11-2013

Hypobaric Chamber Test of Pacific Spaceflight Pressure Garment Mark I at Copenhagen University Hospital

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Citation Details
Smith, C. (2013). Hypobaric Chamber Test of Pacific Spaceflight Pressure Garment Mark I at Copenhagen University Hospital. Pacific Spaceflight Research Brief #2013-1

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Hypobaric Chamber Test of Pacific Spaceflight Pressure Garment Mark I at Copenhagen University Hospital

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25 Nov 2013

Abstract

Pacific Spaceflight's first proof-of concept pressure garment, the Mark I (model *Gagarin*), was worn by a test subject in a pressure chamber to test stable maintenance of blood oxygenation, body temperature and suit pressure. While breathing normal air at a simulated altitude of 4,000m (c.13,000ft) the test subject's blood oxygenation was 90%, a figure expected for an altitude of 2,590m (8,500ft). The test subject's blood oxygenation climbed back to normal (96%-95%) as the hypobaric chamber was repressurized to sea level figures. The garment successfully maintained the test subject in the first half of the Blood Oxygenation Disassociation Range of 'Minimal Sensory Impairment' rather than in the first quarter of the range of 'Minimal Mental Impairment' (expected had the pressure garment not functioned). Additionally, the test subject experienced no temperature discomfort, indicating that the cooling system functioned sufficiently, and experienced no perception of C02 poisoning. Medical staff observing the test observed no elevated heart rate, flushed appearance or other symptoms of hypercapnia (C02 poisoning) during the 35-minute test.

1. Objective

Dr. Svend Helsted Ravn, MD (Herlev Hospital, Copenhagen) states that the 27 August 2013 Trykkammer (pressure chamber) test was designed "to see if [the the pressure garment] would be able to maintain a stable environment with a pressure at 0,7 atm inside the suit at an simulated altitude of 4,000m (13,123 ft) [=.6atm, outside the suit; that is, in the altitude chamber]" [1]. Peripheral objectives were to show that the pressure garment would maintain the correct pressure setting and test subject body temperature throughout the test.

2. Methods

The test was carried out in the Trykkammer (pressure chamber) in the lowel levels of Copenhagen University Hospital, Denmark. Physicians, led by Dr. Svend Helsted Ravn, MD, attended the operation, viewing the test subject and operator through windows. Technicians controlled the chamber's pressure, announcing the altitudes over a microphone installed inside the chamber. Kristian von Bengtson, co-founder of Copenhagen Suborbitals, and several of that organization's photographers, videographers and interns also attended the test.

After donning the pressure garment in the Trykkammer fore-room, the test subject (Dr. Cameron M. Smith of Pacific Spaceflight) and pressure suit operator (John F. Haslett of Pacific Spaceflight) were seated in the chamber. The pressure suit operator was in the chamber to control suit pressure and coolant flow, communicate with with the test subject on the hand-held radios (Motorola 'Talkabout' GRMS), monitor the subject for debilitation, and communicate with the chamber operators with a hard telephone line. The pressure garment's portable life support system (PLSS)--consisting in this case of a 12vDC battery, coolant (iced water) tank and pump, and pressure garment pressure control valves--was also placed inside the chamber.

After verifying that the pressure garment's basic systems were working and that breathing gas was flowing properly to both test subject and operator (a period of about eight minutes) the hatch was sealed and the pressure decreased steadily over the next seven minutes to the lowest pressure of the test, .621 atm, simulating an altitude of 4,000m (13,123 ft) and an ascent rate of roughly 570m/minute (c.1,873ft/min). After ten minutes at 4,000m (13,123ft) simulated, the pressure was increased back to sea level over about 10 minutes, for a total test duration of 35 minutes from visor-close to visor-open.

During the test the subject was supplied with normal air (c.20% oxygen, c.80% nitrogen and other gasses) via an external-to-chamber supply set to deliver 28 liters per minute (c. 1 cubic foot). The pressure suit operator was supplied with 50% oxygen via an oral-nasal mask at the same setting (Figure 2). Neither breathing gas flow setting was altered during the test. The test subject's exhaled carbon dioxide was incidentally exhausted from the pressure garment by a valve.

Throughout the test the pressure garment was set to 1.8psi or .122atm, and the coolant system cycled ice-water from the 3-liter tank. The pressure setting was maintained throughout, and the coolant system was only turned off after the pressure suit visor was opened after the test.

Both the test subject and pressure garment operator were fitted with an earlobe-mounted blood oxygenation meter and pulsemeter (Hewlett-Packard 78352 series) cabled to monitors outside the chamber for viewing by the attending physicians.

3. Results

The aviator's Blood Oxygenation Disassociation Curve (Figure 3) [2] indicates that normal (sea level) blood oxygenation is 96%-98%, whereas at 4,000m (13,123ft or .62atm) it is normally 82%-83%. At 4,000m simulated (when suit pressure {1.8psi/.122atm} + chamber pressure {8.8psi/.598atm} yielded a perceived pressure of 10.6psi/.72 atm within the pressure garment) the test subject's blood oxygenation figure was 90%. This is expected at 2,590m (8,497 ft) or .72atm.

The test subject's pulse varied from 50-70bpm during the test; the test subject sat quietly during the test, doing no physical work other than occasionally adjusting his helmet hold-down cable or bending the left arm to look at the suit's pressure gauge; these are both slightly strenuous actions in the pressurized Mark I garment.

The test subject perceived no temperature discomfort during the test. Breathing was also perceived to be normal by the test subject. An audio recording of the test, made with a recorder inside the pressure suit, appears to indicate normal cognitive functions such as attentiveness to test procedures. The test subject reported “All well, all well,” periodically and his voice exhibits no significant stress-related variations in prosody, volume or grammar.

4. Conclusions

Wearing the pressure garment maintained the test subject's blood oxygenation at 5%-10% greater than would have been available without the pressure garment by providing a 90% oxygenation (equal to 2,590m (8,497 ft) or .72atm) rather than 80%-85% at the simulated altitude of 4,000m (13,123ft). In other words, at 4,000m simulated the ambient pressure of .6atm was supplemented with the pressure garment's .1atm for sum of .7atm. This benefited the pilot, via its supplemental pressure setting, by maintaining a blood oxygenation such that the body perceived an altitude of 2,590m (8,497 ft) rather than 4,000m (13,123ft).

This difference can have a significant effect for aviators. In the US, aviators are required to switch to supplemental oxygen when at physiological pressures (whether in unpressurized or pressurized cabin) of 3,048m (10,000ft). In the case of this test, then, even breathing air, a flying aviator in this pressure garment would have maintained a higher blood oxygenation level than an aviator not pressurized in the suit.

Specifically, the pressure garment kept the test subject within in first half of the blood oxygenation range of 'Minimal Sensory Impairment' rather than in the first quarter of the range of 'Minimal Mental Impairment', where it would have been without the pressurized garment (Figure 3).

5. Comments

Note that this was not a test of survivability of the suit at high altitudes, in which case Aviator's Breathing Oxygen (normally 98%-99% pure 02 and other, mostly non-nitrogen trace gasses) would have been used. This conservative test was only to show that the pressure garment would maintain a higher blood oxygenation than would be expected had the test subject not worn the pressure garment, and to introduce the pressure garment and Pacific Spaceflight personnel to the Copenhagen University Hospital staff and facilities.

As a rule of thumb, blood oxygenation for aviators should be kept above 90% (half way into the range of 'Minimal Sensory Impairment'). In future tests the test subject will breath different gasses, including Aviator's Breathing Oxygen, and undergo oxygen prebreathing / denitrogenization protocols for higher-altitude tests (see [3]). Future tests will also dispense with exhaled carbon dioxide in a way yet to be determined.

6. Acknowledgements

I thank the staff of Copenhagen University Hospital and Copenhagen Suborbitals, and the team at Pacific Spaceflight, for making the tests possible.

7. References

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2.http://legacy.nrao.edu/alma/memos/html-memos/alma162/medical0.gif

3. Webb, J.T. And A.A. Pilmanis. 2000. Optimizing Denitrogenation for DCS Protection. Pp. 46-1-46-3 in Operational Medical Issues in Hypo-and Hyperbaric Conditions. Available at http://www.ntis.gov/search/product.aspx?ABBR=ADP011098

FIGURE 1. (A) Test Subject Standing Before the Trykkammer Wearing the Mark I (*Gagarin*) Pressure Garment. The flight coverall was not worn in this test; visible is the pressure restraint garment that covers the gas retention layer. (B) Test Subject (L) and Pressure Garment Operator (R) During Depressurization Test. Photos courtesy of Jev Olsen, Copenhagen Suborbitals.

(A)

(B)

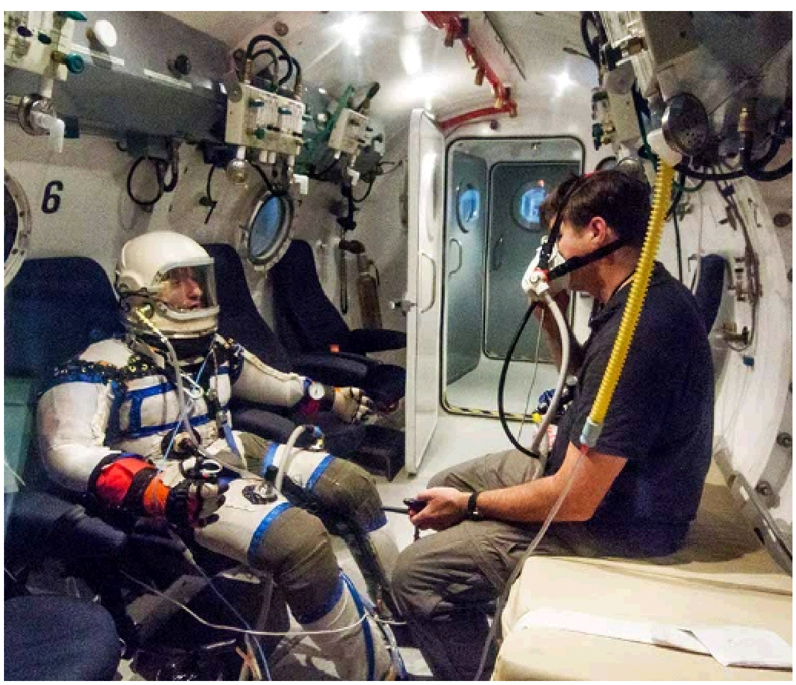

FIGURE 2. Pressure Garment Operator Test Subject in Trykkammer, Monitored by Closed-Circuit Video During Depressurization Test. Photo courtesy of Kristian von Bengtson, Copenhagen Suborbitals.

FIGURE 3. Aviation Blood Oxygenation Disassociation Curve.