Chapter 18

PRESSURE SUITS

Aircraft capable of ascent to high altitudes are equipped with cabin pressurization systems and oxygen systems that keep crewmen well oxygenated at safe cabin altitudes. If cabin pressurization fails, as it may and often does under a variety of conditions, or if an operational capsule is not provided, the crewmen are rapidly exposed to ambient pressure and are totally dependent on the aircraft oxygen system for life support. At cabin altitudes below 50,000 feet, pressure demand oxygen systems generally will maintain safe physiological states long enough to enable the aircrewmen to take corrective action. However, at altitudes above 50,000 feet, even pressure demand oxygen equipment is insufficient to prevent acute hypoxic failure and resultant inability to take effective corrective action.

The survival of man exposed to this hostile environment of low pressure altitudes above 50,000 feet requires that oxygen pressure be provided to the lungs with necessary counterpressure on the outside of the body to prevent pooling of body fluids and subsequent collapse. The required counterpressure can be provided to the body mechanically, pneumatically or by a combination of both. The conventional methods used to provide counterpressure are shown in figure 18–1. The first method shown uses an expansible pneumatic tube (capstan) around which multiple webbings are looped. These webbings are attached to a fabric which fits snugly on the body or extremity. When the tube is filled with gas, it expands and pulls the webbings, thus applying a mechanical pressure to the body. The tube size and pressure can be varied to provide the desired counterpressure to the body. The second method uses a flattened pneumatic tube or bladder that is placed next to the body under a fabric which incloses both the body and the tube. When the tube is filled with gas, it expands and pressurizes the body over which it is placed and mechanically tightens the fabric on the remainder of the body surfaces not covered by the tube. The tube size and pressure can be varied to provide the desired counterpressure to the body. The third method uses a double-walled pneumatic bladder that incloses the body completely. When the bladder is filled with gas, it expands and applies direct pressure through the inner layer of the bladder to the body. A restraint fabric is used over the outside of the bladder to prevent excess ballooning. The fourth method uses a single-walled pneumatic bladder that incloses the entire body. When gas is introduced between the bladder layer and the body, the body is pressurized directly by the gas. The outside of the bladder is restrained from excess ballooning by an overlying fabric restraint layer. The pressure can be varied directly to apply the desired counterpressure. The first three methods are commonly referred to as partial pressure methods and the fourth as a full pressure method.

The pressure suit concept was first advanced by J. S. Haldane, an English respiratory physiologist, in 1920. Thirteen years later, the first such garment was constructed in England for an American balloonist. This suit successfully protected him in a low pressure chamber flight to 85,000 feet for 30 minutes. By 1940, at least five nations, including the United States, had constructed and operated pressurizing garments to be worn on high altitude flights. The early suits were heavy, restricted body motion, exerted severe thermal stresses on their wearers and,

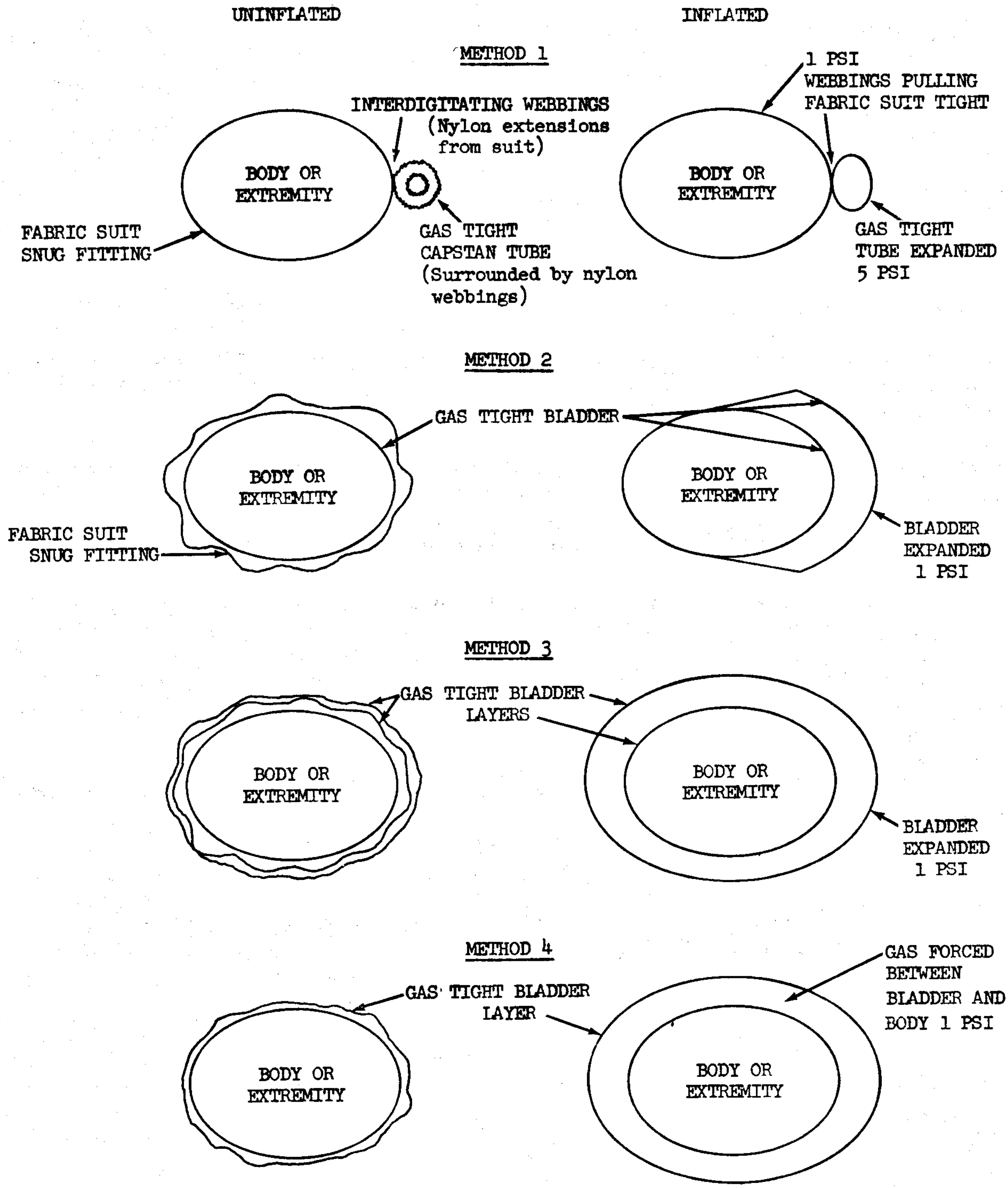

Figure 18–1. Conventional Counterpressure Methods—Cross Section Through Body or Extremity.

as a result, constituted a hazard to safe flying. By the late 1950's, pressure suit prototypes of the present systems appeared feasible. These suits incorporated one or more of the four methods previously mentioned, and helmets that delivered oxygen breathing gas and counterpressure for the head and neck. The source of oxygen came from the aircraft or an emergency supply.

Continuous development of each of these systems has resulted in the current MC-3A and MC-4A partial pressure suit assemblies (see figure 18-2); the CSU-4/P bladder suit assembly (see figure 18-3); the A/P22S-3 (see figure 18-4); and A/P22S-2 (see figure 18-5) full pressure suit assemblies. Further improvements and the possible development of new concepts will provide continued development change in the future.

CAPSTAN PRESSURE SUITS

The capstan suit assembly consists of a helmet, coverall and gloves. The helmet seals at the neck and is pressurized with 100% breathing oxygen from the regulator. Visor fogging is prevented by a laminated heating element in the visor. The helmet is also equipped with earphones and a microphone. The coverall protects the remainder of the body except for the hands and feet. Pressurized gloves protect the hands. A tailored bladder (see figure 18-1—method 3) covers the chest and abdomen including the axillae, groin, and upper thighs. An outer tight-fitting inelastic nylon fabric prevents ballooning of the torso bladder and is continued over the four extremities to form the sleeves and legs. The capstan system provides effective mechanical pressurization of the extremities (see figure 18-1—method 1). As noted in figure 18-1, the capstan system can be described as a two-loop system shaped like the figure "8." One loop incloses the limb and the second incloses an expansible gas tube. Inflation of the gas tube increases the diameter of the capstan loop at the expense of the limb loop, exerting a force to pressurize the limb. The MC-3A and MC-4A pressure suits are so designed that the capstan diameter at any point is about one-fifth of the limb diameter at that point. Therefore, capstan pressures are five times as great as the desired applied limb pressure. *For example,* at 50,000 feet (87 mm Hg), the suit delivers 54 mm Hg pressure to provide a body altitude of 40,000 feet (87 mm Hg + 54 mm Hg = 141 mm Hg). Bladder and helmet pressures measure 54 mm Hg, but capstan pressure is 270 mm Hg (54 mm Hg × 5). Because of the 5:1 capstan to limb pressure

Figure 18-2. High Altitude Pressure Suit—Type MC-3A With Type MA-2 Helmet and High Altitude Gloves.

Figure 18-3. CSU-4/P Bladder Pressure Suit With HGU-8/P Helmet and MG-1 Gloves.

Figure 18-4. A/P22S-3 Full Pressure Suit.

ratio, the actual pressure experienced by the limbs is only 54 mm Hg. The capstan suit regulator is a device which provides for appropriate breathing oxygen pressures, bladder pressures, and capstan pressures to give physiological protection at altitude.

The MC-4A pressure suit is equipped with a built-in G garment to protect against positive G's. Protection against positive G requires pressurization of the abdomen and lower limbs independent of the whole-body pressurization offered by the suit alone. The capstan system provides a high degree of reliability. Properly fitted aircrew members have remained at simulated altitudes of 100,000 feet for as long as 5 hours without demonstrable physiological deficiencies. Naturally, such long exposures require proper preflight denitrogenation and a very good suit fit.

High altitude gloves, type MG-1, are provided for use with the capstan pressure suits if required by the mission duration. These gloves have an outer layer of leather with an inner partial bladder (figure 18-1—method 2) for a counterpressure device. The bladder pressure in the gloves is equal to that in the suit bladder from which gas is supplied.

BLADDER PRESSURE SUIT

The CSU-4/P suit assembly consists of a helmet, a coverall (containing a continuous bladder which covers the torso including the legs and arms) and separate gloves pressurized by gas from the bladder system. There is an inner ventilation layer beneath the bladder. An outer restraining layer prevents ballooning. Ballooning must be minimized in all pressure suits since the consequent change in shape and size not only decreases suit mobility but may also cause the inflated garment to bind on cockpit structures. The garment is equipped with three zippers, enabling a trained flier to don the ensemble in 1 or 2 minutes, giving rise to the name "quick don" suit.

The helmet is constructed of fiberglas with a clear plastic visor for good visibility. A sunshade is also provided. A neck seal around

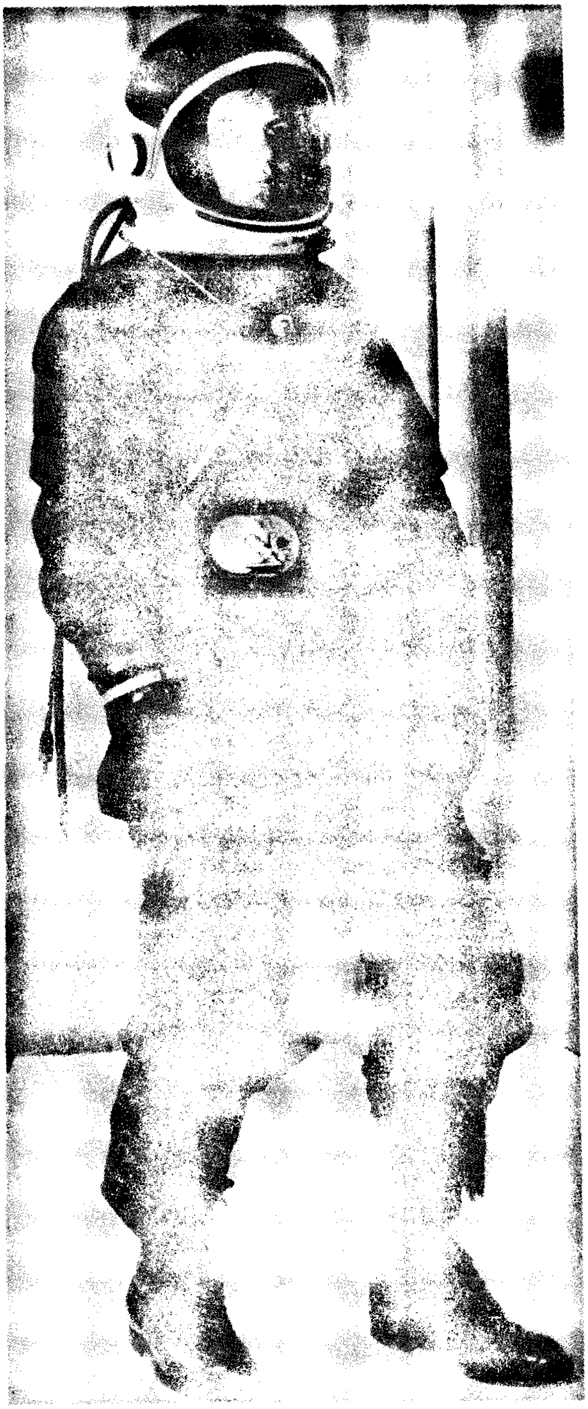

Figure 18-5. A/P22S-2 Full Pressure Suit.

the lower edge of the helmet neckpiece allows containment of breathing oxygen in the helmet. A microphone and earphones complete the helmet assembly.

The bladder pressure suit maintains the wearer at an altitude of 40,000 feet (141 mm Hg). The wearer, breathing 100 percent O_2, is therefore at an equivalent altitude of 10,000 feet and significant hypoxia is prevented. However, decompression sickness which tends to occur at altitudes above 30,000 feet as a function of individual susceptibility, time of exposure, exercise, and terminal altitude, may complicate prolonged suit flights unless adequate preflight denitrogenation has been accomplished. The CSU-4/P has demonstrated its effectiveness by protecting airmen at simulated altitudes of 100,000 feet and above for 2 hours or longer. During rapid decompression, the suit responds with little or no lag time to protect the wearer. In this respect, the "quick don" garment does not differ remarkably from the other partial pressure suits described above.

FULL PRESSURE SUITS

At the present time, full pressure suits of the A/P22S-2 and A/P22S-3 types are used in certain high performance aircraft. Full pressure suits have also been incorporated in the life support systems of the Air Force/National Aeronautics and Space Administration X-15 aircraft and the NASA Mercury, Gemini, and Apollo spacecraft.

The full pressure suit consists of these basic components: helmet, torso, gloves, and boots. The helmet is similar to that used with the bladder suit except that it contains a face seal which separates the helmet and suit cavities. The torso includes an inner layer made of neoprene-impregnated fabric cloth which serves as a gas container and, in conjunction with an outer restraining layer, prevents overinflation and preserves external suit configuration. Special restraining straps and breakpoints provide mobility when inflated. A series of pressure-sealing zippers facilitate donning. The gloves, which must be tight, connect to the torso sleeves in the wrist areas. These gloves are donned last and removed first. Proper glove fit is important if finger mobility and touch sensitivity are to be maintained. With the helmet, torso, and gloves in place, the suit is a completely airtight system. The boots, which are worn over the inclosed feet, provide protection to the suit during walking.

The full pressure suit, as part of the aircraft life support system, requires a source of breathing oxygen, a source of gas (such as compressed air, nitrogen, or oxygen) for suit pressurization, and an aneroid controller which senses cabin pressure and controls suit gas flow accordingly. A seat kit, that houses an emergency oxygen supply for use during bailout, completes the system. Highly reliable regulators of small size have been developed to supply 100% breathing oxygen to the helmet faceplate area at all times from the ground up. The aircraft also delivers a flow of cool dry air through the suit, a necessity to prevent hyperthermia. Should cabin pressurization fail while the aircraft is at an extreme altitude, the aneroid controller senses the change in cabin pressure and immediately activates a suitable flow of 100% breathing oxygen to the helmet and necessary gas pressure for inflating the suit torso and gloves. Regardless of the final cabin pressure, the internal suit altitude (body altitude) does not exceed 35,000 (179 mm Hg) feet.

The suit is compatible with the aircraft emergency escape system. In the event of ejection at high altitude, the backup oxygen supply carried in the seat kit will automatically pressurize the suit and deliver breathing oxygen as necessary during the free-fall period. The garment is designed to withstand the windblast associated with high-speed escape and will also protect against frostbite during exposure to subzero stratospheric temperatures. In addition to protecting aircrewmen at altitude, the full pressure suit provides a reasonable degree of protection against exposure to wet cold. This is particularly important in winter operations at the higher latitudes where water temperatures of 28 to 30° F can incapacitate an unprotected downed flier in minutes.

GENERAL CONSIDERATIONS

Even though current pressure suits provide reliable protection at altitude, improvements in comfort and freedom of motion are desirable. Ideally, a suit should not restrict motion or visibility in routine flight, during an in-flight emergency or during an emergency escape procedure. In addition to providing altitude protection, a suit must resist windblast during bailout and act as a survival garment against both wet cold and dry cold conditions. The Flight Surgeon, who is aware of the difficulties of integrating an all-purpose pressure suit system with the flier and the aircraft, is often able to make useful suggestions and benefit the mission.

Compared to present garments, the early pressure suits provided marginal protection and often added unique stresses of their own. As a result, it was necessary to carefully screen candidates for pressure suit training with particular reference to cardio-respiratory fitness. In the past few years, however, suit technology has improved remarkably and present Air Force garments exert few, if any, measurable physiological penalties. Therefore, an aircrewman who is medically qualified for Flying Class II and has also participated in a low-pressure chamber flight, as conducted by the physiological training program, should be acceptable for suit training.

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