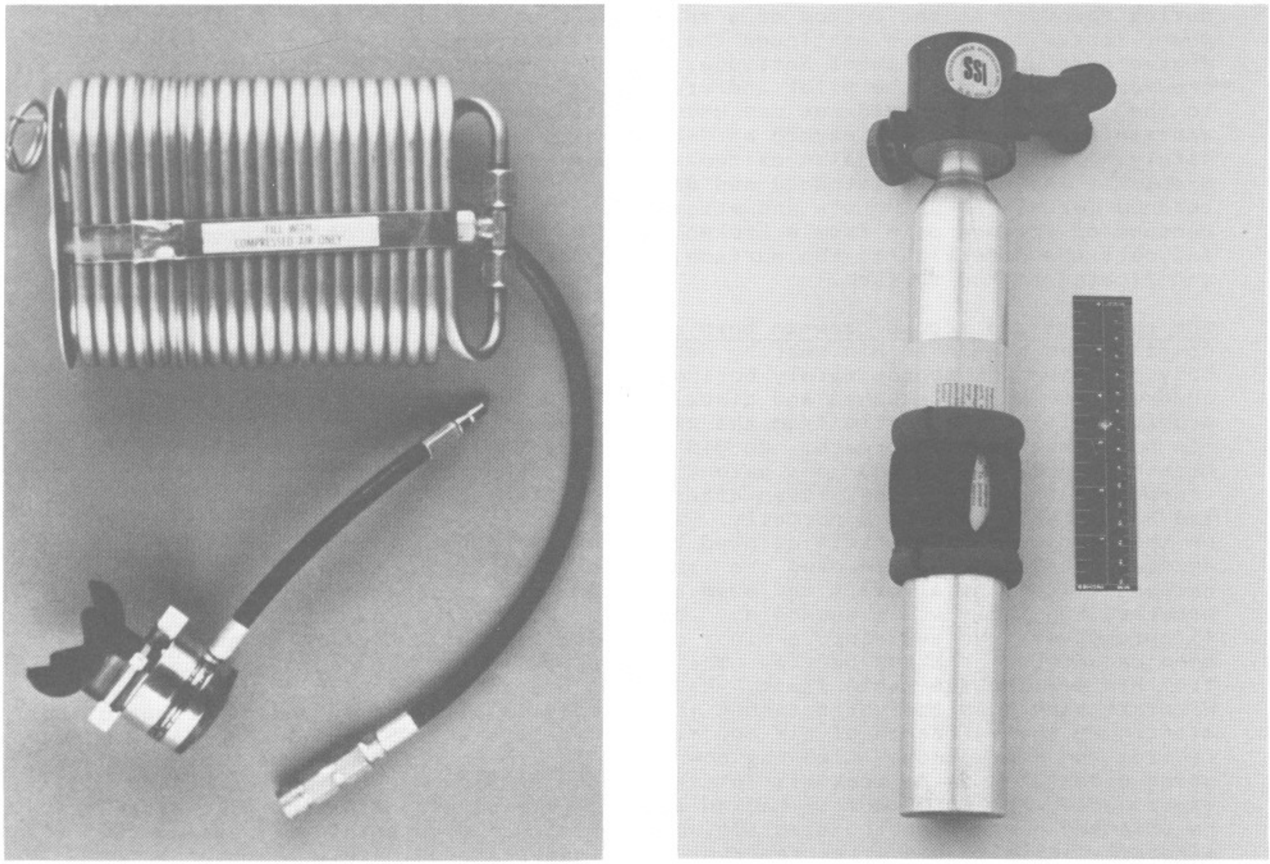
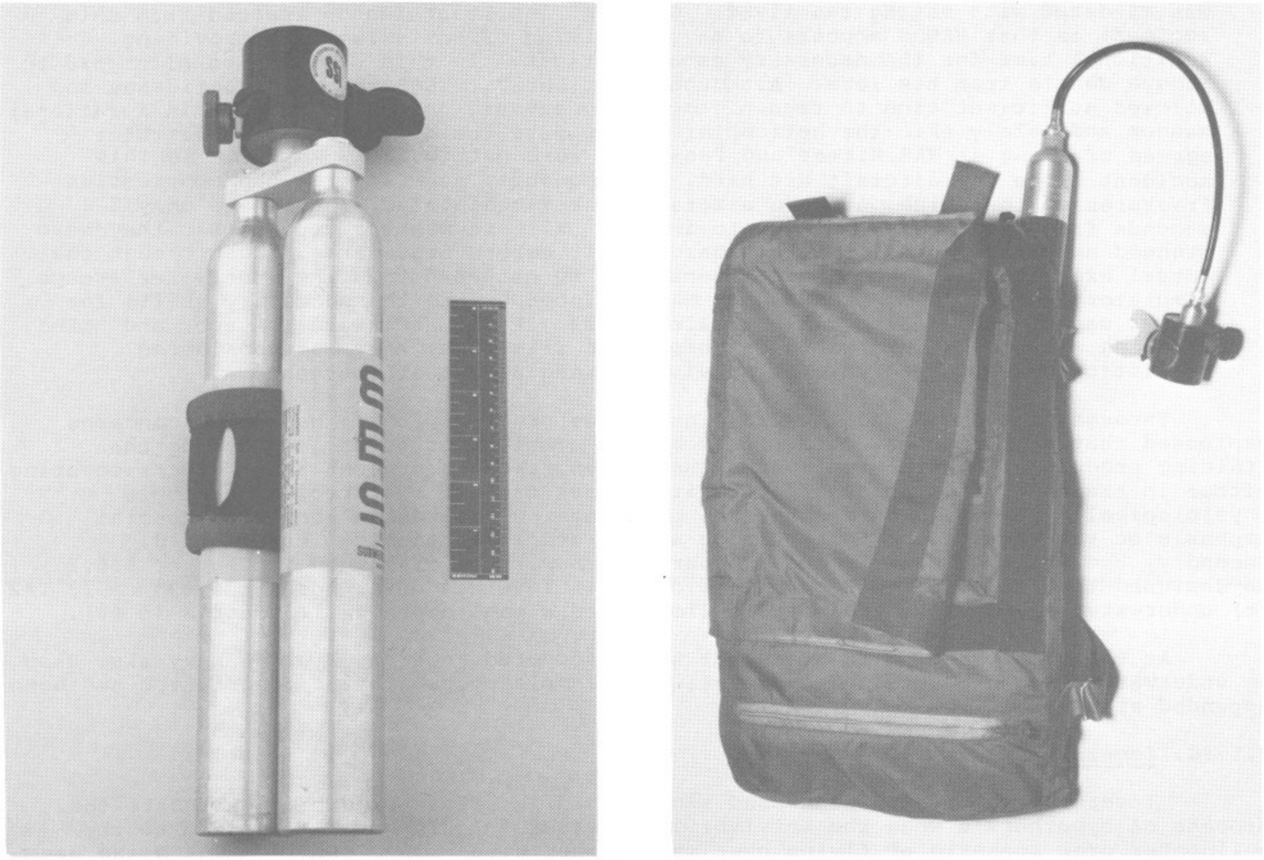
Figure 15. Different compressed air types of helicopter underwater escape breathing apparatus.



A. The original Robertshaw Control model.

B. The first single cylinder model from Submersible Systems Inc.



C. The first dual cylinder model from Submersible Systems Inc.

D. The DCIEM modification with flexible hose and method for stowing in backpack.

Pensacola (9D5).
The helicopter crash occurred in the western Pacific during daylight hours in moderate seas. The helicopter experienced a material failure in the transmission during recovery at the bottom of a maintenance autorotation that resulted in a full power loss. The pilots continued the autorotation and impacted the water in a 10-15 degree nose up, wings level attitude. The helicopter sank immediately, and all four crewmembers escaped; the pilot and crew chief exited the aircraft underwater and swam to the surface. They did not use HEEDS, but did employ underwater egress techniques and training procedures learned at NAWSTP which enabled them to exit the aircraft safely. The crew chief also exited and swam to the surface immediately with no problem. The pilot was stunned and disoriented after exiting. He immediately reached for his HEEDS bottle and attempted to use it but couldn't open his mouth because of intense pain from a broken jaw. He used a blast of air from it to indicate the direction to the surface. Once oriented, he inflated his life preserver and floated to the surface.

<u>The co-pilot and second crewman both used HEEDS to escape</u>. Following impact, the co-pilot was pinned in his seat by debris from a collapsed instrument panel. His body position was approximately horizontal and his face was turned down and underwater. He was stunned and disoriented, but used the HEEDS bottle. He had no problem pulling the bottle from the zippered vest and placed the bottle parallel to his body and began to breath. He did not clear the regulator before taking the first breath of air, but it had no apparent effect, other than a small amount of water trapped in the mouthpiece. Even after impact, the regulator worked satisfactorily and he was able to breath normally. The HEEDS bottle had an immediate calming effect on the co-pilot. The bottle allowed him time to become oriented and concentrate on egress procedures. He removed the instrument panel from his legs, released his harness,exited the aircraft and swam approximately 15 feet to the surface and breathed regularly while ascending. Once on the surface, he inflated his lifepreserver. He sustained a minor cut under his chin which is assumed to have been caused by the HEEDS bottle. The second crewman in the cabin section was thrown from his seat to the cabin floor. He was on his knees in chest deep water as the aircraft sank. As the water rushed in, he recalls being dazed and disoriented, but alert. He took a breath of air and reached for his HEEDS bottle. He easily removed it from the vest pouch. Like the co-pilot, he did not clear the regulator and was going underwater as he took his initial breath of air. Just as the co-pilot had experienced, the HEEDS bottle had an instant calming effect on the second crewman. He oriented himself in the aircraft, disconnected his gunners belt, exited the aircraft, inflated his life preserver and floated approximately ten feet to the surface. He breathed normally while ascending. Like the co-pilot, the crewman also sustained a minor cut under his chin which is assumed to have been caused by the HEEDS bottle, but the crewman cannot say for sure.
An important fact to be considered concerning this accident is that the HEEDS bottle was credited with saving two lives. The most important lesson learned from this accident is that HEEDS appears to have a calming effect as well as providing additional time for the necessary escape actions. In this case the co-pilot had to remove debris from his legs. Although disoriented, HEEDS restored confidence and allowed sufficient time to regain composure, execute egress procedures in a rational manner and safely exit the helicopter and swim to the surface. The underwater egress training at NAS Mirmar and Pensacola were particularly valuable in this accident since the aircraft hit hard. Consequently several crew had compression fractures of the spine, and the aircraft sank immediately. There were only 5-8 seconds from the initial failure to impact. All crewmembers report that they were stunned and disoriented, but remembered their egress procedures. Even though the actual experience was much more intense and spontaneous than the underwater escape simulator, the training provided by NAWSTP incorporated the necessary skills for proper use of equipment and for a safe egress. Pool, underwater escape, and HEEDS training all proved invaluable in this crash situation; they are considered realistic and essential to crew survival during an actual emergency.

Throughout the USN and the Canadian Forces programs, there have been concerns expressed that a trainee may suffer from an air embolism or burst lung during the training procedure. Three simple steps have been taken to prevent these events occuring either in training or in an accident. First, each trainee must recieve a simple physiological explanation on the hazards of breathing compressed air, with special emphasis on the requirement to exhale on ascent and at no time to breath-hold. Secondly, the Shallow Water Escape Trainer (which will be discussed in Chapter 3.6.2.) is so designed that the trainee's head to mid-thorax level is never more than 105 cm (3 1/2 ft) underwater and lastly, training is limited to a pool depth of 1.5 metres (5 ft).

At the time of going to press, it was discovered that the Italian Navy also uses an underwater escape breathing apparatus. For completeness a brief description has been appended at Annex A.

2.5.14. <u>Immersion Suits</u>

Immersion suits have been used since World War II in order to ameliorate the process of hypothermia when the survivor is immersed in cold water. Applied to the helicopter crew scenario of flying over water, they also reduce cold shock and the gasp reflex, and they enhance underwater breath-hold ability. Equally important, and what some agencies don't realize, is that they also protect the survivor from hypothermia while awaiting rescue in their life rafts.

In order for the immersion suit to be universally acceptable, it must be comfortable under a wide range of ambient temperatures, easy to don and doff, durable, simple to operate, and cheap and easy to maintain. It is, of course, only for the rare occasion in the immersion survival situation rather than in the thousands of hours that it may be worn. During an immersion and until subsequent rescue, it must effectively slow down the hypothermic process. This is a very tall order to expect from a garment; in fact, there is no suit on the market that meets all of these criteria.

In 1986, Brooks (13) reported various problems of immersion suits; the principal difficulties are reviewed below. The market is small, so manufacturers are loathe to make a large range of sizes; and hence, many suits don't fit correctly. On one extreme they are too tight and therefore uncomfortable; on the other, they are too loose and bulky and the wearer has to contend with folds of excess material. In either case, the wearer psychologically feels and physically looks awful in the suit.

Allan (7) in 1983 established very good guidelines for policy makers on how much insulation is required in an immersion suit at different water temperatures. Because water conducts heat 27 times more rapidly than air and the sea water temperature in areas where NATO operates barely reaches the upper teens Centrigrade even in summer, a dry suit must be worn (Figure 16).

A dry suit inherently has a number of problems. It is very difficult to make even a brand-new suit watertight unless it is personally tailored. It is even more difficult to maintain watertightness during its operating life. Continuous rubber seals are required at the neck and wrists to maintain watertight integrity, yet manufacturers often incorporate a neck seal, which invariably leaks. Paradoxically, regardless of type, the seal is somewhat uncomfortable, due to sensitivity of the neck, and difficult to maintain.

To close the apertures of the suit requires a water proof zip, which is not only expensive to make, but expensive to maintain. This compounds the problem of keeping the suit watertight. Neoprene nylon fabrics are durable, but extremely hot to wear. Ventile fabrics are vapour permeable, but only waterproof when new; moreover the fabric is difficult to weave, make up into suits, and consequently is expensive. Finally, Gortex-laminated fabrics are very expensive and not as vapour permeable as would be of practical benefit. Only the latter can be bonded with Nomex or a similar fire retardent material. The ideal fabric would be durable, fire retardent, vapour permeable yet waterproof, comfortable to wear and inexpensive; but no such fabric exists. Unfortunately too, the newer insulation liners made from blown polyester microfibres marketed under such trade names as "Thinsulate", lose their insulation when soaked, just like all others and offer little advantage over previous lining materials.

Besides the problem of maintaining the water integrity, there are other problems. Because of the need for trapped air inside the outer shell of the suit to provide insulation, flotation angle of the survivor is affected by the immersion suit. Thus, it is impossible to achieve the "ideal" position of lying 45° in the water facing the oncoming waves. All suits,without exception, force the survivor to lay horizontal in the water. Buoyancy from the air trapped in the suit may also aggravate disorientation and hinder or even prevent escape from a ditched inverted helicopter, if the buoyancy is so great that a survivor cannot swim down to an escape hatch or window. Various valves have been developed to let out excess air, but to date, the valves either leak badly or don't work at all. There is a new type of valve that shows promise, but it is still not in service with any manufacturer; it is undergoing testing at the Robert Gordon's Institute of Technology, Aberdeen.

In summary, the principle of immersion suits has not changed in the last fifty years. They are expensive, uncomfortable and unpopular with wearers and operators and, in their current design, are difficult to maintain and commonly leak. The time has come for new ideas in design.

2.5.15 Equipment Design Improvement

This chapter so far has discussed direct survival factors on the human when confronted with sudden immersion and possible inversion in cold water. There are however a number of indirect factors related to the overall general design of helicopters which effect survival and there is room for improvement.

(i) Helicopter Flotation

As previously observed in Chapter 1, helicopters are inherently unstable in the sea. The work horse of the USN, the H-3 or Sea King is designed to stay afloat in a sea state 3 (with wave height 0.5 - 1.25 metres) with bouyancy bags deployed (76). The U.K. Marine Information/Advisory Service confirm that the wave heights for instance in the Northern North Sea at the Stevenson Station (61° 20'N 0 E) are as follows:

DEC - FEB	3 metres	exceeded	65%	of time
	5 metres	exceeded	20%	of time
MAR - MAY	3 metres	exceeded	25%	of time
	5 metres	exceeded	8%	of time
JUNE - AUG	3 metres	exceeded	28%	of time
	5 metres	exceeded	1%	of time
SEP NOV	3 metres	exceeded	28%	of time
	5 metres	exceeded	5%	of time

It would therefore appear that even the Sea King helicopter, which is relatively well configured for flotation, has a high chance of capsizing under such conditions. What can be done about this problem? Is it possible to increase the flotation characteristics of the helicopter?

The French Navy have fitted special flotation bags to their Alouette II and Alouette III helicopters which appear to work well; the underside of their large troop carrying Super Frelon is also deliberately boat shaped to assist in flotation.

More recently the Saudi Arabian Armed Forces Medical Services have purchased two emergency flotation kits for their Bell 212's. It was developed by Westland Aerospace and Bristow Helicopters and is adaptable to the Bell 205 and 412. There are twelve currently of these kits in service world-wide.

King (40) also studied the possibility of increasing the stability of the H-46 Sea Knight helicopter by the addition of four externally encapsulated spherical flotation bags in two nose-cone and two stub-wing pods. The system could be inflated automatically or by the pilot in under ten seconds. The penalty was that the whole system weighed 220 lbs. The U.S. Navy has recently approved the H-46 Helicopter Emergency Flotation System for full production in 1989 (73).

The CAA as previously mentioned consider that it may be more practical to accept that it is impossible to keep the helicopter afloat, but design into new helicopters the ability to remain on the surface for ten minutes to allow everyone to egress into the liferafts before sinking.

The USCG have recently accepted into the service the Aerospatiale Dauphin II which, theoretically, should float tail up and maintain water integrity in the cabin and passenger compartments. Schreiner Airways had a recent accident (19/4/88) approximately 45 miles of the Dutch Coast in a Dauphin 365-C3 as follows:

> The pilot decided, on an overshoot from the ship due to disorientation caused by floodlights on the bridge, to make a right hand circle for landing. During final, the helicopter hit the water in a slight nose down, left sideways motion with about 15 kts forward and 8 kts sideways speed. The two pilots and three passengers had no warning. The helicopter turned inverted, floating bottom-up on the bouyancy tanks and tail section. Everyone escaped from underwater successfully.

The helicopter acquitted itself very well. Even though it inverted, at least after a severe impact, it remained afloat allowing the crew and passengers to escape. It would therefore now appear to be technically possible to manufacture a helicopter fuselage that will withstand relatively high impact forces and stay afloat even if it is inverted. The next step should be to develop escape hatches in the floor or at least extend the push out windows to floor level. This would make ease of escape in the inverted position much simpler.

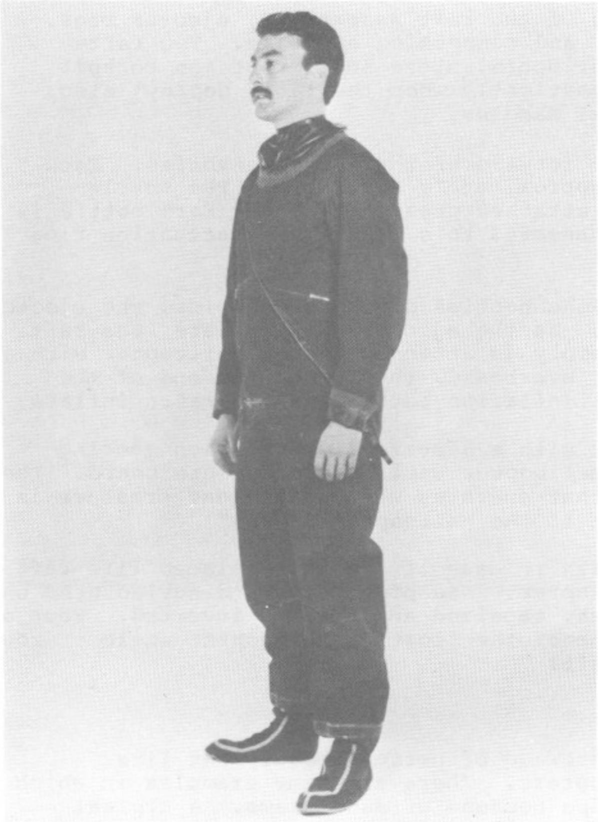
(ii) Liferaft Deployment

A fundamental flaw in the concept of escape survival is that all multi-seat liferafts are stowed internally within the cabin of the military helicopter. Anyone who has attempted to escape from an inverted rapidly-sinking helicopter or from an escape trainer would understand that while completely submerged and holding one's breath in darkness, it is against all sense of survival and reason to go in a direction opposite to that of the escape route to attempt to release and deploy a liferaft. It is a simple fact that deployment of an internally-carried liferaft from an inverted submerged helicopter is virtually impossible. Yet helicopter companies show little interest in vacuum packing liferafts and mounting them so that they can be externally jettisoned and illuminated on inflation. King (40) conducted a study in 1976 for Boeing Vertol and confirmed that it was possible to mount two fifteen-man liferafts externally on the USN H-46 Sea Knight helicopter, but little progress appears to have been made since then. Only recently, the RAF have developed a system for mounting them on to the Sea King helicopter; it is very close to production standards, but lack of funding has caused the project to be put on hold.

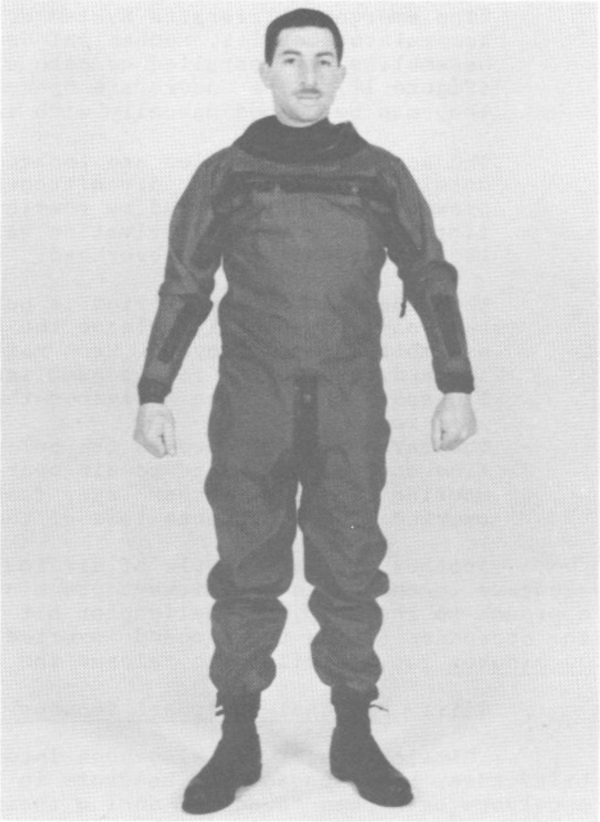
Figure 16. Principle types of helicopter survival suits used in military and civilian operations.

A. CF double layered cotton ventile suit,
- Horseshoe zip.
(Courtesy Mustang Industries Inc.)

B. CF Quick-don suit, - Semi-vertical zip.

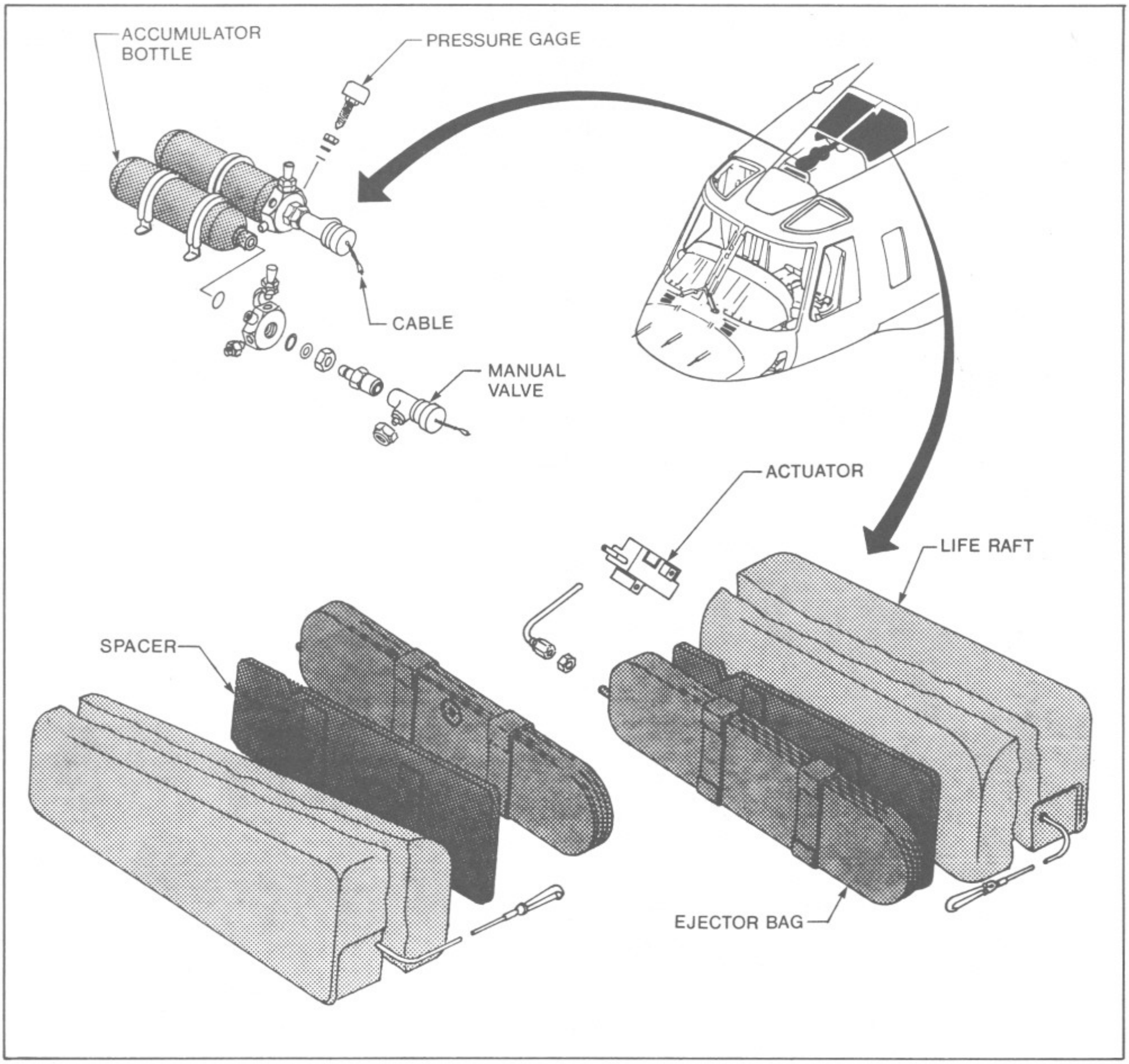


C. RAF upper half single layered cotton ventile suit for NBC conditions.
- Diagonal zip.
(Courtesy Dunlop - Beaufort Ltd.)



D. USN Gortex Nomex suit. - Transverse zip.
(Courtesy N.A.D.C. Warminister. Pa.)

Figure 17. The system of externally mounted liferafts on the Bell 214 ST helicopter.
(Courtesy Bell Helicopter TEXTRON and Flight Safety International.)



After impact, the third crewman was thrown forward between sonobuoys and bulkhead still attached to his gunner's belt. First he had difficulty releasing the belt, then as he exited through the cabin door, he became tangled in his headset. He swam clear with the aid of the second crewman and inflated his life preserver on the surface.

Many of the passengers are staying overnight in oilrigs, merchant or military vessels and some of course are on crew change. They all are on business and at the very least carry a briefcase and overnight bag. Many people wish to work from their briefcases on longer flights, others carry pocket books, newspapers and additional carry-on warm clothing. More consideration is needed in the design of stowage for this type of equipment.

2.5.16 Post Escape Problems

Once a person has escaped from the helicopter, whether injured or not, there is still the problem of survival in the open water or in a liferaft prior to rescue. Even the hoisting is not without its hazards!

(i) Life Preservers

There have been several reported cases of crew members unable to find and then grasp the toggles to activate their life preservers. This is made worse with slippery gloved hands. Many life preservers are still made with very small toggles on their activation devices. These can easily be confused with buttons and other accoutrements on the front of the survival suits, flying coveralls, and other work dress. In addition, there are still many life preservers available, both in the military and civilian markets, which require two separate activations, often with separate hands, to achieve full buoyancy. In an emergency, this is not acceptable. Brooks (15) reported on four such incidents in his 20 year study of Canadian Forces aircraft accidents. The crews of two helicopters in this series likely perished because of inability to find the activation toggles. Certainly one aircrew of a fixed-wing aircraft that ditched ahead of an aircraft carrier lost a leg in its propeller because he could only activate one side of his life preserver. With only about eight lbs of positive bouyancy in his life preserver, instead of coming straight to the surface, he traversed the complete hull underwater. The other three aircrew also traversed the hull for the same reason but were lucky to survive without loss of limbs. The following is an accident narrative from a narrative from a USN H-3 Sea King Helicopter which hit the sea following a tail rotor failure. Both pilot and co-pilot had trouble activating their life preservers in daylight:

> The pilot was unable to find his life preserver inflation toggles, swam to surface, found the toggles and inflated his life preserver. The co-pilot was pinned to the left side of cockpit by the spin, prior to impact. He unbuckled his seat belt and exited through the open co-pilot window. He was also unable to find the life preserver toggles. He swam to the surface, took off his helmet and used it for flotation. He found the right toggle, inflated right side of his life preserver and put his helmet back on. He then found the left toggle and inflated it. Both crewmen had problems inflating their raft. They had to remove it from its container and unroll it in order to find the inflator pull handle.

The above incident also illustrates the need for a pre-flight briefing to include post-crash survival and a brief description of how to operate life jackets, life rafts and all personal survival equipment. Often with the noise of downwash from the rescue helicopter blades and engine, it is quite impossible to communicate with each other when in the raft or in the water.

(ii) Life Rafts Reliability and Servicing

Even if the multi-seat life raft is successfully deployed in the water, there is no guarantee that it will always stay afloat, or that the required survival equipment will be stowed in it.

> While en route from the offshore oil rig SEDCO off Sable Island to Halifax Airport, the crew of the Canadian-registered S61 helicopter noted that the main transmission oil pressure was decreasing and that the torque indication had dropped to zero. As the oil pressure continued to decrease, the pilot decided to carry out a controlled ditching in the Atlantic Ocean about six miles from land. During the evacuation of the helicopter, the co-pilot boarded 14 passengers into the forward raft in an attempt to get as many of the occupants as possible away from the helicopter, as he feared the aircraft might capsize. After the pilot-in-command had shut down the helicopter engines and stopped the rotor, he moved aft to the passenger cabin. Once he had passed the airframe-mounted Emergency Locator Transmitter to the passengers in the life raft, the raft was pushed away from the helicopter. As the raft moved into the outer limit of the rotor arc, the stationary rotor blades were swinging in the water dangerously close to the raft, and the occupants had difficulty keeping the raft from being struck by the rotor blades.
>
> After launching the Number 1 life raft, the pilot, co-pilot and remaining passenger inflated the Number 2 life raft beside the aircraft and stepped directly into the life raft. The raft was then pushed away from the helicopter, and it drifted under the tail pylon. The three occupants had difficulty keeping the raft clear of the stationary rotor blades as the helicopter was pitching and rolling in the water. Shortly after the Number 1 life raft was launched, the lower buoyancy chamber began to deflate, and water began to enter the interior of the raft through the boarding entrances. When the raft survival equipment containers were opened, the occupants were unable to find a bailing bucket or oars. In an attempt to remove the water from the interior of the raft, some of the occupants used their protective overboots as bailing buckets. By the time the rescue helicopters arrived, the occupants were sitting in about 18 inches of water. Except for the initial difficulty they experienced clearing the helicopter, the occupants of the Number 2 life raft had no problems during the one hour they were awaiting rescue. When the life rafts and their contents were examined, the following observations were made:
>
> a. There was no reflective tape on either life raft;
>
> b. There were no grab lines on the inside of either life raft;
>
> c. The two entrance areas of the life rafts are outlined with lights which are energized by a salt-water activated battery. The batteries in both rafts were time-expired;

d. Both rafts had several large patches on the buoyancy chambers which were not stamped with the date of repair;

e. Eight D cell batteries were found wrapped in a plastic bread bag and taped closed. All the batteries showed signs of corrosion;

f. One flashlight was recovered and was not in operating condition;

g. Two metal signal mirrors were recovered. The surfaces were not highly polished and were not smooth. No safety lines were attached to the mirrors, nor were there instructions or markings for their use;

h. One of the two flares recovered had a loose striker in the cap. The striker could have been lost when the cap was opened for use; and

j. The expiry date on a bottle of analgesic tablets was past dated, and the tablets should have been replaced during the last raft inspection.

These survivors were lucky that the rescue times were short. Although the accident occurred in winter, it was a calm clear relatively warm day and there were several serviceable Search and Rescue helicopters with rotors turning only a few miles away on the morning of the accident. The next two days the weather conditions deteriorated to the extent that it was impossible to fly. Under those circumstances, they may well have perished because of the poor maintenance of their life rafts.

(iii) Personal Survival Equipment

The first problem is that flying gloves when wet become very slippery and virtually useless for gripping anything, particularly inflation toggles on life preservers. Yet it appears that no one has undertaken research to develop a material that would improve the grip of a wet glove. This may be wishful thinking, but must be worth attempting. The second problem is that the survival aids in the life raft and issued as personal equipment with the life preservers just do not always work when needed. A typical example of this happened to the crew of a USN H-3 Sea King helicopter who became disoriented during transit to rescue a man overboard. The helicopter crashed into the sea and had problems not only with the life preserver but also the location aids:

> The pilot, co-pilot and SAR crewman were thrown from the helicopter. The other crewman left the helicopter underwater through a hole in the side; their life preservers inflated normally. However the SAR crewman did not have a life preserver, he had a life vest which did not inflate despite being actuated. The SAR crewman had only his wet suit and a cushion that was floating near him to buoy him up. In order to be seen, he shone his flashlight on his helmet. The pilot used a red flare, but had a problem seating other flares due to broken threads. JP5 in the water discouraged use of other pyrotechnics. The pilot and the crewman used their radios and the crewman used his strobe and flashlight. The co-pilot had trouble with his radio and used the crewman's flashlight. The SAR crewman being a distance from the others was rescued first. A swimmer from the rescue helicopter was put in the water especially for the SAR crewman as the pilot was already being hoisted; however, the co-pilot was attached to him by a shroud line which was tightly snagged around his legs. As the hoist went up the co-pilot reached for his knife, but the line broke. Once in the rescue helicopter, the return to base was uneventful. All crewmen were hypothermic when brought ashore.

This accident clearly demonstrates that the survival equipment such as flares and radios must be made failure-proof and that materials used for life rafts and life preservers abrasion and puncture proof. Furthermore, the crew must be well briefed on how to use the equipment and on how to provide pre-flight briefings to passengers who have never used it.

(iv) Problems with Hoisting

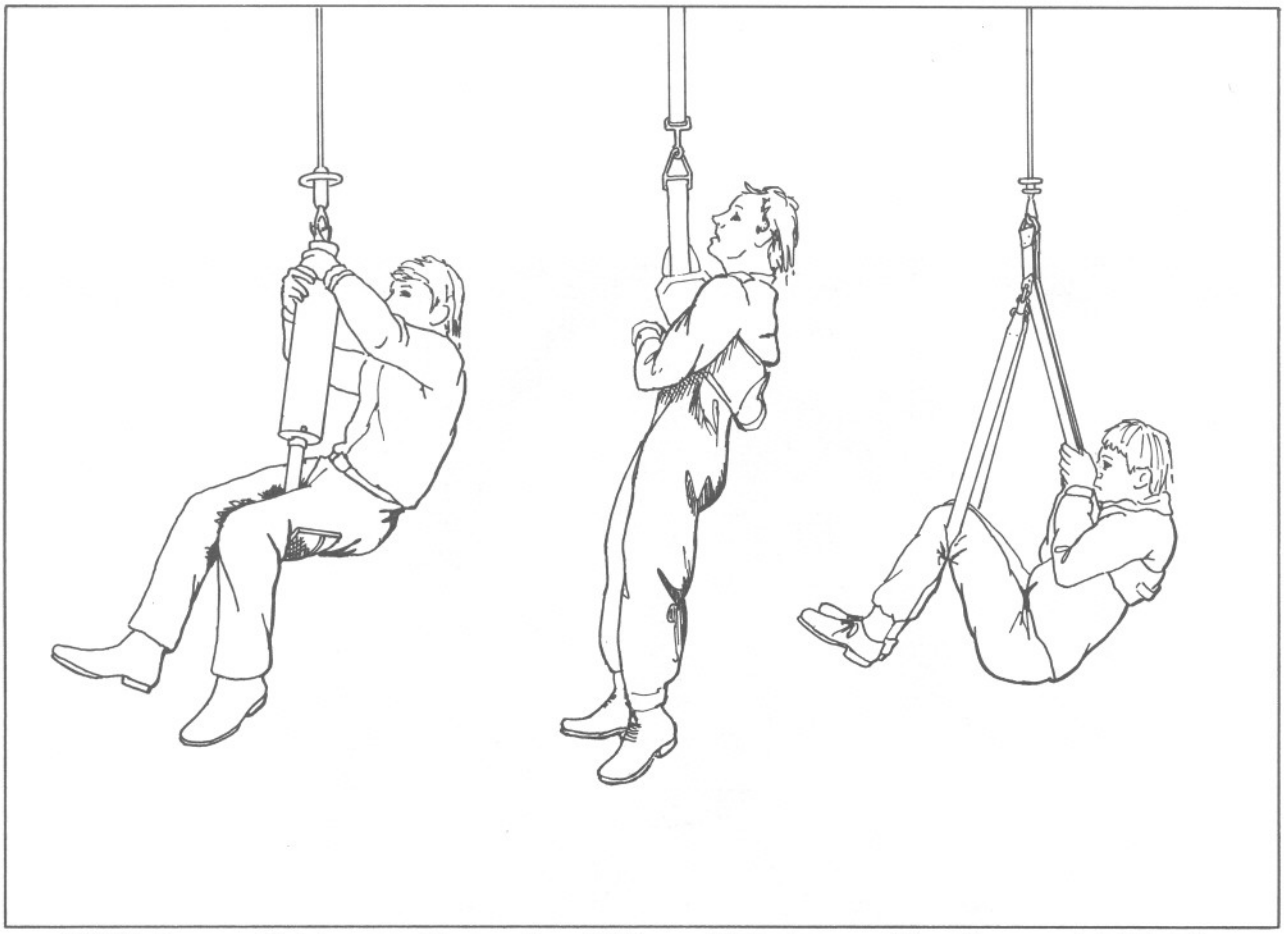
During the 1979 Fastnet race (water temperature 15-16°C), three (20%) of the 15 fatalities among the competitors occurred during the rescue following the storm - one while being rescued by helicopter and two while endeavouring to climb up a scrambling net thrown over the side of a ship.

It would appear that post-rescue collapse and death occurs in about 15-20% of hypothermic victims (29). As Golden pointed out, it may not be a phenomenon entirely limited to exposure in <u>very</u> cold water. The exact mechanism for this has still not been proved; it is unlikely simply "the afterdrop" effect of a "cold bolus" of blood returning to the heart during rewarming (28,30), but more likely to be cardiovascular in origin (29). The current theory is that it is principally due to the sudden withdrawal of the supportive hydrostatic squeeze. Thus, when the body is removed vertically from the water, there is a tendency for the blood to pool in the legs, thus compromising the cardiovascular system. This drop of blood pressure during the hoisting of hypothermic subjects was well demonstrated and reported by Ocker and Koch in 1984 (48).

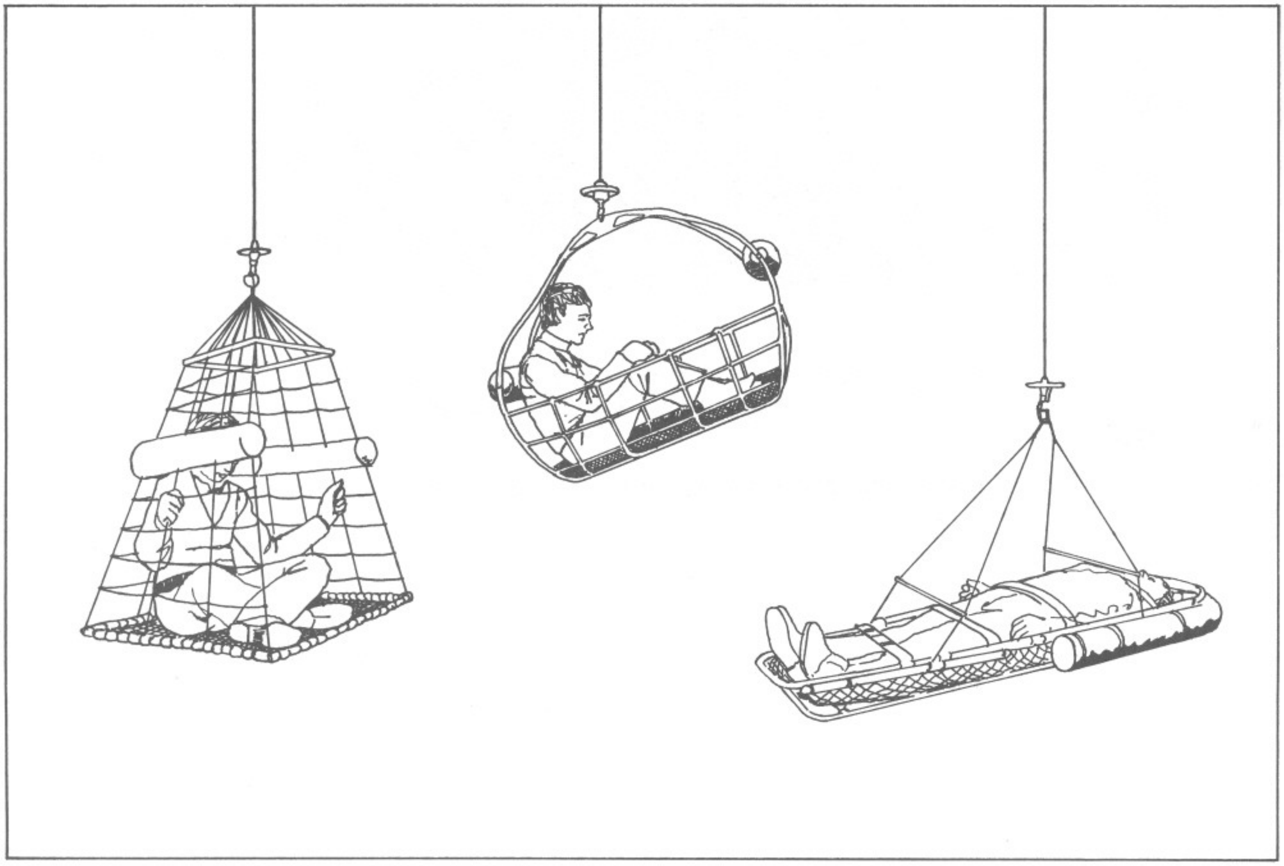
Therefore, for those who are hypothermic, hoisting in a vertical position is not recommended. In spite of this, most rescues are still done using either a horse collar or some form of double-lift harness. Wherever possible, rescuers should be encouraged to use horizontal lifting in devices such as the Billy Pugh nets, U.S. Coastguard style of baskets, or even folding Stokes Litters if there is room for them, particularly if the condition of the survivor is critical (Figure 18).

There are two promising new hoisting ideas, first, the horizontal lift strap, developed and currently undergoing testing by the Royal Navy and, second the concept of picking the complete life raft up by helicopter for multiple casualties. Using their 22-man life raft and a Sikorsky S61 for hoisting, this multiple casualty concept has recently been successfully tested by Viking in Copenhagen with twenty-two 70kg sandbags to represent the survivors. The raft was picked up, flown at 60 knots and landed with no displacement of the sandbags or other problem. This system has the added advantage that the survivors are protected from the wind by the canopy. An early test in Canada, using a large open net called the EMPRA basket that held up to 50 people, was a failure because of the windchill effect on the survivors. If this concept is introduced to prevent overloading it will require a rescue technician to be lowered first of all to control the number of survivors allowed into each raft.

Figure 18. A series of different methods of hoisting survivors from helicopters ditched in water.

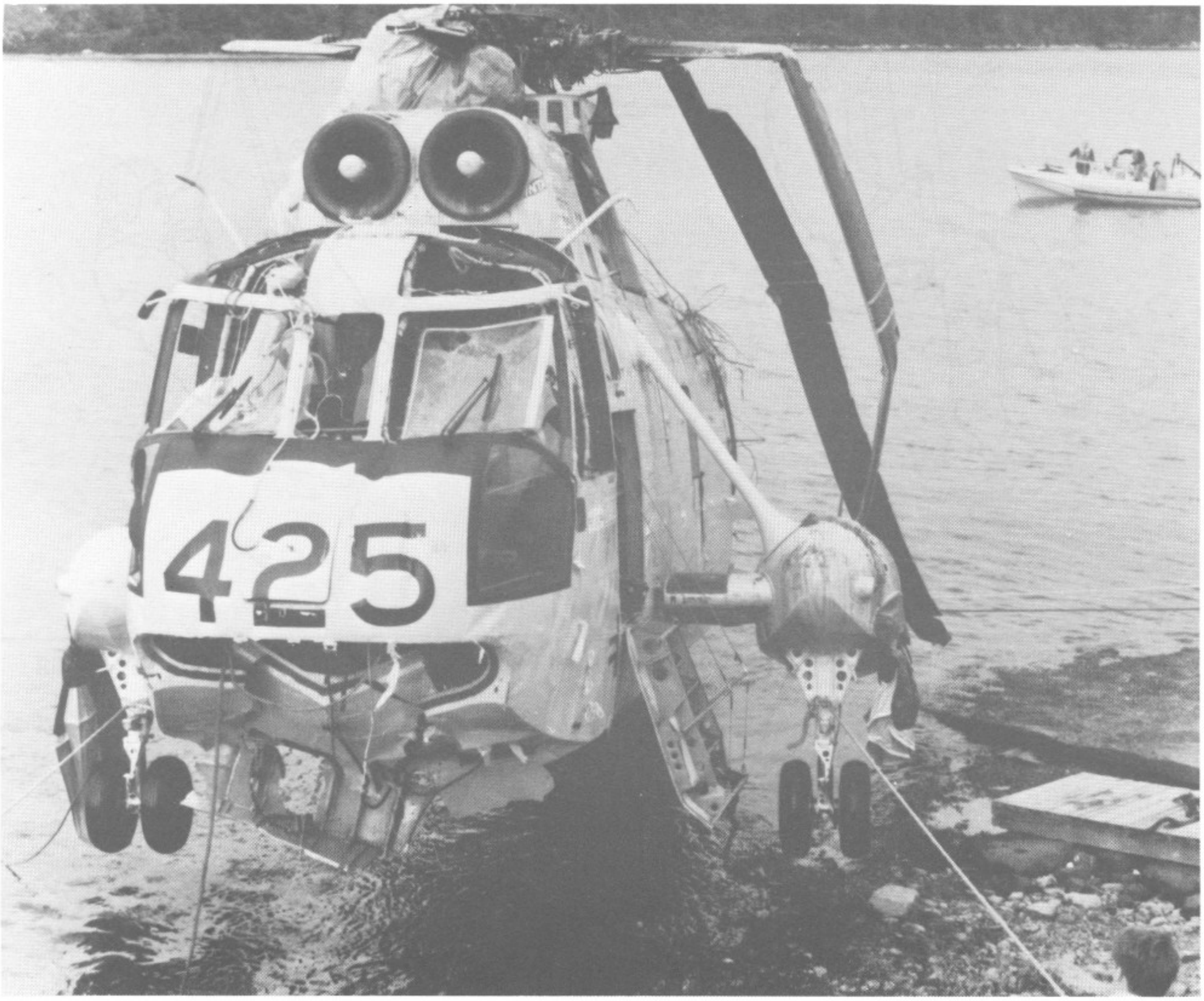


USAF Rescue Hoist **Conventional "Horse Collar"** **New Proposed R.N. Sling**



Billy Pugh Net **US Coastguard Basket** **Folding Stokes Litter**

SWC831383-1 .



The 4 crew of this Sea King helicopter had less than 15 seconds warning before it hit the water, rapidly inverted and sank. Escape was very difficult and one crewman came close to perishing.

This accident demonstrates the necessity for good underwater escape training.

CHAPTER 3: UNDERWATER ESCAPE TRAINING

3.1 Recommended Course Syllabus

In order to reduce fatalities caused by helicopter accidents in the water, it is essential to have a good practical training program. This short narrative, in conjunction with the previous ones, illustrates the reason why.

> During a night ASW operation, the USN helicopter impacted the water, rolled over and sank. All aircrew egressed the helicopter underwater. The pilot made three unsuccessful attempts to jettison the window. He then opened the sliding window, pulled himself halfway out, inflated his life preserver, cleared the helicopter and floated to the surface. The second crewman's window was pushed in by in-rushing water. He became momentarily disoriented. On first escape attempt, he struck his head. On second attempt, he felt for familiar objects, regained his orientation, and exited through the window. Both the co-pilot and first crewman were able to jettison their windows while still above water. The first crewman had no difficulty during egress, but his lack of underwater escape training could have prevented safe egress, if he had been on the low side of aircraft. The crewmen ended up in two groups on the surface with the helicopter in between them. There was no coordination in the use of their radios and the guard frequency of one group interfered with voice transmission of the other group. The pilot fumbled with his life preserver in search of smoke flares. This was difficult due to sea state, darkness and leg straps not being tight enough, allowing his vest to ride high, making access difficult. Both groups of survivors used various signalling devices, including pencil flares, day/night flares, strobe lights and radios. They were eventually rescued by boat.

It is quite essential that 1) personnel be trained in the correct operation of their life preservers and life rafts, 2) they understand how to operate flares and radios, and 3) crewmembers and rescue specialists be aware of the difficulties of pulling injured people into life rafts and of hoisting people, either injured or relatively well into helicopters.

The aim of the training is to provide aircrew and passengers with the knowledge and skills required to be able to egress successfully from a helicopter ditched in water. It is recommended that ideally six, but not more than ten students at a time, be loaded on such a course to ensure both close supervision and that each student receives good practical training in all aspects of the equipment. As a prerequisite for the course, aircrew must have a current aircrew medical certificate and passengers must have passed a medical-equivalent to the USAF Class 1 Flight Physical. The major subjects should be covered, in three or four classroom lectures (depending on whether an underwater breathing apparatus is to be used) and one practical exercise in an underwater escape trainer, they are: 1) hazards of over water operation; 2) safety and survival equipment; 3) underwater breathing apparatus (if used); 4) pre-ditching preparation, and 5) underwater egress.

3.2 Hazards of Overwater Operation

A brief description of potential problems that may occur to the aircraft and result in ditching should be presented. They include mechanical, electric or hydraulic failure of engines, transmission and tail rotors, and the ever-present potential for fire. It should be emphasized that these problems tend to occur during the critical phases of flight, i.e., approach, missed approach, transit and hover.

Students should be aware of the environmental hazards, particularly thunderstorms, icing conditions, low visibility, and water, when a water landing has to take place. They should have a basic knowledge of sea states and of the causes and prevention of cold water-induced hypothermia.

Most important, the problem of underwater escape should then be described, i.e., in-rushing water, fire, smoke, fuel, darkness with no visual reference, and difficulties of releasing the restraint harness and of finding and releasing an escape hatch. Other factors that must be described are the problems of inevitable disorientation, the potential for being hampered by equipment, cold, injury, being pinned, being blocked by other passengers, and finally, reduced breath-holding ability, particularly in very cold water.

To complete this first classroom period, a description of the hazards that may occur after a successful underwater escape should be given, particularly the very real dangers of drowning, hypothermia, and potential injury that may occur during the rescue phase.

3.3 Safety and Survival Equipment

The equipment should be described in the second classroom period, divided into two sections, for personal and helicoper equipment.

3.3.1 Personal

Important points to teach about personal equipment are 1) the principles of the immersion or survival suit, how it should be worn, donning and doffing procedures, and importance of good care and attention; 2) the principles of the life preserver, its inspection and how it is operated; 3) the head set and/or helmet, how to obtain a proper fit, how to wear it, and use of visors; and 4) functional use of other equipment such as knives, flashlights, flares and personal items.

3.3.2 Helicopter

In the helicopter equipment section the helicopter seat and harness and its physical relationship to the stowage of all items of of safety equipment and communication should be described. Life rafts, emergency locator transmitters, fire extinguishers, first aid kits, sea anchors and tow lines, pyrotechnics kits, search and rescue packs and rescue gear should be individually described and, practically demonstrated. Then, a description and practical demonstration of the location and operation of the emergency exits and alternative routes, in case of being unable to reach the primary exit, should be given. It is very important that students are able to feel the amount of force required to open such exits, and that they activate such devices to their own and the instructor's satisfaction.

3.4 Underwater Breathing Apparatus

If an underwater breathing apparatus is to be used, then one classroom session should be devoted to its description, the requirements for pre-flight inspection, the method of operation and care of the unit. Specifically to be included are the technique of purging the regulator underwater and a caution about recharging the cylinders when there is a risk of contaminated air. Finally, a very short and simple physiology explanation should be given for the necessity to exhale during ascent after escape. This description is essential to prevent the trainee in the pool or the survivor in an accident suffering from an air embolism or burst lung.

3.5 Pre-ditching Preparation

This last classroom period should describe the paramount importance of the pre-flight briefing. For all crew and passengers, the pre-flight brief must include procedures to be taken in preparation for ditching, either with advanced or with very little or no warning. With only very little warning, the only course of action is to teach the crew and passengers to adopt a good crash position, and this should be practically demonstrated. With advanced warning, it is important that each person is taught how to 1) secure loose articles, 2) check their immersion suit and life preserver for correct donning and security, 3) ensure that their harness is secured tightly, 4) reconfirm escape exit location, 5) prepare to adopt a good crash position before impact.

For the aircrew, the lesson will also include the normal flight briefing items, the importance of crew responsibilities under normal operations and, during emergency procedures, the importance of the checklist and potential implications of deviating from the checklist, both before and after ditching.

For the passengers, the lesson will also teach the necessity to check and visually locate all parts of the personnel safety equipment, helicopter emergency equipment and helicopter emergency exits, and to reconfirm mentally normal emergency and abandonment procedures.

3.6 Underwater Egress

3.6.1 Without Emergency Breathing Apparatus

This section of the training must be conducted using some form of helicopter underwater escape trainer. In addition to two instructors, a minimum of two professional standby safety divers will be required in the pool at all times during the training sessions. Following the practical demonstration of how to abandon the helicopter, first in the upright surface position and then in the inverted position, the students must each demonstrate that they can successfully conduct the procedure themselves and then deploy all of their safety equipment at the surface. It is recommended that each student complete a minimum of two surface abandonments to ensure a thorough familarization of the equipment and procedures before attempting an abandoment in the inverted position.

The number of sequences that should be conducted in the inverted position will depend on the type of helicopter and the type of operation. As a minimum, it is recommended that the students be required to egress successfully from the helicopter configured to the type in which they will operate or, if a passenger, in which they will most likely travel. To achieve qualification, it is recommended that students successfully complete a minimum of four unassisted escapes, in sequence, from the designated position as follows:

(a) with no escape window/hatch in place while wearing life preserver and immersion suit, in day conditions;

(b) with escape hatches/windows and release mechanisms in place while wearing life preserver and immersion suit, in day conditions;

(c) with escape hatches and release mechanisms in place, while wearing full equipment (life preserver, immersion suit, helmet and backpack, if applicable), in day conditions, and

(d) with the escape hatches and release mechanisms in place, while wearing full equipment, in night conditions.

Additional training using secondary escape routes in the underwater escape trainer can also be added if desired. The complexity of the escape can also be enhanced by the addition of requirements to release life rafts and emergency locator transmitters before escape. This will all depend on the requirement of each helicopter operator.

3.6.2 With Emergency Breathing Apparatus

As has previously been mentioned, there has been much discussion concerning the safety of training personnel with an underwater breathing apparatus, particularly the possibilities of air embolism and ruptured lung. Recently the US Coastguard has put into service a simple, portable, inexpensive device, constructed from plastic plumbing pipe, called the Brooklyn Shallow Water Escape Trainer (SWET). It resembles a cube with no solid sides, the plastic pipes form the external margins (Figure 19). There are two additional bars fitted to enable the instructor to rotate the device to the inverted position. In the centre of the open cube a seat and harness is fitted; ahead of this, if required, a mounting can be placed for an emergency breathing device (if the device to be used is not man-mounted). In the open areas on either side of the seat outlined by the plastic pipe, it is possible to fit windows, hatches and release mechanisms that represent the type of helicopter used by the student. In order to prevent the student suffering from an air embolism or ruptured lung, buoyancy bags are fixed to the underside of the SWET. This ensures that the students' head to mid-thorax distance is never more than 105 Centimetres (3 feet) underwater. As a further precaution, training in the SWET is limited to a pool depth of 1.5 metres (5 feet).

The advantage of such a device, is that it is easily transportable, it can be picked up by two people and lowered into the pool; furthermore, it can be operated by the same two people - one performs the duty of device operator and the other the duties of the safety swimmer. The principal duties of the device operator are 1) to ensure all students have met all medical pre-requisites; 2) are properly dressed and briefed; 3) are strapped in and ready to be submerged and rotated; 4) if all these requirements are fulfilled, then to slowly rotate the device with the aid of the rotation bar and 5) be prepared to retract the device if the student has difficulties.

The principal duties of the safety swimmer (using a diver's face mask and snorkel) are: 1) to observe the students progress underwater; 2) in cases of emergency, signal to the device operator to initiate emergency retraction, and 3) to assist the student out of the device.

Because safety is paramount in training, it is recommended that subjects practice underwater escape breathing using only a SWET. It is advised that if an underwater breathing apparatus is to be used in a HUET or 9D5 type of trainer, then it should be done with extreme caution and with full medical monitoring. The SWET training should be as follows:

(1) With escape hatch removed, subject strapped in, subject activates flow of gas and breaths from the apparatus at the surface. Device operator inverts the SWET and, after thirty seconds of breathing underwater in the SWET, subject egresses through open hatch.

(2) With escape hatch in position, subject strapped in, subject activates flow of gas and breathes from the apparatus at the surface. Device operator inverts the SWET and, after thirty seconds breathing underwater, subject releases escape hatch and egresses.

(3) With escape hatch removed, underwater breathing apparatus stowed, subject strapped in, device operator inverts the SWET. The subject is then required to activate gas flow from the breathing apparatus, purge the regulator and breath from it for 30 seconds. Subject releases escape hatch and egresses.

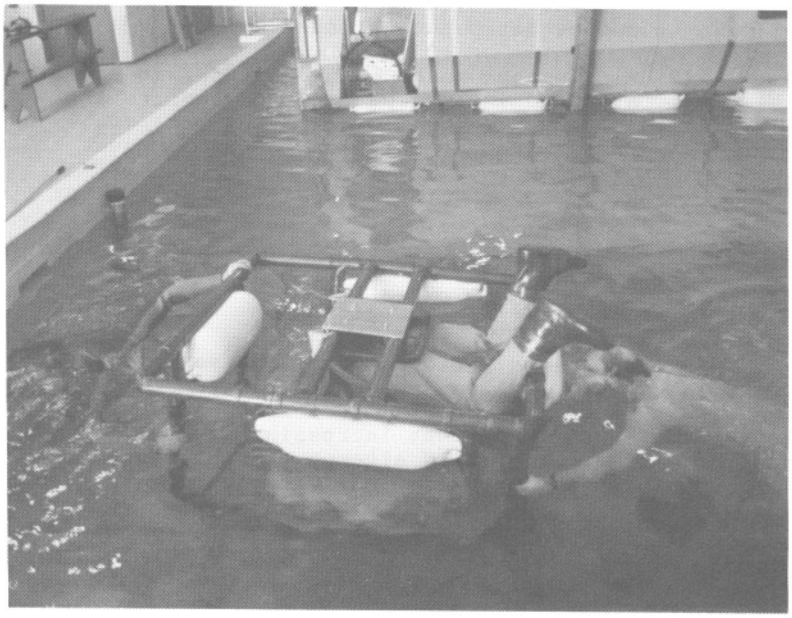
(4) With escape hatch in position, underwater breathing apparatus stowed, subject strapped in, device operator inverts the SWET. The subject is then required to activate gas flow from breathing apparatus, purge the regulator and breath from it for 30 seconds. Subject releases escape hatch and egresses.

3.7 Performance Objectives

There are two performance objectives, the first is to demonstrate the ability to escape successfully from the underwater escape trainer in full equipment. This is measured by a simple pass/fail criteria. Each subject may be given three opportunities to achieve each of the four increasingly more difficult scenarios. A fail should be recorded if, after a third attempt of any scenario, a student cannot successfully egress the helicopter trainer from underwater configured for aircraft type and position.

If an underwater breathing apparatus is being used, then the second objective is to demonstrate the ability to escape from the SWET using the breathing apparatus. This is again measured by a simple pass/fail criteria. A fail should be recorded if, the

Figure 19. The Brooklyn Shallow Water Escape Trainer (SWET).
(Courtesy U.S. Coastguard and Survival Systems Ltd. Dartmouth, N.S.)



subject cannot achieve any of the four level in the SWET after three attempts. The following accident scenario demonstrates yet again the success of such training:

> A Norwegian military Bell UH-13 was on a night-time search and rescue mission to a sinking yacht with two volunteer crew onboard as the regular SAR helicopter crew was on another mission. During first pick-up trial, the hook at the end of the hoist wire got caught in the boat and later broke leading to severe control problems. The pilot lost visual reference and the helicopter crashed with low nose and low speed. It immediately capsized and came to rest upside down in about two metres depth of water of 10°C temperature. Both crewmembers described the evacuation as very similar to what they had done during underwater escape training. The pilot put his left hand on the seatbelt and tried to find and pull the emergency egress handle on the right door with the other hand. He was not sure he had found the handle and instead located the normal door knob. He opened the right door in the regular fashion and got out. The flight engineer, who had been operating the hoist, was not strapped down during the crash and tried to support himself by tensing his arms and legs as he realized that the helicopter was crashing. He was caught by the inrushing water as the helicopter turned over and was probably sitting on the ceiling of the helicopter after it had come to rest. He stood up, disoriented, not aware that the helicopter had turned over. He freed himself from the monkey strap and got out probably through the same door as the pilot. Search and landing lights were still working and helped him find the escape route. A large air bubble inside the cabin was also a help.

3.8 Training Facilities

Single-placed underwater escape trainers, nicknamed Dilbert Dunkers, have been in service with the US Navy since the Second World War. However, these were designed only for fixed wing aircrew. Underwater breathing techniques in the cockpit were later added to the training and, to enhance this, the US Navy 9H19 apparatus was introduced into service for use in the shallow end of a pool prior to training aircrew in the fixed-wing underwater escape trainer where their standard aircraft panel-mounted regulator was fitted. In 1961, the US Marines built a prototype helicopter escape trainer and attempted to train combat troops.

It was discontinued for unknown reasons. In 1962, the Royal Navy put an escape trainer into operation and made training mandatory for all flight personnel.

In 1972, the USN re-established the requirement to provide practical underwater escape training (74); the first device, called the 9D5, was built by Burtek Incorporated, Tulsa, Oklahoma, and was commissioned at the Naval Aviation School's Command, Pensacola, Florida in 1978. Subsequently it was widely recommended for training of all USN helicopter pilots, and the USN currently have seven 9D5 trainers in service. The US Coast Guard train their personnel at the closest USN facility and have, in addition, as previously mentioned, introduced the SWET to teach the underwater breathing apparatus.

Very recently Dr. Allan at the R.A.F. Institute of Aviation Medicine (5) has built a simple helicopter underwater escape simulator. With this it is possible to carry out research into many of the problems of underwater escape such as underwater lighting, escape size hatches and interface of aircrew equipment.

The following helicopter underwater escape trainers are currently in service in the Western World (Figure 20).

Australia:	
- National Safety Council of Australia, Sale, Victoria, Woodside Petroleum, Port Headland.	Airframe of Bell 206
- Industrial Foundation of Accident Prevention, Freemantle, Western Australia.	Non-specific Mock-up
Canada:	
- Survival Systems, 110 Mount Hope Rd, Dartmouth, Nova Scotia.	HUET
- Memorial University, St. John's, Newfoundland.	HUET
France:	
- Centre d'Expérimentations Pratiques de l'Aéronautique Navale, Base d'Aéronautique Navale Fréjus - Saint Raphael, 83000 Toulon Naval.	Lynx simulated fuselage
Germany:	
- Naval Air Station 2859 Nordholz.	Modified 9D5

Italy:

- Base Elicotteri, Marina Militaire Aeroporto De Lunisarzana (La Spezia)	Modified Dilbert Dunker
- Base Elicotteri, Marina Militaire (Maristaeli) Aeroporto Di Catania, Fontanarossa, Sicilia	9D5

Norway:

- NUTEC, Gravdalsveien 255-5034 Ytre Laksevag, Bergen	HUET
- Tjeldsund Offshore Centre, Fjeldal 9440 Evenskjer, Tromso.	HUET

United Kingdom

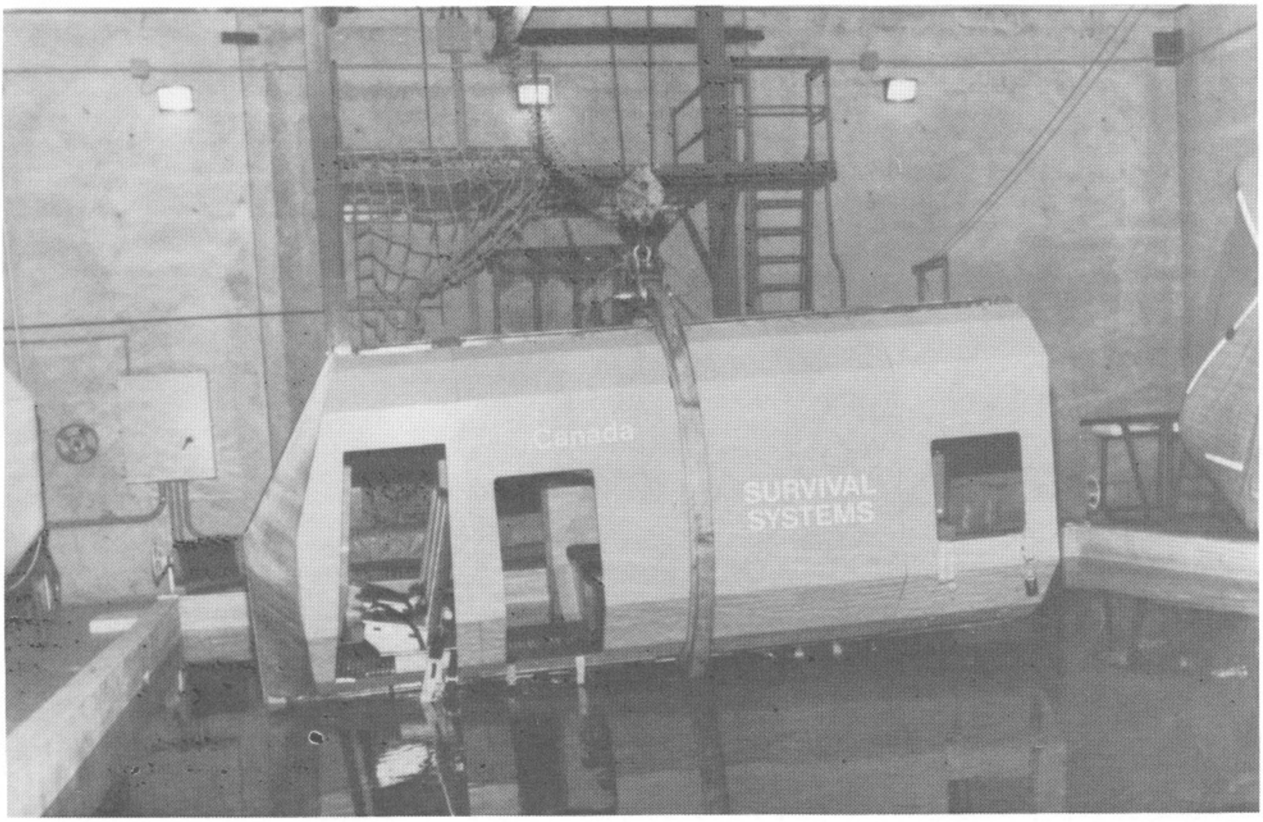
- The Royal Navy Underwater Escape Training Unit, HMS Heron, Yeovilton, Devon.	Modified HUET
- Robert Gordon's Institute of Technology, Aberdeen Scotland.	HUET
- Royal Air Force Institute of Aviation Medicine, Farnborough, Hampshire.	Dr. Allan (prototype)

United States Naval Air Station

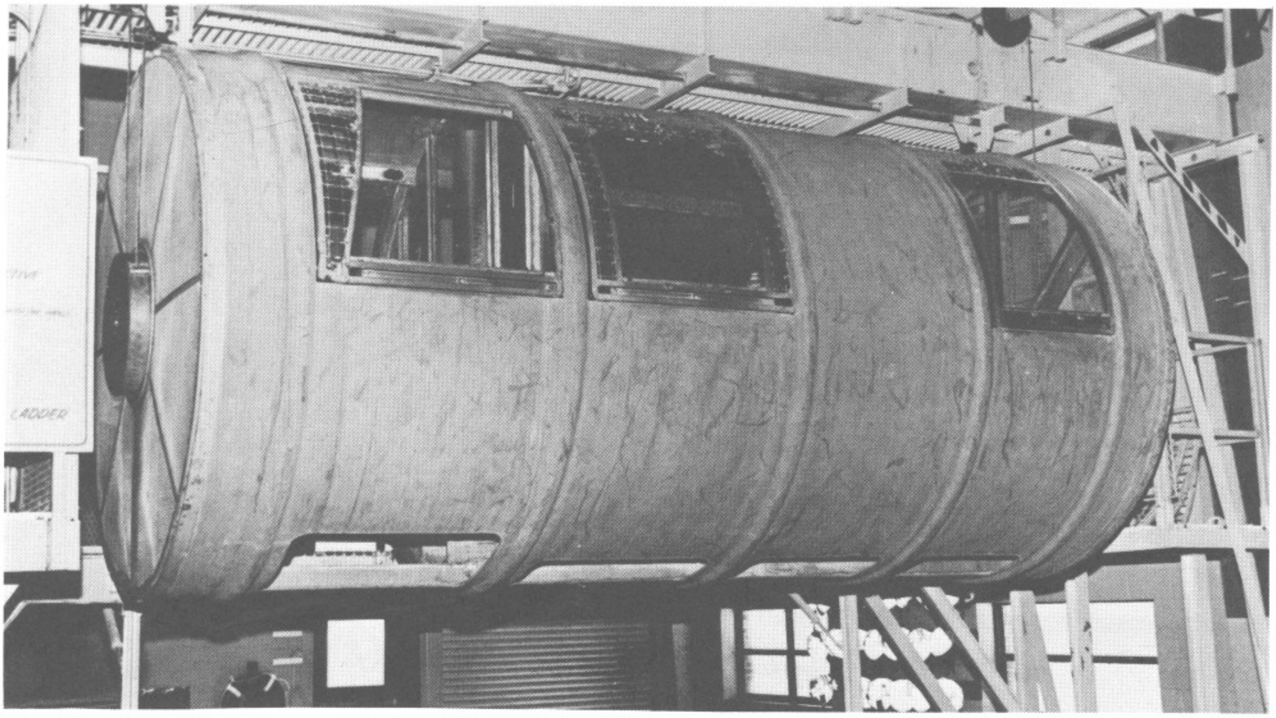
- NAS Lemoore, California.	9D5B
- NAS El Toro, California.	9D5B
- NAS Miramar, California.	9D5A
- NAS Pensacola, Florida.	9D5A
- NAS Jacksonville, Florida.	9D5A
- NAS Norfolk, Virginia.	9D5A
- NAS Cherry Point, North Carolina.	9D5A

Figure 20. Typical types of helicopter underwater escape trainers.

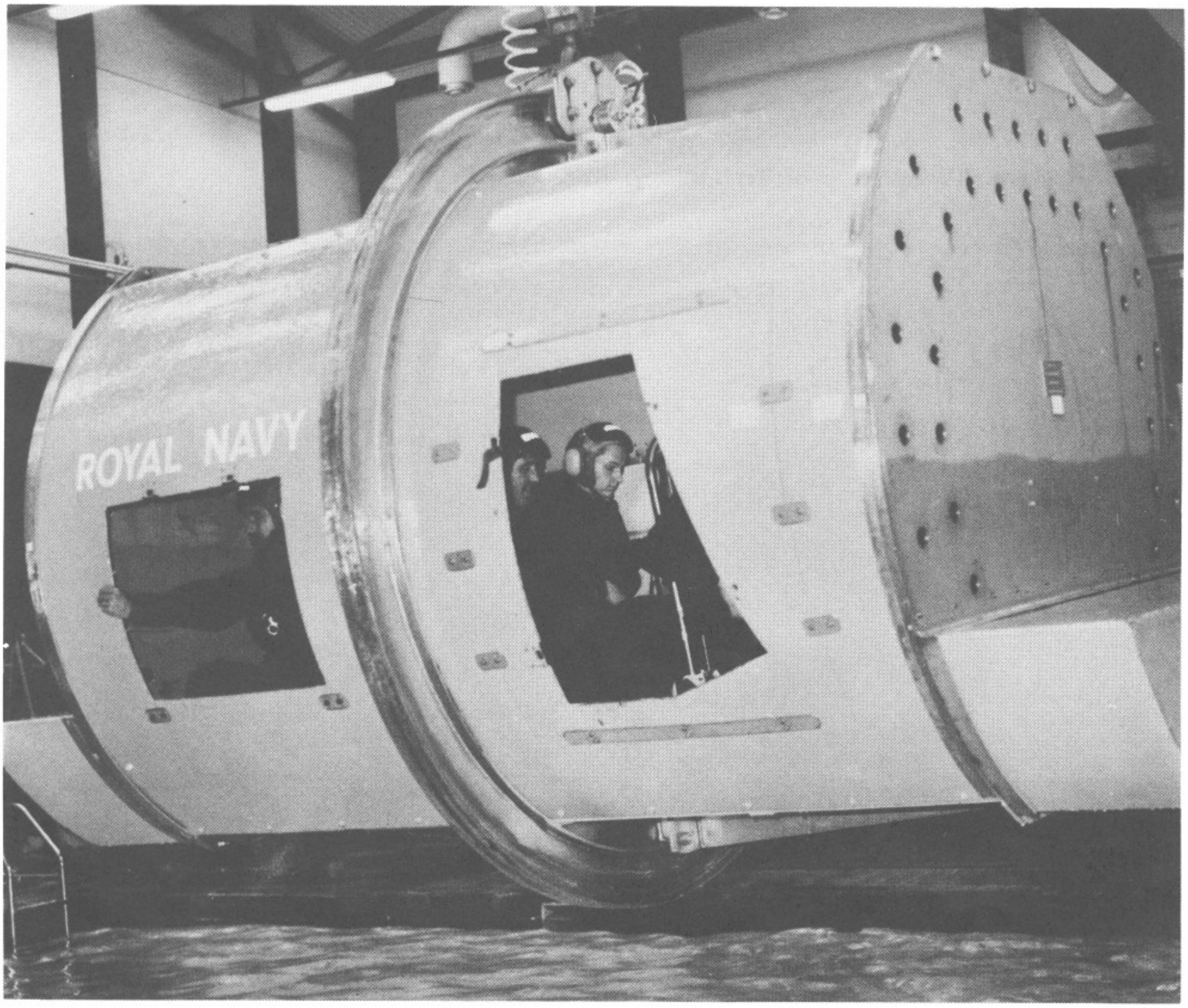
A. Robert Gordon's Institute of Technology, Aberdeen, Scotland HUET.



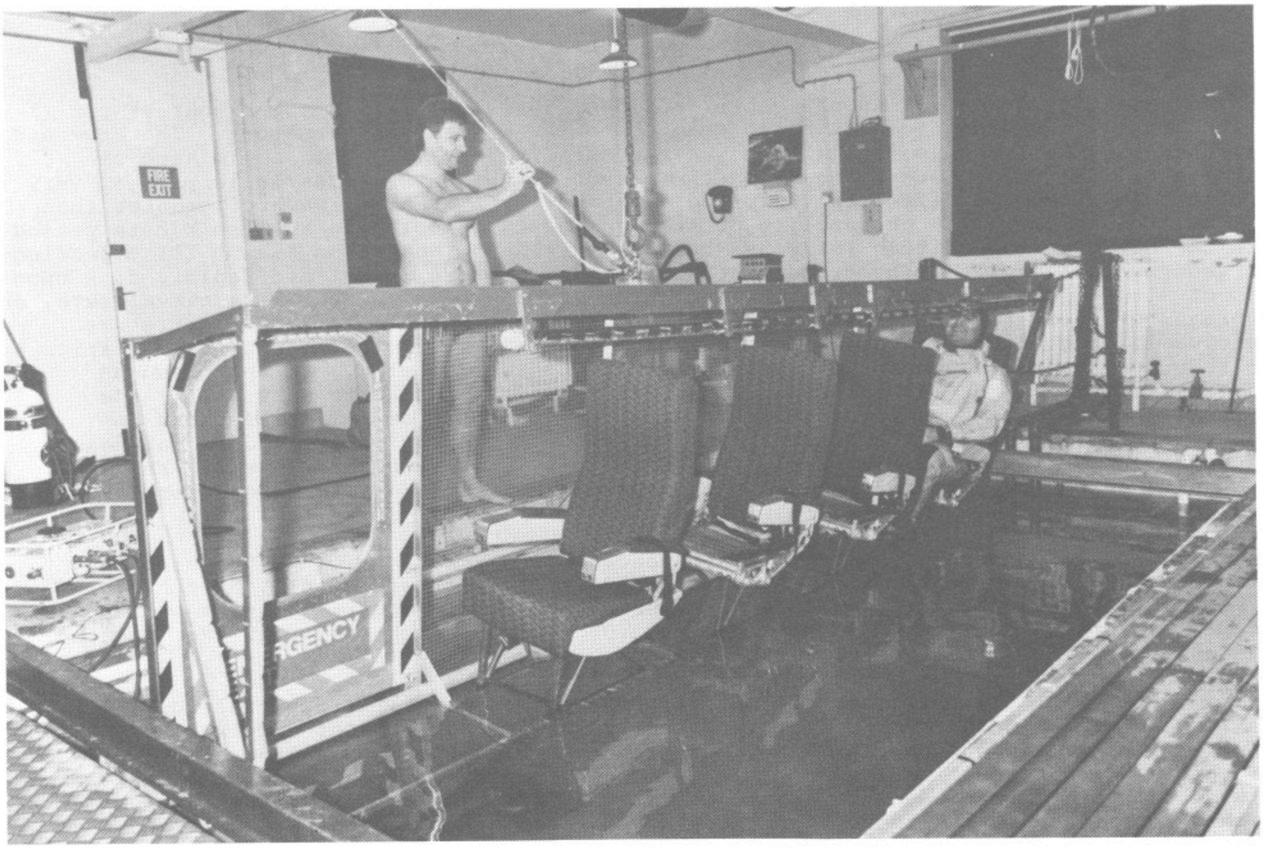
B. Survival Systems, Dartmouth, Nova Scotia. Modified HUET.



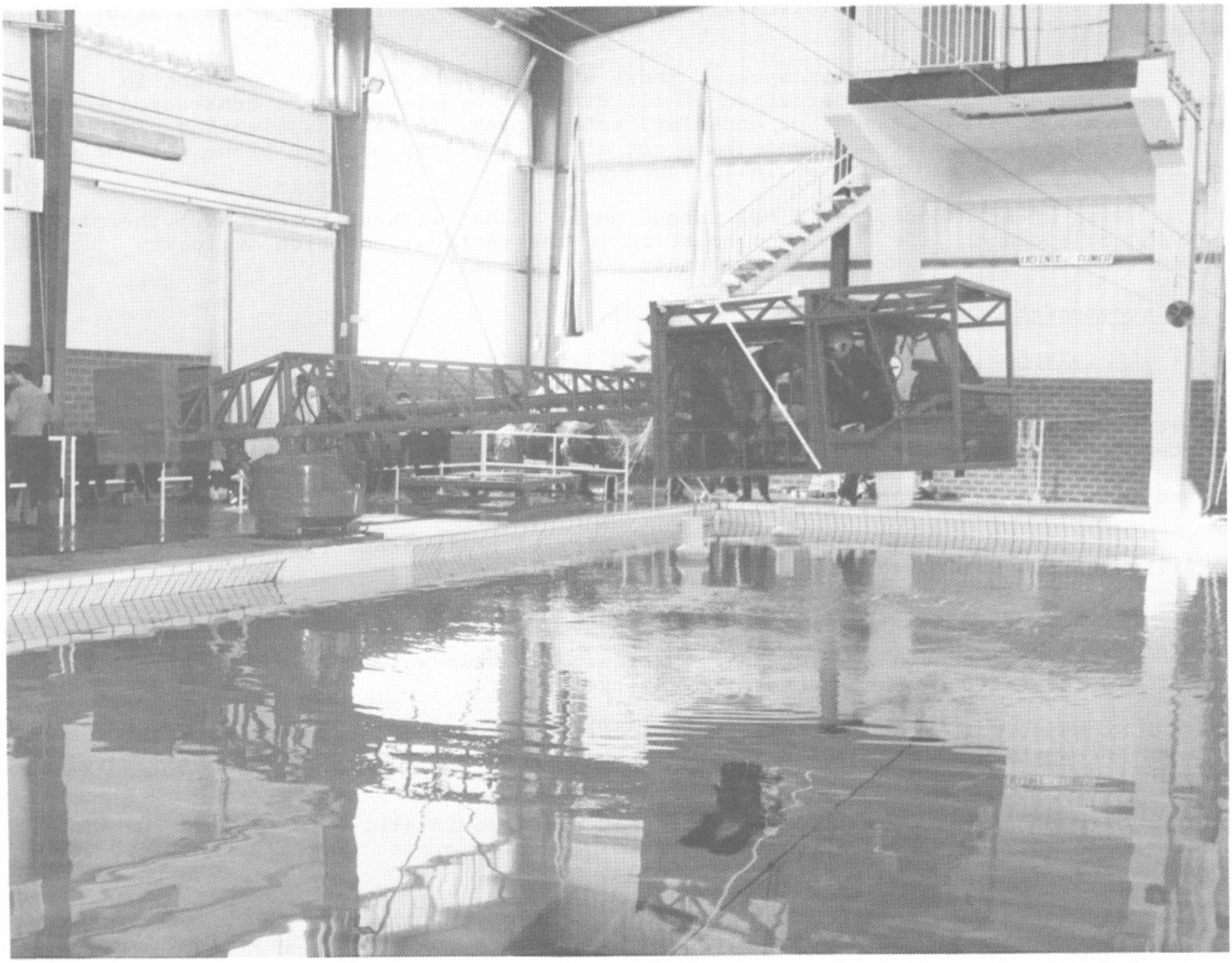
C. U.S. Navy Burtech 9D5 N.A.S. Pensacola, Florida.



D. Royal Navy, H.M.S. Heron, Yeovilton, Modified HUET.



E. Royal Air Force I.A.M. Farnborough - Dr Allan Experimental.



F. French Navy, Base d'Aéronautique Navale de Fréjus / St Raphael. Lynx simulated fuselage.

4.2.3 Training

Helicopter underwater escape training should be mandatory for all aircrew and, whenever possible for passengers flying overwater operations. Included in this should be the practical demonstration of the correct crash positions to adopt.

If an emergency breathing system is part of the equipment, the practical use of it should be included in the training using a Shallow Water Escape Trainer. The emergency breathing system should be used with extreme caution in a HUET or 9D5 type of trainer and only then with full medical supervision.

4.2.4 Future helicopter design

A systematic approach to crashworthiness should be taken. Specifically to be included should be the seats, landing gear, fuselage, layout of consoles and instrument panels, escape path, flotation lighting and life support equipment.

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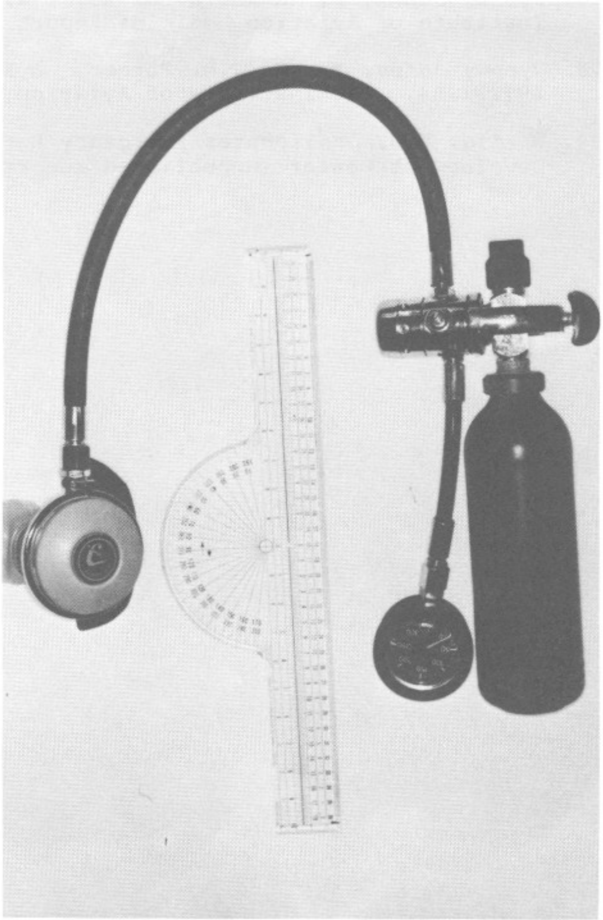
Annex A. Figure 21.

Italian Navy Helicopter Underwater Escape System.

**This system is made by CRESSI and fits on the lifejacket.
The cylinder measures 29 cm long by 6.3 cm in diameter;
fully charged to 165 Atmospheres it weighs 1880 grams.**



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Survival in water
Underwater escape
Underwater helicopter lighting

14. Abstract

This AGARDograph describes the worldwide incidence of military and civilian over-water helicopter accidents and the problems related to survival. It reviews the typical accident scenario from the moment the occupant steps on board the helicopter and the pre-flight briefing through to the accident itself, the difficulties with escape (commonly from underwater and in darkness), to the rescue and return safe and sound to dry land. It also proposes improvements to crashworthiness and life support equipment in current in-service and future helicopters and a syllabus for underwater escape training.

This AGARDograph was sponsored by the AGARD Aerospace Medical Panel.

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Defence & Civil Institute of Environmental Medicine
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P.O. Box 2000
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PREFACE

One miserable Saturday in March 1977, I was lowered from a Sea King Helicopter to the pitching deck of a small Canadian stern trawler some 80 miles east of Louisburg, Nova Scotia. One of the deck hands had suffered a penetrating wound to the abdomen and required urgent medical attention.

The journey was far from simple; we flew through sun, snow, sleet and fog and arrived on station only to find that the Master could not control the speed of his vessel in the heavy seas. This made hoisting very difficult and brought us to the edge of our hovering time very quickly despite the fact that we had "hot fuelled" in Sydney enroute.

I quickly developed a healthy respect for the professional skills of the aircrew, particularly as I hung dependent at the end of a horse collar over mid-ocean. I was also very surprised to learn how ill-equipped and ill-prepared the modern helicopter is for survival at sea in the event of ditching.

This began my personal interest in helicopter escape and survival and I began to examine the problems in more detail. This AGARDograph is the result.

It describes the worldwide incidence of military and civilian over-water helicopter accidents and the problems related to survival. It reviews the typical accident scenario from the moment the occupant steps on board the helicopter and the pre-flight briefing through to the accident itself, the escape (commonly from underwater and in darkness), to the rescue and return safe and sound to dry land. It also proposes improvements to helicopter crashworthiness, life support equipment and a syllabus for underwater escape training. It is dedicated to all maritime aviators who fly over the sea for their living and in particular to Captain Stewart Russell and Captain George Smith of the Canadian Forces who dropped me into the fishing nets and rigging of the trawler on that appalling afternoon of the Eastern Canadian Seaboard.

* * *

Un malheureux samedi du mois de mars 1977, l'on m'a hélitreuillé en "Sea King" sur le pont d'un chalutier Canadien navigant a quelques 80 milles au large de Louisburg, Nouvelle Escosse. L'un des hommes de pont avait subi une blessure profonde à l'abdomen nécessitant des soins médicaux d'urgence.

Le voyage fut loin d'être simple; au cours du vol, nous avons été confrontés au soleil, à la neige, au grésil, au brouillard, et, arrivés sur place, nous avons constaté que le commandant du chalutier était incapable de contrôler sa vitesse, tellement la mer était houleuse. Les opérations de hissage se sont avérées très difficiles et nous avons très vite épuisé notre potentiel de vol stationnaire, malgré le fait que nous avions effectué un ravitaillement en carburant en urgence à Sydney, en cours de route.

Suspendu au-dessus de l'océan, au bout de l'élingue de sauvetage, j'ai eu très vite l'occasion d'admirer le professionalisme de l'équipage de l'hélicoptère. J'étais en même temps étonné de voir à quel point les hélicoptères modernes sont mal équipés et mal préparés pour la survie en cas d'amérissage.

Ainsi est né ma motivation personnelle pour les problèmes d'évacuation et de survie des équipages d'hélicoptère et par la suite j'ai commencé a approfondir la question. La présente AGARDographie en est le résultat.

Elle décrit l'incidence des accidents survenant dans le monde aux hélicoptères civils et militaires au-dessus de l'eau et les problèmes de survie. Elle examine le scénario type d'un tel accident à partir du moment où la personne transportée mont a bord de l'hélicoptère, le briefing avant vol, l'accident lui-même, l'évacuation (le plus souvent en hélicoptère immergé et dans le noir), le sauvetage, et enfin le retour sain et sauf sur la terre ferme. Elle propose également certains améliorations qui seraient à apporter dans le domaine de la résistance au crash des hélicoptères et les équipements de survie, ainsi qu'un programme de cours sur l'évacuation sous l'eau. Elle est dédiée a tout aviateur qui survole la mer pour gagner sa vie, et en particulier au Capitaine Stewart Russell et au Capitaine George Smith des forces armées Canadiennes qui m'ont fait descendre dans les filets et les haubans du chalutier cet après-midi épouvantable au large du littoral Est du Canada.

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