THE AIR POCKET HELICOPTER EMERGENCY UNDERWATER BREATHING SYSTEM

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1) THE DESIGN, DEVELOPMENT AND TESTING OF AIR POCKET

Air Pocket is a unique Helicopter Emergency Underwater Breathing System (H.E.U.B.S.), which represents a major step forward in helicopter transport safety. It has been developed as part of the Integrated Survival System, that is, personal survival equipment which is compatible and complementary, designed and engineered to maximize the survival prospects of the immersion victim by comprehensively and effectively addressing all of the hazardous physiological responses which he or she will experience. Air Pocket is so unique that it has been covered by worldwide patents.

Prior to the six years of research work which underpinned the development of the Integrated Survival System, the physiological responses to immersion in cold water were studied in depth by Dr Mike Tipton of the Robens Institute of Health and Safety, working at the Institute of Naval Medicine. "Cold Shock" was identified as the primary physiological hazard which has to be addressed in a cold water immersion emergency. The initial respiratory responses include reflex gasping and uncontrollable hyperventilation. In addition heart rate goes up, blood vessels constrict and blood pressure rises, leading to increased risk of stroke or heart attack. Apart from the danger of aspirating water, the victim's breath-hold time is significantly reduced. It has been shown that the insulating effect of normal clothing, even when supplemented by a survival suit intended to provide protection from hypothermia, will only enable a mean breath-hold time of about 17 seconds to be achieved during submersion in cold water (5-10º C). This is approximately half the time estimated to be required for an individual to make a controlled, successful escape from a helicopter which has crashed into the sea and become submerged. It was concluded that a H.E.U.B.S. which was safe and simple to use would be an essential component of an Integrated Survival System, since unless the transit passenger could survive "Cold Shock" and egress from the helicopter, other physiological responses such as hypothermia did not become a factor in his or her survival.

The development of Air Pocket took three years and was sponsored by Shell and Esso U.K. Exploration and Production Ltd. It went through 7 phases of development and testing before being declared safe for general use.

In the beginning divers were used at the National Hyperbaric Centre to prove that it was possible to re-breathe from a counterlung underwater and to establish whether a bag volume of 1VC or 2VC was required to attain 60 seconds re-breathing underwater.

The conclusions reached were that :-

1. 1VC was all that was required.
2. That the counterlung part of the Air Pocket required an in-depth design exercise.

To create an appropriate development and testing resource we designed and engineered a manikin which could be rotated in both anterior and lateral planes in a tank of water. This was used with our Breathing Machine to establish the system breathing resistance as well as the hydrostatic breathing resistance. We were able to use the data from our experimental work to design a counterlung which could be:

a) breathed in any position underwater
b) which would not be subject to shut off
c) sized so as to keep the breathing resistance to a minimum

Having now established that Air Pocket was safe for humans to breathe underwater, we then commenced experimental work with human volunteers in a series of test conducted by the Robens Institute of Health and Safety, both in air and in the cold tank at the Institute of Naval Medicine, and later by Survival Systems in Canada.

The first experiments in air established the recommended method of use. Various subjects took a deep breath in, held it to maximum breath-hold and then re-breathed on Air Pocket to its maximum duration. Others re-breathed on Air Pocket immediately without performing a maximum breath-hold. These experiments were performed at rest and during two levels of exercise. The results indicated that whichever way the Air Pocket was used, the duration was the same and on average Air Pocket more than doubled the time subjects could spend without fresh air. It was decided from these data that we would recommend that individuals breath-hold for as long as possible before using Air Pocket, thus ensuring that it can only be an advantage to those who use it (they would otherwise have drowned).

The experiments continued in warm water, to determine the ability of individuals to use Air Pocket in all orientations underwater and remain submerged for 60 seconds. The results confirmed that Air Pocket could be successfully used for this time span, whatever the position underwater, consistent with the earlier unmanned tests. It was concluded that Air Pocket required further evaluation under controlled conditions in both warm and cold water.

At this stage the Air Pocket underwent various refinements to establish it as a pre-production model rather than a prototype – the distribution manifold was fitted internally to the counterlung and an improved lighter weight mouthpiece was manufactured.

The next series of experiments was carried out, using 8 volunteers, by the Robens Institute at the Institute of Naval Medicine. Each individual undertook two resting submersions, one in warm water (25.6º) and the other at 9.9º, chosen to represent the average temperature of the water around the U.K. A maximum time of 70 seconds submersion was fixed in advance as the medical withdrawal criteria. Each subject took a 'slightly larger than normal breath' in, held it to his or her maximum breath-hold time, and then re-breathed using Air Pocket. It is clear from the results that Air Pocket significantly extended the time all the subjects could spend at rest under cold water compared to their maximum breath-hold times (see Figures 1 and 2).

Experiments were then carried out to establish that Air Pocket could be used as effectively during a simulated simple helicopter underwater escape. The maximum time underwater during these experiments was pre-set at 60 seconds. As the graphs (Figures 3 and 4) show, the maximum breath-hold time of subjects was recorded, the ability to re-breathe with Air Pocket after maximum breath-hold extended the average time underwater (i.e. survival time) by a factor of 2.5.

A diagrammatic representation of the increase in underwater survival time presented by Air Pocket is given in Figures 5 and 6. In these graphs the percentage of subjects able to achieve any given time underwater when performing a maximum breath-hold is compared with underwater time achieveable when Air Pocket was used. Although they only cover a small number of subjects, they are indicative of the benefit provided by Air Pocket over maximum breath-holding alone. The shaded areas indicate the potential extra survival time given by Air Pocket. Figure 6 shows that for 100% of subjects to make a successful simulated underwater escape in 10º water, some would have had to reach the surface within about 10 seconds if breath-holding. When the subjects are using Air Pocket they have about 35 seconds to reach the surface.

Alternatively if 20 seconds is required to make such an escape, 12.5% of subjects (1 in 8) should be able to do this by breath-holding alone, but 100% (8 out of 8) should manage in this time using Air Pocket. The withdrawal criteria did, however, prevent Air Pocket from demonstrating its full potential, since subjects were removed from the water whilst still using it. The average maximum breath-hold time of 17.2 seconds which was established by the experiments provides further evidence for the need for a H.E.U.B.S. such as Air Pocket Plus for helicopter transit.

The final phase of the project was then initiated to establish the effect of the Air Pocket on the performance of escapes from a Helicopter Egress Trainer and ensure that manoeuvrability was not compromised. It was not our intention to draw a comparison with the "Factors" trial i.e. "Emergency Breathing System as an Aid to Egress from a Downed Flooded Helicopter" carried out in May 1990 by Canadian Oil and Gas Land Adminstration (C.O.G.L.A.) It was, however, agreed that a modified exit procedure as shown on the attached figure 2.3 from C.O.G.L.A. Report 108 i.e. S61 M.E.T.S. Configuration would be used.

A group of 6 experienced instructors and a group of 6 naïve subjects volunteered to take part in these experiments. The instructors were briefed and verbally instructed in the use of Air Pocket and then immersed themselves to try the procedure underwater, re-breathing on Air Pocket following a maximal breath-hold.

Each instructor was then immersed in the Shallow Water Egress Trainer (S.W.E.T.) chair, having taken in a deep breath and changing over to Air Pocket when maximum breath-hold was reached. The chair was then inverted and the instructor pushed out the side window and egressed whilst re-breathing on Air Pocket.

The instructors then progressed to the Dunker itself and each made four egresses - one each from positions 1, 2 and 3 and a further exit from position 4 at a radical angle which would ensure that Air Pocket was needed. Having successfully completed this phase, the instructors commenced exiting from the pilot's seat. The exit route in this case was via the bulkhead door behind the pilot's seat and through a type 4 window. This did not prove problematic - in fact the first two egresses were performed by an instructor who is 6' 2" tall and weighs 230lbs.

The naïve subjects who took part, a group of 4 young, healthy males and 4 young, healthy females, had no prior knowledge or any survival training. They repeated the training and egress scenario described above with the exception of the radical angle, seat 2 egress and the exit through the type 4 window. They successfully completed their training and used Air Pocket during their simulated escapes without problems. It was interesting to note the extent of the problem of disorientation experienced by immersion victims who are inverted – one subject entangled herself in the top of the S.W.E.T. chair rather than egressing from the side. In a real emergency, time is required to orient and escape – again underlining the need for a H.E.U.B.S. such as Air Pocket to extend underwater survival time. Only one subject failed to egress from the Dunker within 60 seconds, the medical withdrawal time limit. All other egresses were concluded successfully.

The trials at Survival Systems successfully concluded the development and testing of Air Pocket. The next stage was to introduce this new product to the offshore oil industry and to demonstrate its potential as a new safety aid for helicopter passengers flying over water.

2) THE SUCCESSFUL INTRODUCTION OF AIR POCKET TO NORTH SEA OPERATIONS

Before Air Pocket could be introduced, it had to be approved as part of the industry standard Civil Aviation Authority (C.A.A.) Specification 19 survival suits and for use with the C.A.A. Specification 5 lifejacket, which is part of the aircraft equipment. The C.A.A. approved Air Pocket following a series of tests demonstrating compliance at Robert Gordon's Institute of Technology (R.G.I.T.), Aberdeen. Air Pocket has been approved in the Shark S.I.S.S. and 93204 Nomex Gore-tex immersion suits as well as in a number of other industry standard suits. Shell U.K. Expro was the first oil major to purchase Air Pocket, for introduction to the Northern, Central and Southern Sectors of the North Sea. The logistical problem of introducing a new safety product to a large workforce overnight then needed to be solved.

Firstly, we designed the Air Pocket Dry Trainer, a device which simulates the breathing characteristics of Air Pocket when it is used in various orientations underwater. The Dry Trainer can be set up anywhere that training is needed – all that is required is a water supply. The Dry Trainer has become an accepted part of the training regime and is the standard method of introducing any trainee to the use of Air Pocket.

A Training Video was produced to explain the background to Air Pocket, show the Dry Trainer and explain the deployment of Air Pocket in the event of a ditching. A Viscom disc was developed for Heliport briefings.

The major training establishments were involved in a familiarization exercise and were introduced to the training methods, both wet and dry. The nominated trainers, who were part of Shell's workforce, were given in-water escape training with Air Pocket to enable them to train the rest of the workforce, passing on their experience and using the Dry Trainer.

Once the training regime was in place, the Shell immersion suits were modified and introduced sector by sector. Dry Trainer units were placed on all Shell's offshore installations so that personnel could familiarize themselves with Air Pocket regularly. Air Pocket was then introduced extremely successfully and very rapidly.

A similar exercise was carried out very successfully by British Gas Hydrocarbon Resources Ltd for their Morecambe Bay field, when Air Pocket was introduced for all personnel, setting the pattern for future introductions of Air Pocket by other oil companies. Several thousand Air Pockets have been in daily use in the offshore oil industry since its introduction in early 1996.

In water training has been developed and delivered. It is ready for implementation as and when oil industry operators require it as a standard feature of escape training. We believe such training would be advantageous.

3) AIR POCKET –A SURVIVAL ASSET FOR THE IMMERSION VICTIM

Air Pocket has been developed to address the extremely hazardous situation faced by an immersion victim in a helicopter ditching emergency, when the helicopter passenger has to contend with “Cold Shock,” which drastically reduces breath-hold, increases the heart rate and constricts the blood vessels causing blood pressure to rise increasing the risk of heart attack and stroke. Reflex gasping and hyperventilation can occur, so that the immersion victim may aspirate water and drown.

Air Pocket has been designed to support the immersion victim during the most critical phase of survival – the underwater escape. The design criteria for Air Pocket is that it is simple in design and when used as recommended can only be of assistance in extending the underwater survival time of the user.

It meets this requirement because

- it is simple to use
- it is used unprimed, so that the user only re-breathes the volume of air in his lungs on submersion, avoiding the risk of pulmonary overpressure accident
- it can be breathed in any position underwater, within prescribed, acceptable limits

- it has been designed to facilitate access and deployment but is not a snagging hazard nor does it increase buoyancy
- training is uncomplicated and can be delivered in air using the Air Pocket Dry Trainer. In-water training has been developed for introduction as and when the industry requires.
- maintenance is simple and low cost.

Air Pocket is relatively inexpensive and as experience shows, can be introduced smoothly to significant numbers of people. Independent testing has demonstrated that Air Pocket can be a significant survival asset to the immersion victim.

4) AIR POCKET PLUS

A second generation product has now been developed, Air Pocket Plus.

Air Pocket Plus is based on the same research as the original Air Pocket, but is a stand alone device, worn outside the survival suit, between the lobes of the lifejacket.

Air Pocket Plus is deployed by simply pulling down the cover, placing the mouthpiece in the mouth and breathing ambient air, switching over to the counterlung once the user is about to be submerged. Air Pocket Plus has been fitted with a small cylinder which contains 3.5 litres of breathing air, the equivalent of one breath, which is added to the counterlung automatically on immersion. This means that even if the user is unable to breath-hold, there is air available during the underwater escape.

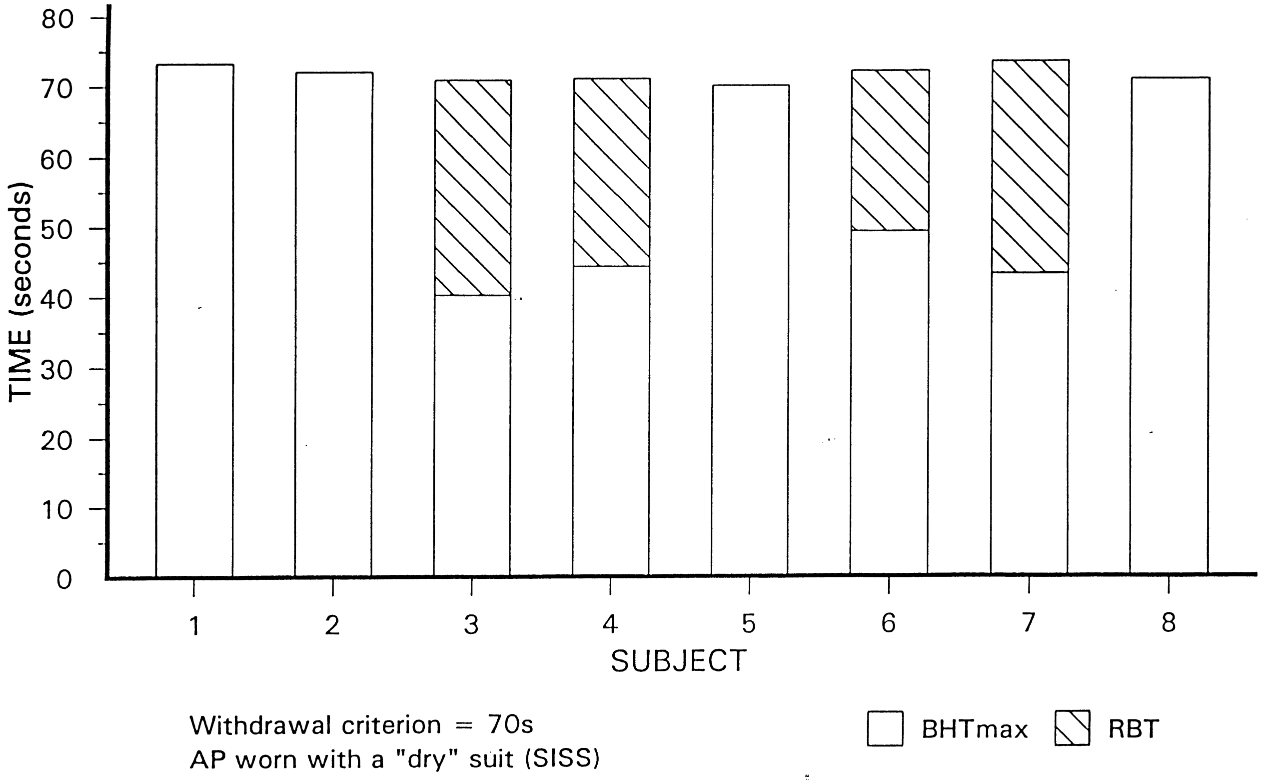
Air Pocket Plus has gone through a similar design process to the Air Pocket and has been subjected to verification and validation at all stages. Extensive trials using naïve subjects were carried out at Nutec by Cranfield University, witnessed by the C.A.A., which resulted in Air Pocket Plus being approved by the C.A.A.

Air Pocket Plus has been designed to minimize the risk of cerebral arterial gas embolism which results from any system which introduces supplementary gas – the breathing bag is generously sized to contain the air charge plus any breath from breath-hold, without producing over-pressure.

Air Pocket Plus is now in use in the offshore oil industry in the U.K., Netherlands, Canada and Australasia.

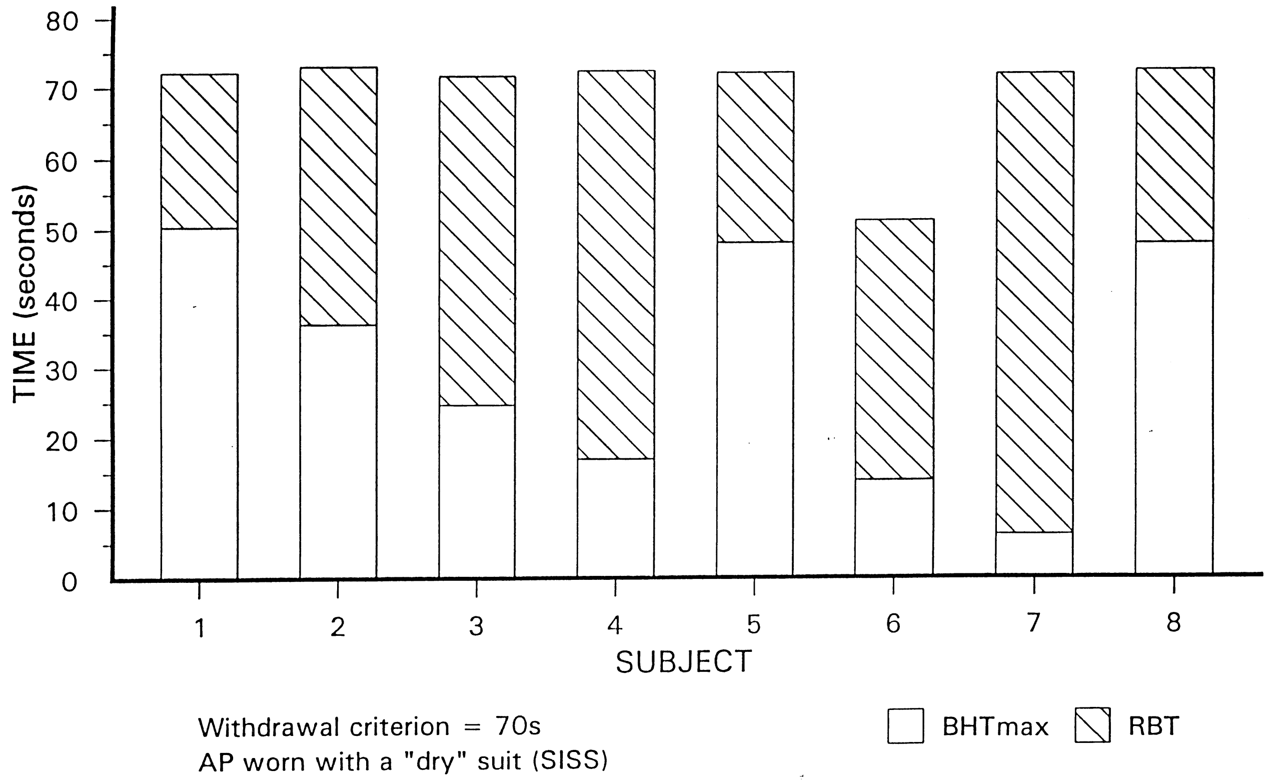
Air Pocket and Air Pocket Plus have been selected as Millennium Products by the U.K. Design Council , as two of the most innovative products for the new Millennium.

Figure 1. Maximum breath hold time (BHTmax) and total time (RBT) spent under 25 deg.C water using Air Pocket at rest



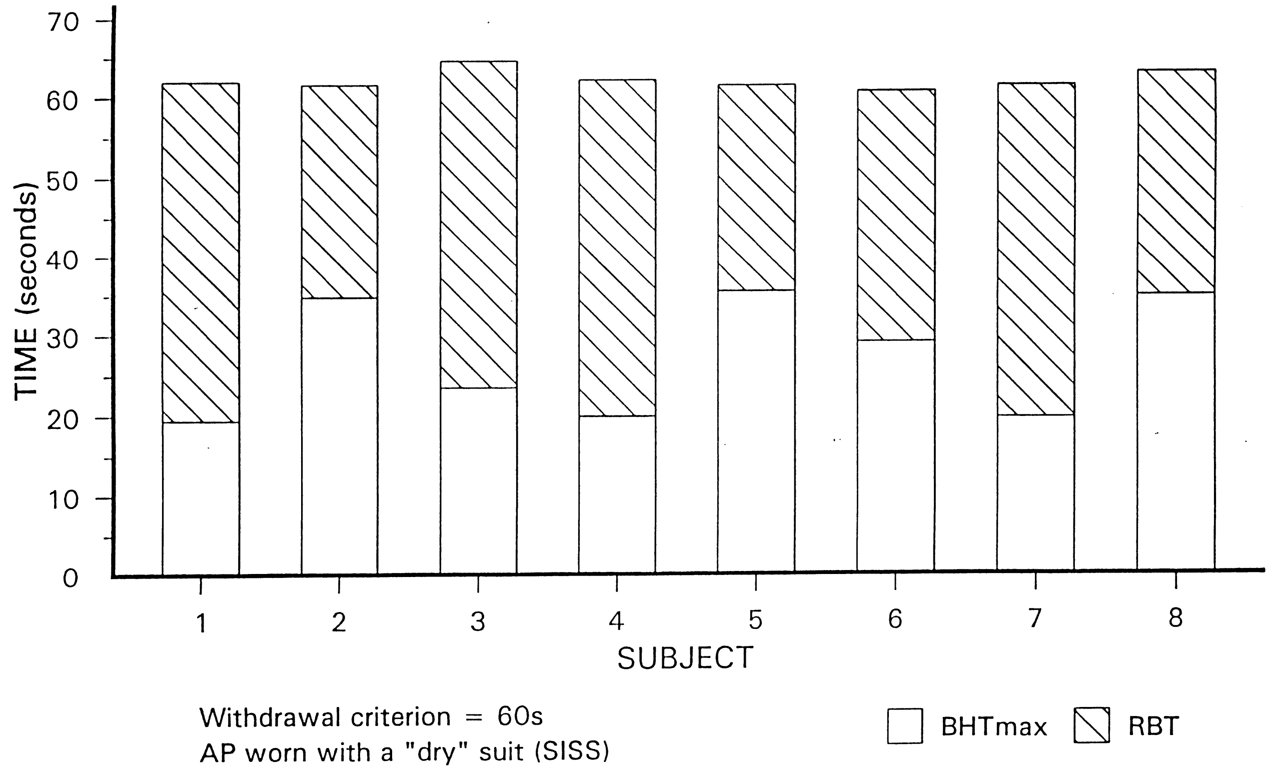
Graph produced by Dr.M.J.Tipton, Robens Institute, based on data obtained in the Phase V and VI experiments carried out at the Institute of Naval Medicine – July 1992.

Figure 2. Maximum breath hold time (BHTmax) and total time (RBT) spent under 10 deg.C water using Air Pocket at rest



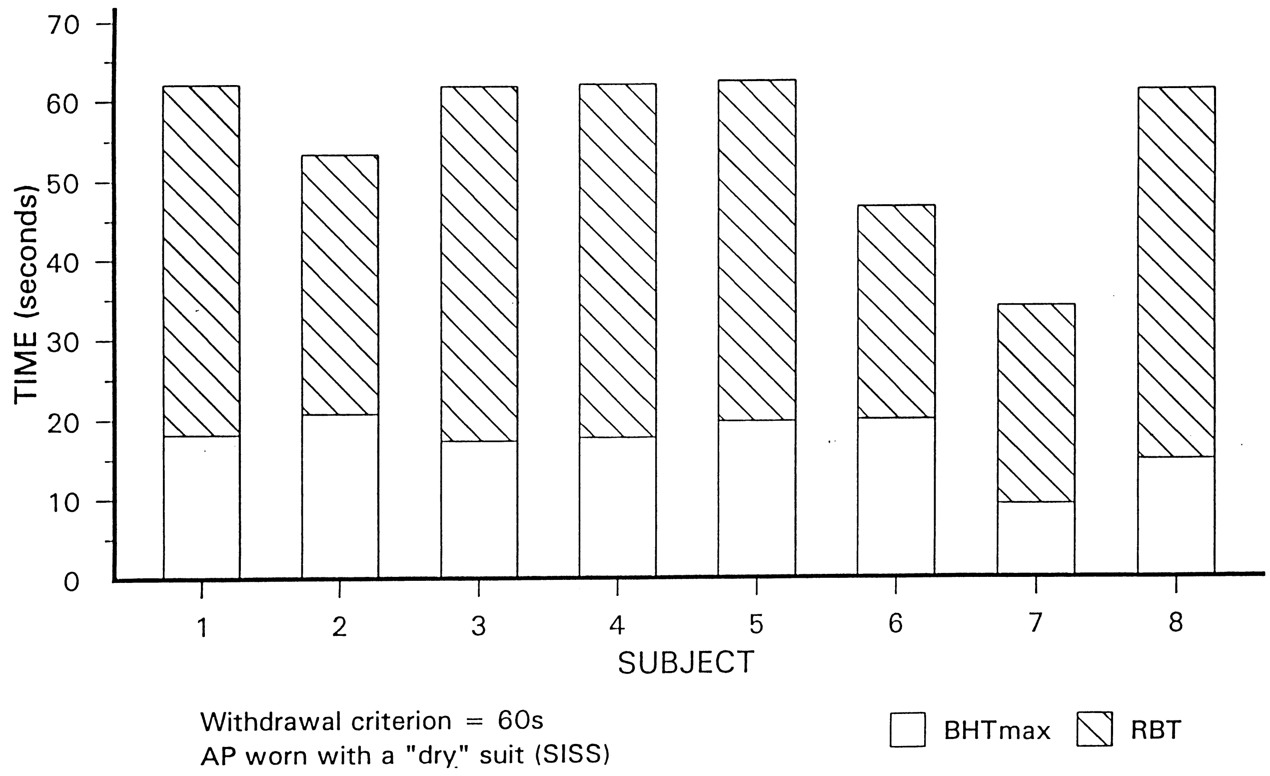
Graph produced by Dr.M.J.Tipton, Robens Institute, based on data obtained in the Phase V and VI experiments carried out at the Institute of Naval Medicine – July 1992.

Figure 3. Max. breath hold time (BHTmax) & total time (RBT) under 25 deg.C water using Air Pocket during a simulated helicopter underwater escape



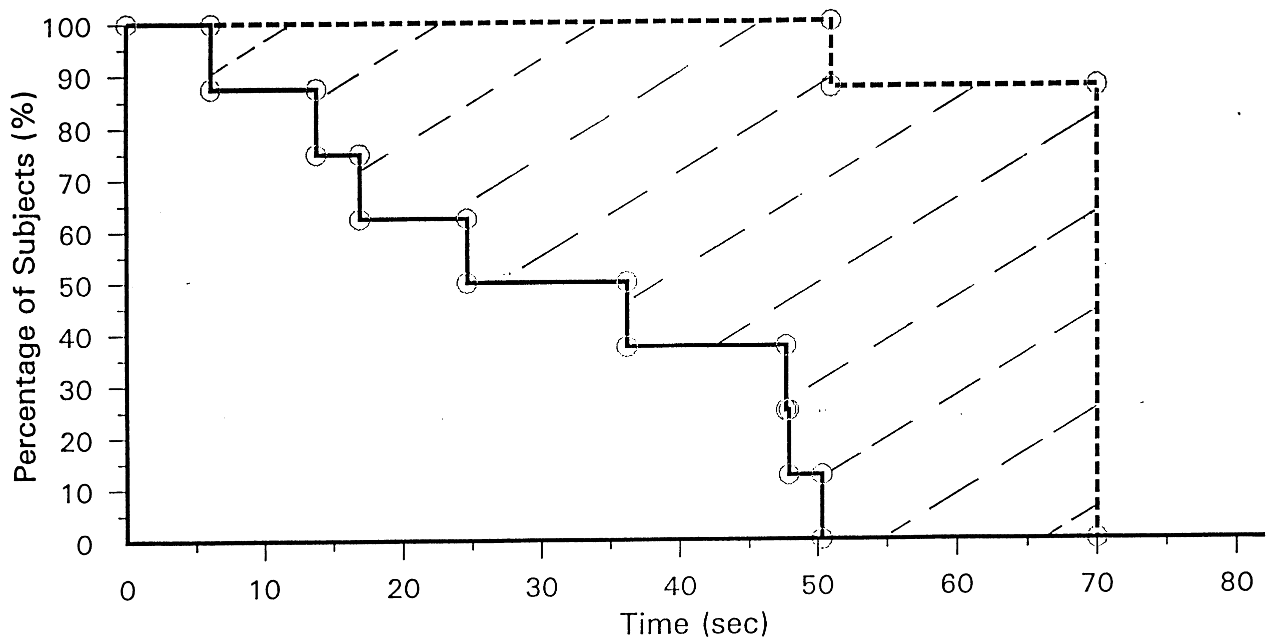
Graph produced by Dr.M.J.Tipton, Robens Institute, based on data obtained in the Phase V and VI experiments carried out at the Institute of Naval Medicine – July 1992.

Figure 4. Max. breath hold time (BHTmax) & total time (RBT) under 10 deg.C water using Air Pocket during a simulated helicopter underwater escape



Graph produced by Dr.M.J.Tipton, Robens Institute, based on data obtained in the Phase V and VI experiments carried out at the Institute of Naval Medicine – July 1992.

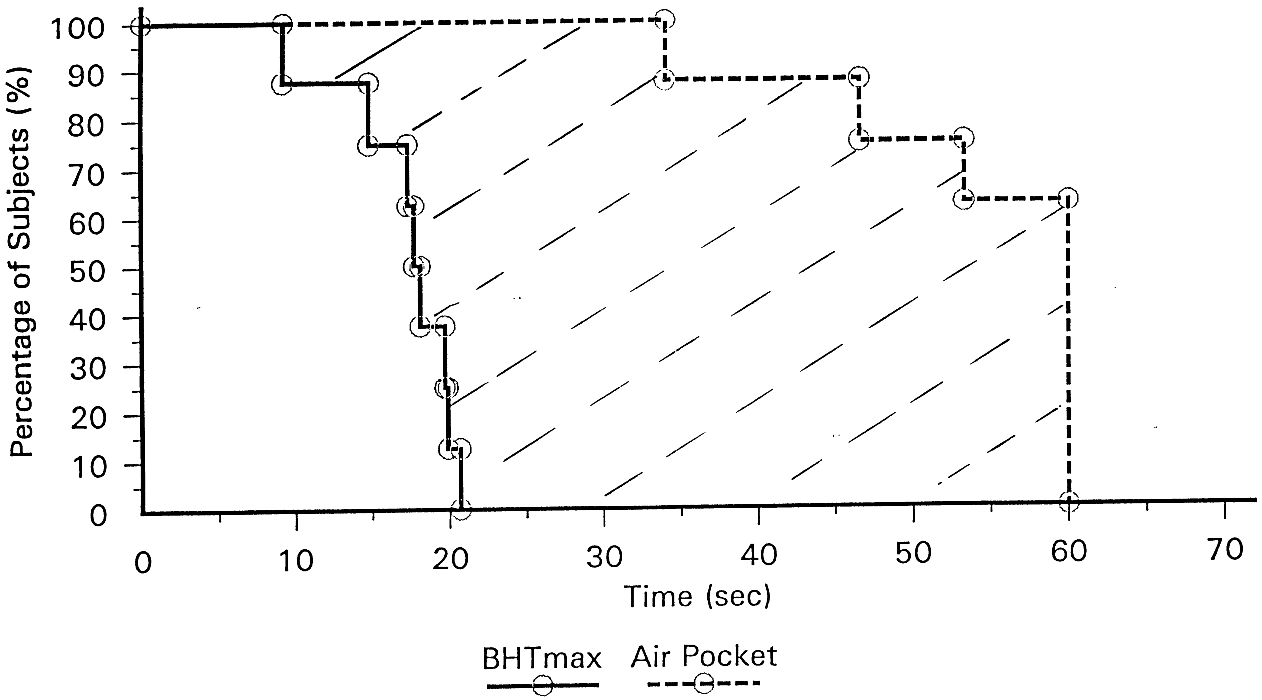
Figure 5. The percentage of subjects able to remain submerged for any given time when breath holding (BHTmax) or using Air Pocket (n=8)



Resting submersions Tw 10 deg.C
Withdrawal criterion = 70 seconds
Air Pocket worn with a "dry" suit (SISS)

Graph produced by Dr.M.J.Tipton, Robens Institute, based on data obtained in the Phase V and VI experiments carried out at the Institute of Naval Medicine – July 1992.

Figure 6. The percentage of subjects able to remain submerged for any given time when breath holding (BHTmax) or using Air Pocket (n=8)



Exercising submersions Tw 10 deg.C
Withdrawal criterion = 60 seconds
Air Pocket worn with a "dry" suit (SISS)

Graph produced by Dr.M.J.Tipton, Robens Institute, based on data obtained in the Phase V and VI experiments carried out at the Institute of Naval Medicine – July 1992.

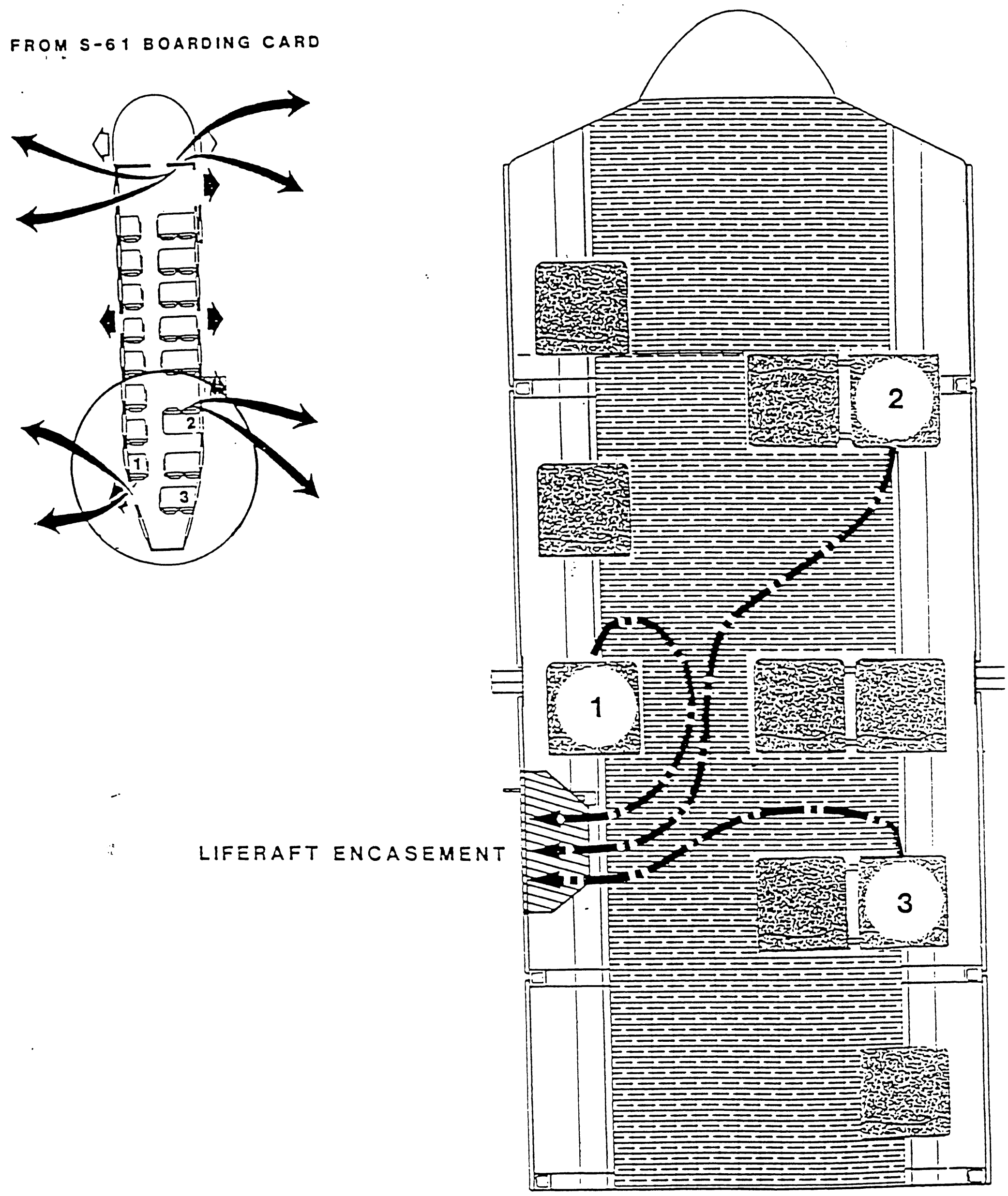


Figure 2.3 The S-61 METS Configuration

The amended diagram was originally shown in COGLA Technical Report 108
- May 1990.

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