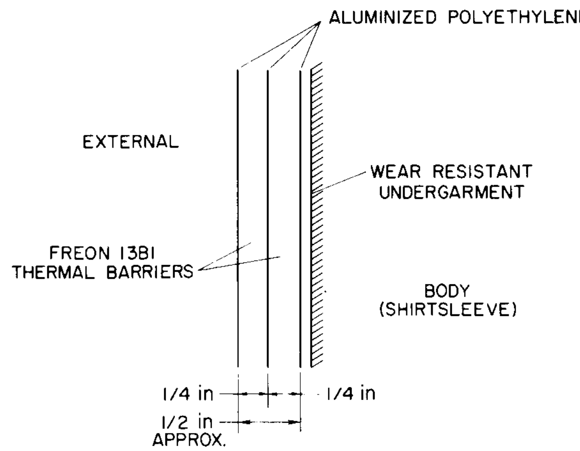

Figure 26.2 *Garment cross section.*

Heat loss also occurs by conduction through the garment wall. In space, this term is quite small for a superinsulator because of the vacuum-inner-space between the aluminized surfaces. For the 1 atm condition, however, it is necessary to fill the suit inner space with a gas, which increases wall conduction. Convection is considered negligible because the close spacing of the suit walls prevents appreciable gas circulation within.

Designing for air as the insulating gas with a suit conduction heat loss equal to one half the total allowable (100 Btu/hr for the -40° F condition), requires an inflated suit thickness of about 1.1 in. Inflating the suit to this thickness is considered practical. However, a better alternative is the use of another gas with better thermal insulative properties. This permits a thinner suit wall.

The gases that were considered are shown in figure 26.3, with thermal conductivities plotted as a function of molecular weight. As a general rule, the greater the molecular weight, the lower the conductivity value. Hydrogen and helium are also shown for comparison. The most favorable gas was found to be Freon 13B1, which is relatively inexpensive and is used for fire fighting because of its inertness and comparatively high density.

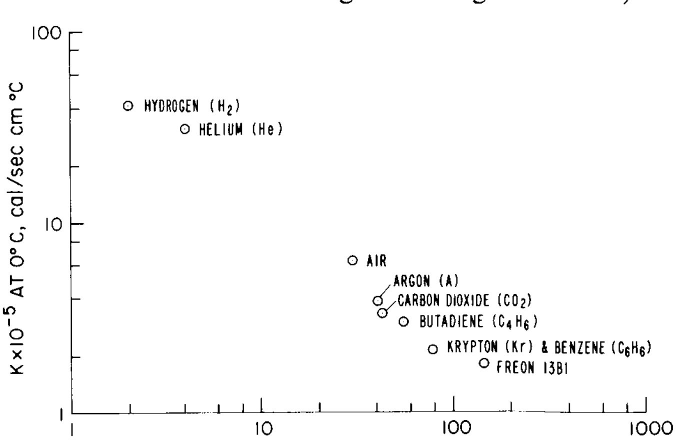

Figure 26.3 *Thermal conductivity of various gases as a function of molecular weight.*

Compared to air, Freon 13B1 is more than twice as good an insulator. In addition, it has a liquification temperature of -70° F, which provides an ample safety margin for a system designed for a minimum environmental temperature of -40° F. With Freon 13B1, the required inflated suit wall thickness is 0.5 in. This provides for a conduction heat loss of 240 Btu/hr. The total calculated heat loss is then 450 Btu/hr for the conditions given. Respiratory heat loss is also included for a total heat balance. The sensible heat loss resulting from breathing 40° F air is about 40 Btu/hr for the sedentary condition. An additional 30 Btu/hr is lost through the latent heat for vaporizing lung moisture. Carbon dioxide was also considered because it is a better insulator than air, and it is readily available in small, high pressure vessels.

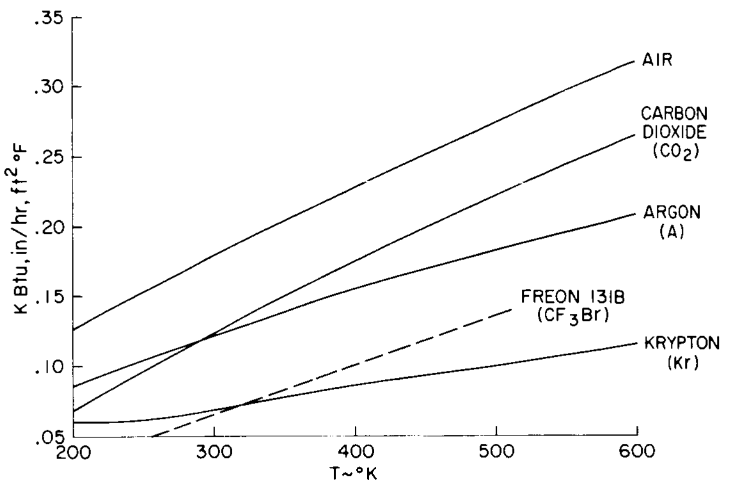

Figure 26.4 *Thermal conductivity of various heavy gases and air.*

Figure 26.4 shows a plot of thermal conductivities for various gases as a function of temperature. In the temperature range from -40° F to normal body temperatures, the conductivity of the Freon is approximately 0.05 Btu-in/hr-ft^2-°F.

TESTING

A cold room with a liquid nitrogen cooling source was used for testing. The test subject wore a short-sleeved shirt, slacks, and socks without shoes. He stood in a small insulated enclosure approximately 3 X 3 X 6 ft with a thick piece of foam plastic on the floor. The foam simulated insulating shoes that would be incorporated into the final design. The enclosure was cooled by a liquid nitrogen baffle and a large air circulating fan mounted directly in front of the subject. During the test, it was necessary to exhaust the cold, vaporized nitrogen directly into the cabinet to attain the coldest air temperatures. The cabinet was inclosed to minimize heat loss to the lab environment, with a fresh air duct used during the latter portion of the test to facilitate breathing. Air temperature was measured with an iron-constantan thermocouple and a Leeds and Northrup potentiometer. The thermocouple was placed in front of the fan next to the test subject.

The garment without Freon was found to be a satisfactory insulator down to about 10° F. At approximately this air temperature, the test subject began to feel cold, and the Freon was introduced. The coldness soon disappeared and test subject again began to feel comfortable. The temperature was then lowered to - 20° F. The test subject was comfortable except for his hand that was holding the air duct. Also, the elbow became somewhat cold because in the bent position it created a thermal short through the radiation shields in the area of the bend. By alternately using the other hand to hold the breathing duct, the previously cold region became warm as soon as the insulation was restored.

The temperature was then lowered to -40° F and held for 15 min. Temperature was then reduced to -45° F for an additional 15 min. At this temperature the test subject's hands and elbows became quite cold where thermal shorts occurred. The subject noted that his toes were also cold, and with shirt sleeves, that his bare arms were cool. He mentioned that a sweater would have made him more comfortable. However, he reiterated that the rest of his body was comfortable. He felt the test could have continued much longer, and perhaps indefinitely, had he been wearing shoes, and had he not had to grip the breathing duct with his hands.

CONCLUSION

The test subject had been in an environment corresponding to a moderate wind at a temperature of -20° F, or lower, for more than an hour with 0.5 hour of this time at or below -40° F. The test was considered a success with the results showing the technical feasibility of the design approach.