Under Pressure: A Brief History of Pressure Suits
Part 1

By Phillip Keane

For the most part of our history, we have not ventured too far outside of a very specific set of environmental conditions, optimal for human life. It wasn't until we began to explore the depths of the oceans in the 18th century, and then began to explore higher altitudes in the 20th century that we noticed the effects of pressure on human physiology. These new environments introduced variations in temperature and pressure that were far in excess of our comfort zone, up to the point of being fatal to those not properly equipped.

Pressure

Pressure, in hydrostatic terms, is the force exerted on a body from a column of fluid of a certain height. This principle applies to air as well as water. The pressure acts perpendicular to the body from all directions. So in any fluid, the pressure experienced is proportional to the product of ρgh, where ρ is the density of the fluid, g is the gravity and h is the height of the column of fluid. At sea level, the pressure exerted by the atmosphere above is equal to 1 atm, or 101.1 bar. As we traverse skywards, the height of the air column acting on the body decreases, and therefore so does the pressure experienced.

The opposite can be said for when the human body descends beneath the ocean surface: pressure increases as the depth increases, and because water is much denser than air, the pressure increases proportionally faster with respect to depth. As mentioned previously, we operate best in a very narrow margin of atmospheric conditions, and outside of these conditions, we need to bring a suitable environment with us to survive, and this is where the story of the pressure suit begins.

> Humans operate best in a very narrow margin of atmospheric conditions

Siebe, Gorman & Co. Ltd. bolted diving helmet. – Credits: David L. Dekker www.divescrap.com

Diving

Although underwater diving and high altitude flight involve different extremes of the pressure spectrum, it is worth mentioning them both from a historical perspective, as the development of altitude suits, and later on, the space suit, both share a common design heritage to underwater diving equipment.

The very first aviation pressure suits resembled diving suits, as they were largely just modified versions of the sub-aquatic equipment. The most obvious commonality between the two types of suit is the need to create a fluid-tight seal, be it for water or for air, and George Edwards was the first to design a diving suit with a bolt-on helmet that prevented ingress of water. Previous designs relied on a helmet that was held in place purely by its own weight, which frequently resulted in the deaths of divers from drowning.

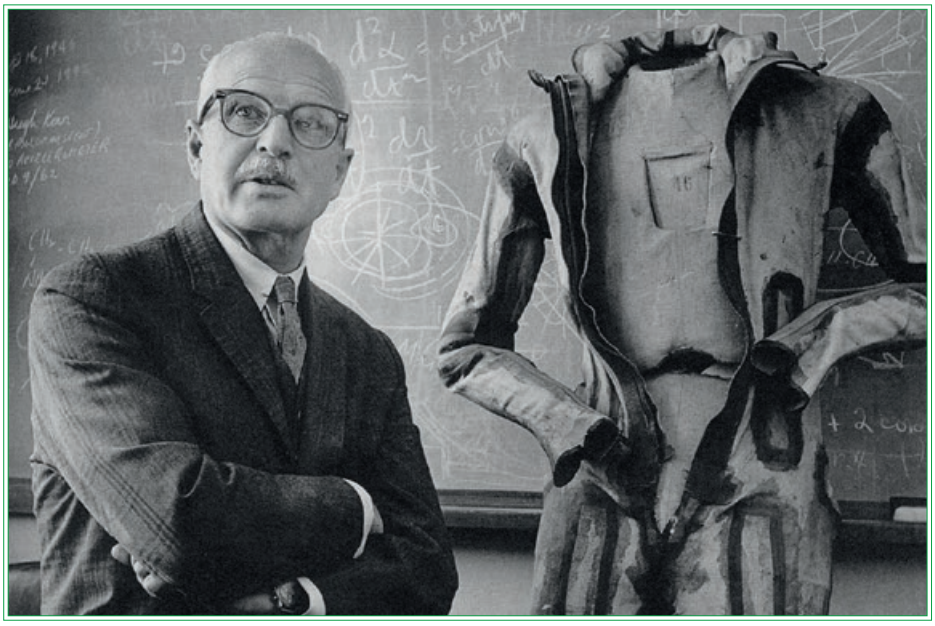
Development History

World War I saw the first widespread use of fighter craft in combat, and consequently pilots were subjected to high g-loads as well as exposure to altitudes above 4,572m as they strove to avoid enemy fire. Pilots reported loss of vision during high g maneuvres as well as headaches, dizziness, and fatigue. It was realized by medics that most of these symptoms were related to lack of oxygen at altitude, although the effects of acceleration were not realized until much later on.

The first conceptual pressure suit was designed after World War I by Fred Sample, an engineer from Florida, US. On 16th July 1918 he was awarded the patent for his "suit for aviators", that featured a bolt-on helmet, an oxygen hose that connected to a tank fitted on the back, and an inflatable gas-bladder which provided mechanical counter pressure to the lungs (much like the partial-pressure suits later designed). It was intended for pilots and mountain climbers. The suit was never manufactured, although it shared similarities with designs implemented in the late 1940's and 50's.

The first pressure suit ever manufactured was designed in 1931 by Evgeniy Chertovsky, a Soviet engineer working for the Aviation Medicine Institute in Leningrad. It was designed to protect the crew of Russian High-Altitude balloon experiments, but due to a catastrophic fire on the test balloon in 1935, it was never put to use.

Wiley Post in his full pressure suit.
Credits: US Air Force



Canadian Wilbur Rounding Franks with his "Franks Flying Suit," the first G-suit, with water filled bladders. – Credits: University of Toronto Archives/Jack Marshall Photography

The 1930's are often seen as a Golden Age for aviation, with various parties competing to achieve higher altitudes and faster speed records. Two such gentlemen were the Swiss physicists August Piccard and his associate Charles Knipfer, who on May 27th 1931 became the first human beings to reach the stratosphere using a balloon and pressurized gondola.

Meanwhile, in Massachusetts, USA, another daredevil explorer had his eye on the altitude record. Mark Edward Ridge, who had previous experience in skydiving, had realized that the weight of a pressurized gondola would affect the performance of the balloon, and came to the conclusion that in order to survive at these altitudes he would be better off surrounding himself with pressurized air in a more lightweight and close-fitting form.

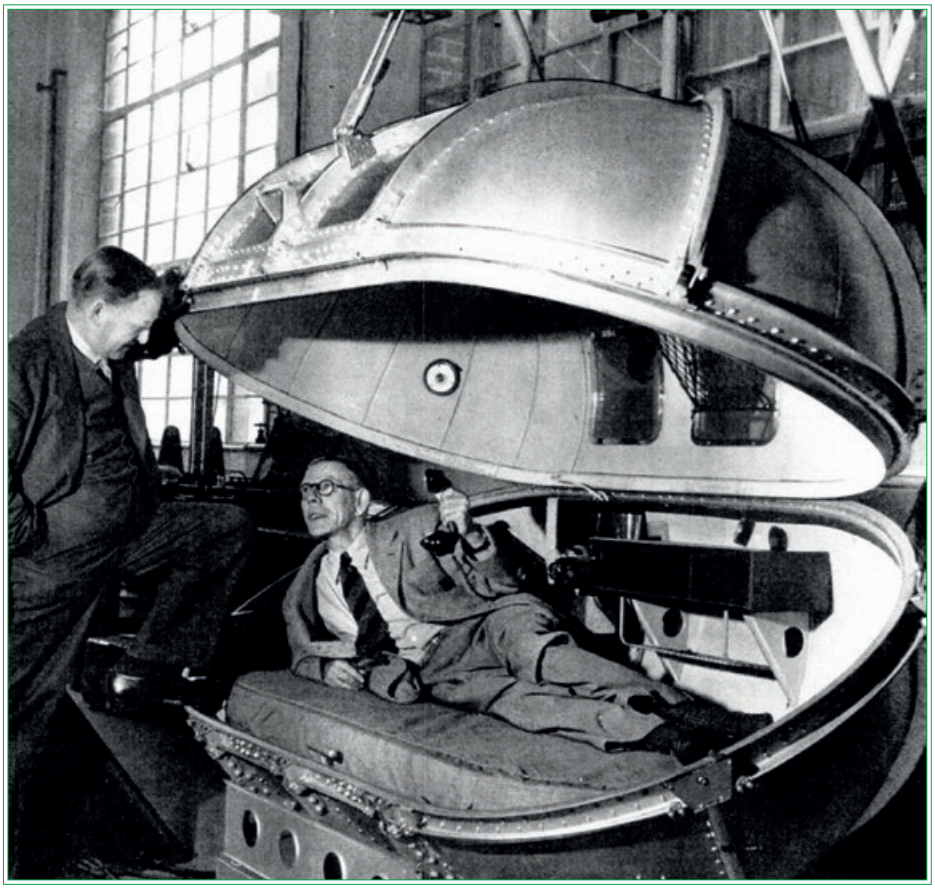
Ridge first turned to the US military for funding, but was refused assistance, so he then approached Dr. John Scott Haldane, a professor at Oxford University, UK. Haldane had previous experience working with pressure chambers as a researcher investigating the effects of decompression sickness in divers. Haldane also had experience of high altitude, as he led an expedition to the summit of Pikes Peak in Colorado, US, to investigate the effects of low pressure at high altitude.

Haldane had previously worked with Sir Robert Davis from Siebe Gorman & Company, an equipment manufacturer for deep sea divers. Ridge and Haldane approached the company with the Ridge design, and SG&C modified one of their diving suits to enable it to offer protection in a low pressure environment. This suit, made from rubber and canvas, was the first full pressure suit in history.

The first aviation pressure suits were modified versions of sub-aquatic equipment

The Ridge pressure suit was never tested in flight, but on November 16th 1933, Ridge became the first person to test a suit in an altitude chamber.

The honour of first flight in a pressure suit goes to an aviator by the name of Wiley Post. Post had already won several flight endurance awards and had realized that he could fly a lot faster at higher altitude, due to decreased air resistance. This reduced air resistance also meant that the piston engines of the time could not breathe enough oxygen to sustain combustion. This situation changed with the advent of the supercharger and other forced air induction systems. On August 30th 1934, Post became the first person to test an operational pressure suit in flight.



Winston Churchill's Personal Pressure Chamber was fitted to his personal aircraft, maintaining pressure at an equivalent of 1524m which enabled the ailing Prime Minister to travel above 2438m. – Credits: LIFE Magazine

During the remainder of the 1930's, several countries were developing their own suit designs in parallel, with a variety of different results. The German company Drager was working on hard-shelled full-pressure suits, but the lack of mobility provided by the metal suit rendered it useless for aviation. The lack of mobility caused by the pressurized suits ballooning was a design challenge that engineers would attempt to overcome for decades after.

World War II and G-suits.

One name that resonates through the history of aero medicine is that of Harry Armstrong, a physician in the US Air Force who investigated formation of gas bubbles in the blood and the necessity for prebreathing, examined toxic hazards in aircraft, and defined the point in the atmosphere known as Armstrong's Line: the altitude at which unconfined water on the human body would boil at body temperature.

As first observed during WWI, pilots

In 1934 Wiley Post became the first person to test a pressure suit in flight

were suffering from effects of blood pooling in the legs and from organ shifts inside the abdominal cavities. Armstrong discovered that by applying pressure at the extremities and at the chest that these effects could be prevented. There were several different concepts being tested at the time, all of which required a pressurized fluid contained within bladders positioned within the suit. The Canadians opted for water filled bladders, and the Australians, British, and Americans opted for pneumatic systems. Some systems required hand pumping for pressurization, while others used compressed air of the engine superchargers. It was during this period that the legendary David Clark

US Air Force pilot being equipped with air-bladder type anti-G suit. – Credits: US Air Force

company entered into the pressure suit business with the "T-1 model," and they have remained at the forefront of pressure suit design ever since.

At the end of the war, a new paradigm was about to emerge. With the invention of the jet engine by Frank Whittle and with developments in rocketry by the Germans, human endurance was about to be pushed to new extremes, never before experienced. The seeds of the Space Age had been sown, and the pressure suit manufacturers would be forced to change with the times.

To be continued in Part 2: The Jet Age, The Cold War, Apollo, and beyond.

The "Tomato Worm," one of the few full-pressure suits developed during WWII for US Air Force pilots. – Credits: US Air Force