REPORT FOR THE
OFFSHORE HELICOPTER SAFETY INQUIRY

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1.0 INTRODUCTION

1.1 Background

Dr Susan Coleshaw was approached by Commissioner Wells, to prepare a report covering a number of 'Issues for Consideration' relating to the Offshore Helicopter Safety Inquiry, posted 2010-03-24. Four of these issues, relating to personal protective equipment, research into the prevention of inversion of helicopters, offshore helicopter safety training and personal accountability have been considered and are discussed in the report herein.

The views expressed in this report represent the professional opinion of the author, unless otherwise stated. They are based primarily on experience of helicopter safety relating to the UK offshore industry, and to a lesser extent on worldwide operations.

1.2 Credentials of SRK Coleshaw

Susan Coleshaw is an independent research consultant working in the field of marine, offshore and aviation safety. With a background in human applied physiology, she has considerable experience in immersion hypothermia, cold water survival, helicopter underwater escape and personal protective equipment. She is a Fellow of the Institute of Ergonomics and Human Factors. Clients include the UK Civil Aviation Authority (CAA), UK Health and Safety Executive, Oil & Gas UK; numerous oil and gas operators such as Shell UK, BP, Marathon, and Talisman; OPITO; and a number of equipment manufacturers including Shark, Survival-One and Viking.

With a background in human and applied physiology, she has a BSc in Physiology from the University of Leeds, and a PhD from the University of London covering thermal problems in divers, immersion hypothermia and mental performance at low body temperatures. After 10 years in an academic environment working in the field of thermal physiology she moved to the RGIT Survival Centre in Aberdeen (now a division of Petrofac Training), where she remained until 2000. There she was responsible for research and consultancy in various aspects of offshore safety, and managed a test laboratory assessing lifejackets, immersion suits and other safety equipment.

Susan Coleshaw is actively involved in the development of technical standards for lifejackets, immersion suits and other safety equipment for small craft. She is Chairman of the BSI Technical Committee responsible for buoyancy garments (PH3/6) and attends the European and International mirror committees (CEN TC 162/WG6 and ISO TC 188/WG14) as UK principal expert. She is currently working on a project to develop a technical standard for helicopter emergency breathing systems on behalf of the UK Civil Aviation Authority (CAA).

2.0 WHAT PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING IS NECESSARY FOR HELICOPTER PASSENGERS AND PILOTS; WHAT ARE THE STANDARDS, AND SHOULD THE C-NLOPB REQUIRE GUIDELINES TO ENSURE SUCH EQUIPMENT IS PROPERLY FITTED?

2.1 The need for personal protective equipment

In general, helicopter crew and passengers flying over water in hostile environments, where sea temperatures can be very cold and sea states severe, need a range of personal protective equipment to protect them in the event of a water impact accident.

Following impact, the first hazard will be the temperature of the water. In water temperatures below 15˚C the use of an insulated immersion suit will help to protect the wearer from both cold shock and the longer term effects of cold water immersion that can lead to the development of hypothermia. Cold shock is a reflex response to a sudden decrease in skin temperature. It is characterised by an initial gasp and an inability to control breathing during the first few minutes of immersion in cold water. When faced with the need to undertake underwater escape from a capsized helicopter, it becomes very difficult to breath-hold for sufficient time to complete the escape process. Risk of drowning is high as a result. Emergency breathing systems (EBS) provide a means of mitigating this problem, extending the time that can be spent underwater, and allowing users to overcome any problems that might slow the process of escape.

On escaping from the helicopter, the occupant will be exposed to waves and wind. Buoyancy, either supplied as part of the suit or through the use of a lifejacket, is used to support the head of the wearer in the water, keeping the airways above the water surface and thus reducing the risk of drowning. Spray hoods play a vital role in further protecting the airways from breaking waves.

As time in the water progresses, peripheral tissues will gradually cool. Manual dexterity will be quickly lost, particularly if gloves are not worn, making it difficult for the individual to help themselves in the rescue and recovery process. The limbs cool and fatigue quickly. There are many cases of even good swimmers, who are not supported by buoyancy, drowning before reaching safety. It is thought that 'swim failure' may be due to an inability to coordinate an increased breathing rate (due to the cold) with the swimming stroke (Golden & Tipton, 2002). The chance of taking in water increases, and swimming becomes inefficient. In trying to keep the head above water, the individual tends to swim with a more upright posture, which increases the sinking force, and makes it yet more difficult for the individual to swim and stay afloat. Rapidly cooling muscles and fatigue will add to the problems of coordinating breathing. Without the buoyancy provided by an immersion suit or suit and lifejacket system, drowning could result long before the onset of hypothermia.

Hypothermia, defined as a decrease in deep body temperature to below 35°C, will develop with time in cold water. Body temperature decreases when heat loss to the environment exceeds metabolic heat production. The insulation of an immersion suit will reduce heat loss and thus delay the onset of hypothermia. The insulation is provided by air trapped in the thermal lining and clothing worn under the suit. Good thermal performance of an immersion suit will depend upon the suit being correctly sealed. Water leaking or flooding into the suit will wet the thermal lining and clothing, greatly reducing the insulative value of the suit. Without the protection of an immersion suit, some individuals would develop hypothermia within the first hour of immersion in very cold water, and the risk of drowning would be greatly increased in all.

In recent years, helicopter crews and passengers have been equipped with personal locator beacons (PLBs). Following escape from the helicopter, survivors will attempt to board a liferaft. This can prove difficult, particularly in high sea states, whilst there have been many accidents where the liferafts are damaged or fail to deploy. In these circumstances survivors left in the water often drift apart, and may drift some distance from the accident site. In these circumstances, PLBs allow the rescue services to home in and locate the individual.

2.2 Immersion suit performance

Helicopter immersion suits are designed to protect the wearer both from cold shock and from hypothermia. The level of protection from cold shock will be dependent upon the area of skin covered, preventing rapid cooling of the skin. Protection from hypothermia will be dependent upon the level of insulation provided by the suit system. When assessing the level of insulation needed in a suit system, the decision should be based on the water temperatures that might be experienced in use, as well as a consideration of the likely time needed to locate and recover the last person from the water in the event of an accident.

Insulation is primarily provided by air trapped in a clothing system. Air can be trapped within the fabric and between layers within the clothing. The insulation of suit fabric is generally related to thickness; if the fabric is compressed, insulation will be reduced. On immersion in water, trapped air will be forced out of a suit due to hydrostatic forces. By forcing out this air, insulation will be reduced. This is also a time when some water can leak into the suit due to the seals being broken by the escaping air. (One-way valves can be used to mitigate this problem, although faulty valves can also be a source of minor leakage).

Maximum insulation is achieved if the suit and clothing remain dry. The ingress of water into a suit will result in a decrease in the amount of insulation provided, with a wet trunk being much more critical than wet limbs. Work by Tipton (1997) demonstrated that a 500ml leak of water in the trunk area produced a 30% reduction in clothing insulation. A 200g leak did not affect rates of body cooling whereas a leakage of 500g of water into a suit increased body cooling.

Whilst it is possible to measure the insulation of a suit, it is difficult to control the level of clothing worn under the suit, and hence to know the total insulation of the suit and clothing system. In the UK offshore sector, operators have summer and winter clothing policies where they advise on and check the numbers of layers of clothing worn under the suit.

It has been said that insulation is primarily provided by trapped air. Thus, the more air trapped in the suit, the warmer the suit will be and the higher the level of thermal protection provided in the event of cold water immersion. Indeed, on reaching the water surface after submersion it may be advantageous to allow air back into the suit (to replace the air that was squeezed out when underwater). However, the trapped air that is beneficial for thermal protection has a very adverse effect when it comes to escape from a submerged helicopter. Any air trapped in the suit will provide buoyancy. If the helicopter sinks in the upright position, then the body will tend to float up towards the surface on release of the seat harness, making it more difficult to escape. The occupant may have to pull themselves down to an exit or escape window in order to escape. Conversely, if the helicopter capsizes, the occupant will be forced back into their seat by the upwards buoyant force, and float up as soon as the harness is released. Again the occupant will need to pull down to reach the exit. Following the inversion caused by capsize, helicopter occupants commonly feel very disorientated, making it much more difficult to find the exit, particularly if it is dark. Thus, the more air is trapped in the suit, the higher the buoyancy and the harder it may be to escape.

There is therefore a conflict and a balance to be made between the amount of insulation (thermal protection) provided and the inherent buoyancy of the suit which can cause problems during helicopter underwater escape. Manufacturers are currently looking at innovative technologies such as phase change materials that may allow the same level of thermal protection with thinner, less bulky materials. At the current time the benefits of such technology are limited, but improvements may be made in the future. In the meantime, training should be used to familiarise passengers and crew with the problems of buoyancy during escape.

The buoyancy of the suit will not only be affected by the fabric used to provide insulation, but also the fit of the suit and the size of the suit. A large suit, using more fabric, will have higher inherent buoyancy than a smaller sized suit. The overall buoyancy of the suit when worn will depend on the amount of air trapped in the suit, which will be a function both of size and fit. A well fitting suit will trap much less air than a poorly fitting loose or over-sized suit. Conversely, there is also a case to suggest that a large individual will be better able to cope with a given absolute level of buoyancy than a small individual.

The fit of the suit will itself depend on a number of factors:

- The range and number of sizes supplied - the more sizes, the greater the probability of achieving a good fit.
- Body shape - suit sizing tends to be based on height and chest size; these are likely to fit a person of average build better than a person who fits the average proportions less well.

- Whether the correct size of suit is selected - who decides which size shall be selected and how is this monitored?

It is therefore concluded that, if the buoyancy problem is to be reduced to a minimum it is important that helicopter suits are well fitted to the individual, limiting the air that can be trapped. Measures to check that the correct size of suit was being worn by each passenger would also be beneficial.

A further conflict exists between the level of insulation provided to protect the individual in the event of cold water immersion and the degree of thermal comfort that can be achieved in the helicopter cabin. Helicopter cabins can get very warm during summer months, at times when sea temperatures are still very cold. Helicopter suits of the type used by the Canadian offshore industry are warm under normal cabin conditions due to the high level of insulation. If the suits were worn fully deployed, with the hoods and zips up, there is no doubt that the wearers would feel very uncomfortable at times and could be exposed to a degree of thermal stress. The suits, with a central zip and face seal are therefore normally worn with the hood down and zip undone, allowing air to circulate. In the event of an emergency, the hood must be donned and the zip pulled right up to seal the suit. There are also double seals at the wrist cuff that must be adjusted. If there is some warning of an emergency, the occupants will have time to carry out this action. They may or may not do this effectively in the panic that could ensue. However, there are other scenarios where the occupant will have no warning and little or no time to seal the suit. This could lead to the suit being flooded with water on immersion, and much of the thermal insulation of the suit being lost.

The design of helicopter suits worn in the UK sector of the North Sea was changed following the water impact accident close to the Cormorant Alpha platform in 1992. At that time, passengers wore a suit with central zip and neck seal. Whilst most of the passengers were reported to have managed to don their hoods and zip up the suit to "*at least 3 inches from the top*", one of the non-survivors was found with his suit partially unzipped and had taken in a considerable amount of water (AAIB, 1993). When the RAF Institute of Aviation Medicine investigated the suit leakage (Appendix J of AAIB, 1993) they recorded that some of the survivors had later said that they had been in the water with their immersion suits partially unzipped, although they had not been aware of leakage. Rescuers also described finding bodies with their suits partially undone and full of water. Tests were undertaken to measure water leakage into a partially unzipped suit. Over 20 minutes, 17 litres of water leaked into the suit, compared to just over 500ml in the zipped up suit. The authors stated "*it is pointless providing a person with a watertight immersion suit, if at the time of immersion it is not properly sealed*". They also pointed out that large amounts of water in the suit would increase initial cold shock, would hinder attempts at climbing into a liferaft as well as destroying the insulation of the clothing worn under the suit.

Following the Cormorant Alpha accident, the design of helicopter suits used by the UK offshore industry changed to incorporate a bellows neck seal, with an across chest zip that was done up and sealed at all times during flight. The only action that must now be taken in an emergency, in relation to the suit, is to don the separate suit hood.

One further issue is worth consideration in relation to these interconnecting issues. When a suit is fully donned and sealed it is recommended that the suit be vented to remove as much air as possible from the suit. If the suit is fully donned before flight this can be done by crouching down, squeezing air out of the suit, while releasing the seal. This will help to limit the buoyancy problem that can be experienced during underwater escape. If a suit is worn with the hood off and zip partially undone, and is only fully donned in an emergency, it is likely that excess air will be left in the suit.

To overcome these problems, careful consideration must be given to the level of thermal protection provided in the suit and balance this with what are considered to be acceptable levels of buoyancy. Whilst both escape from the submerged helicopter and protection from the cold water are both critical, the policy of flying with the suit unzipped means there may be some cases where the insulation of the suit is greatly reduced due to water ingress. There is no obvious solution to this problem meaning that compromises must be made.

2.3 Immersion suit standards

A number of standards have been written for helicopter immersion suits:

- CAA (1991) – CAA Specification No 19: Helicopter crew members immersion suits.
- CGSB (1999) Helicopter passenger transportation suit systems. CAN/CGSB-65.17.99.
- EASA (2006) European Technical Standard Order. Helicopter crew and passenger integrated immersion suits. ETSO-2C502.
- EASA (2006) European Technical Standard Order. Helicopter crew and passenger immersion suits for operations to or from helidecks located in a hostile sea area. ETSO-2C503.

Reference may also be made to the international standard for constant wear immersion suits :

- ISO 15027-1 : 2002 *Immersion suits — Part 1: Constant wear suits, requirements including safety;*
- ISO 15027-3 : 2002 *Immersion suits — Part 3: Test methods.*

CAA Specification 19 has now been superseded by ETSO-2C503, but the approvals of suits meeting this standard are still valid. Most of the suits currently in use in the UK sector of the North Sea are approved to CAA Spec 19. Several new designs of suit have now been developed by European manufacturers, meeting the new ETSO standards.

Insulation

CAA Spec 19 did not include a requirement for thermal protection as such. It's scope covered dry coverall types of suit that are designed to keep the wearer dry, relying on the clothing worn underneath to provide insulation. Water leakage was assessed (see below). Information was provided regarding the thermal performance that can be expected if a standard range of clothing is worn under an approved suit. The standard did call for 2 Clo of insulation in the hood.

The ETSO states that helicopter suits approved to this standard shall provide the user with thermal protection to meet a Class B suit tested to para 3.8 of EN ISO 15027-3:2002. This involves 4 hours immersion in water < 2˚C. This was considered to be equivalent to insulation of 0.5 immersed Clo.

This compares to the Canadian standard that requires 0.75 immersed Clo of insulation if measured using a manikin or, a 6 hour test in water at 0-2˚C if conducting tests with human subjects. This higher minimum requirement for insulation reflects the colder average sea temperatures off the eastern seaboard of Canada in relation to average sea temperatures experienced in European waters. Immersion suits developed in Norway tend to have a higher insulation than those developed in the UK, again due to differences in average sea temperatures.

The measurement of thermal protection in immersion suits is currently under review by an ad hoc group of the ISO (International Standards Organisation) committee responsible for immersion suits. Consideration is being given to requirements and methodology, the reproducibility of thermal manikin measurements and their correlation with data from human subject studies.

Leakage

Water leakage is a test normally included in suit standards, particularly for suits classified as 'dry' suits, with the test methods varying dependent upon the likely use of the suit. Methods include measuring leakage following a feet first jump into water, or following a period of swimming. The European standards for helicopter crew and passenger suits (ETSO-2C502 and ETSO-2C503) allow maximum water ingress of 200g, as did CAA Spec 19.

The Canadian standard includes a measurement of leakage for dry suit systems within the thermal protection test, involving a jump into water and 60 minute swim. The measured leakage is introduced into the suit before the thermal protection test.

Buoyancy

The effects of buoyancy are measured both by checking that test subjects can escape from a helicopter underwater escape simulator (HUET), and by specific measurements of the buoyancy due to air trapped within the suit and clothing system.

ETSO-2C502 states that the maximum trapped buoyancy of a suit and recommended clothing, with the suit fully vented, shall be no more than 150N. The figure in CAA Spec 19 was 15 kg, equivalent to 147N.

In the Canadian standard it is stated that the maximum escape buoyancy shall be no more than 175N. It is understood that this higher value was allowed to assist helicopter suit manufacturers meet the thermal insulation requirements of the Canadian standard, this being $0.116^{\circ}C.m^{2}.W^{-1}$ / 0.75 Clo (see Brooks, 2003). This is explained by the problems described in the previous section of this report.

Previous work investigating the amount of buoyancy that would permit or prevent escape showed that trained divers failed to escape through a simulated helicopter exit with added buoyancy levels varying between 173 N and 267 N (Brooks & Provencher, 1984). However, a group of non-divers found escape more difficult, with escape failures occurring between 98 N and 178 N. A number of possible reasons for the poorer performance were given including shorter arm reach and less upper body strength.

In follow-up trials (Brooks 1987, Brooks 1988) undertaken using a helicopter underwater escape training simulator, 12 mixed gender naïve subjects wearing a specially designed immersion suit with 134 N buoyancy were all able to escape from an inverted helicopter simulator, from a seat in the centre of the cabin and 20 cm in front of an unoccupied cabin window seat. The exit measured 51 cm by 66 cm. The author concluded at this time that inherent buoyancy in crew/passenger immersion suit systems should not exceed 146N.

It is understood that the level of added buoyancy is currently under review by the CGSB committee. A reduction would in buoyancy would most likely mean the development of less bulky suits with less trapped air, and could compromise the level of thermal protection provided.

2.4 Buoyancy equipment

Different strategies are used in different sectors of the offshore industry with respect to the provision of buoyancy to support the head of the wearer and reduce the risk of drowning.

The Canadian and Norwegian sectors provide suits that have sufficient buoyancy to provide flotation, with an integral additional inflatable buoyancy element to further support the head. In the Canadian standard a minimum flotation buoyancy of 156N is currently required (CGSB, 1999). It is understood that spray hood performance, to protect the airways and further reduce the risk of drowning, is provided in CAN/CGSB-65.16-2005 'Immersion suit systems' (CGSB, 2005). The suit system must provide a stable floating position i.e. once the user is floating on their back, it must be easy for them to stay in that position.

In the UK offshore industry, a separate lifejacket is worn over the helicopter suit. This is a manually operated inflatable jacket. Once the user has escaped from the helicopter they are required to pull a tag to inflate the jacket. An oral inflation backup is provided. CAA Specification 5 (CAA, 1979) required an aviation lifejacket to have a minimum buoyancy of 16 kg (157N), and capability to turn the unconscious wearer to a face-up position. Later requirements were brought in to ensure compatibility between helicopter suits and any lifejacket worn with them.

The European standards cover both options. ETSO-2C502 covers helicopter suits which incorporate the functionality of a lifejacket. The wearer must be able to turn themselves from a face-down into a stable face-up position. ETSO-2C504 covers helicopter constant wear lifejackets. This standard requires the lifejacket to turn an unconscious wearer from a face-down into a stable face-up position. No minimum buoyancy value is stipulated; buoyancy must be sufficient to support the wearer in the required floating position. A spray hood is required.

The overall performance requirements for flotation are thus similar in Canada and Europe.

2.5 Emergency breathing systems (EBS)

2.5.1 EBS performance

It has been recognised for some years that the time needed to escape from a submerged or capsized helicopter, estimated to be 45 to 60 seconds in a real accident, exceeds the time that most individuals can breath-hold in cold water due to the effects of cold shock. In subjects wearing helicopter suits, immersed in water colder than 10˚C, mean breath-hold time is likely to be close to 20 seconds, but can be as little as 10 seconds in some individuals (Tipton and Vincent, 1989, Tipton et al, 1995, Tipton et al, 1997). This would allow very little time for an individual to escape from a capsized helicopter. Maximum breath-hold time is therefore a limiting factor in the survival of the individual. EBS provide a means of extending the time that can be spent underwater, and thus a means of increasing the probability of making a successful underwater escape in water impact incidents.

The effectiveness of EBS will to some extent be dependent upon the type of water impact that occurs. In a controlled ditching, the crew and passengers will have some warning of the impending alighting on water, and therefore have some time and opportunity at least to think through the escape process and prepare for impact. In sea states up to 4 or 5 there is a reasonable chance that the helicopter will remain afloat for long enough for occupants to be evacuated from the cabin. However, in controlled ditchings, relatively few lives are lost and the incidence of drowning is low, despite the helicopter inverting immediately of sinking in at least 24% of cases (Clifford, 1996). Given the low incidence of drowning, the benefits of EBS may be limited to incidents occurring in the higher sea states. In this situation, EBS users will have the best chance of having time to deploy the equipment if the need arises.

In vertical descents with limited control, there is likely to be a little warning, and less time to prepare than might be expected in a controlled ditching. In these situations, fatality rates are much higher, and the majority are due to drowning. Clifford's data shows that inversion occurred immediately in about 60% of cases. The incidence of drowning increased further with fly-in accidents. In these accidents there would be no warning and it can be assumed that in many cases the cabin would rapidly flood. Time to deploy an EBS could be very limited in this situation. The ability to deploy underwater would then be an advantage.

The last category of water impact described by Clifford related to uncontrolled impacts with high impact forces. Fatalities due to impact injuries predominated over drowning in this group. It must be questioned how many occupants would manage to deploy and use EBS in this type of accident.

To be effective in these circumstances, EBS must be easy to use under emergency conditions, must be quick to deploy, must be compatible with other equipment and must not impair the normal escape process (see Coleshaw, 2003). When this is achieved, EBS may reduce the level of panic experienced, increasing the likelihood of a successful escape. Successful deployment would allow the user additional time to complete a number of complex actions which must or may have to be undertaken in the process of escape:

- overcome disorientation;
- release the seat harness - particularly if the harness jams or snags;
- locate an exit - allowing time to cross the cabin if the nearest exit route is blocked;
- jettison an exit - operate a handle, remove window rip cord if present, push out window;
- escape through exit - overcoming any snagging;
- overcome impact injuries which would slow but not prevent escape.

The ability to deploy the EBS with one hand would allow the occupant to keep one hand locating the nearest exit. Two hands could be used as long as the harness is still secured, but the user would need time to relocate the nearest exit once deployment was completed. Once the harness is released, both hands will be needed to maintain a grip on the escape route, bearing in mind that buoyancy problems may be experienced.

EBS are likely to be of little or no benefit to individuals who are seriously injured by impact with the water, particularly serious head and facial injuries or hand/arm injuries incurred as a result of flailing, both of which would prevent deployment.

Three generic designs of EBS have been developed for helicopter underwater escape; compressed air devices (being introduced for the Canadian offshore workforce, and favoured by the military), rebreather systems (used by the Norwegian offshore workforce) and a hybrid system consisting of a rebreather bag with a small cylinder of additional air (used by the UK offshore workforce). All tend to be carried in a pouch or pocket, which may be fitted to the lifejacket or suit. In all cases, it is important that it is easy to open this pouch and remove the EBS.

Compressed air systems tend to be relatively simple to deploy, with air on demand. They have the disadvantage that once deployed, the air supply is starting to run out, so they should only be deployed just before submersion. A big advantage is that, with training on purging techniques, they can be deployed underwater. Rebreather systems must be activated once the mouthpiece is in place. This is an additional task compared to the compressed air device, but it has the advantage that, if time allows, the user can deploy the mouthpiece in advance, breathing to the atmosphere, and only switch to breathing to the counterlung just before submersion. Some rebreathers have been designed with automatic activation, opening the system to allow breathing from the counterlung when immersed. This simplifies deployment, but has the disadvantage that if not deployed before submersion, the system will be open to the water, making successful underwater deployment very unlikely. In general, most rebreathers have been designed for the scenario where there is time to deploy before submersion, whereas compressed air systems have the capability for underwater deployment. The hybrid system used in the UK was originally designed for the controlled ditching scenario. However, with manual activation, it is possible to purge water from the system during underwater deployment, before switching to breathe to the bag. The additional air means that the user has sufficient air to breathe from the counterlung. Thus, though not designed for this purpose, underwater deployment is possible.

With compressed air systems, including the hybrid EBS, there is a very small risk of barotrauma injuries if the user holds their breath during ascent to the surface. This is only of concern during training, with many hundreds of personnel trained in a year. Some authorities regard compressed air EBS as mini diving equipment, meaning that specific requirements may be imposed in relation to medicals.

When introducing EBS it is important to make certain that the benefits outweigh any disadvantages, to ensure that there is an overall improvement in safety.

2.5.2 Standards for EBS

As far as is known, there is no published technical standard for helicopter emergency breathing systems.

The OLF's "*recommended guidelines relating to requirement specifications for survival suits for use on the Norwegian continental shelf*" (OLF, 2004) require a breathing aid as one of the components in their integrated survival suit. The system is required to extend the time that can be spent underwater when compared to the individual's capacity to hold his/her breath. A number of further requirements are made:

- The breathing system must be compatible with the survival suit and must not reduce the suit's efficiency.
- The breathing system shall be automatically activated when submerged.
- The breathing system shall provide sufficient air supply for 60 seconds of breathing time at a depth of ≤ 2m and at an activity level corresponding to 40% of maximum aerobic capacity of a person weighing 90 kg.
- It is mandatory that all suit users undergo training in how to use the breathing system. It is a further requirement that none of the breathing systems that become used requires training beyond the standard training for breathing systems.
- It shall be possible to activate the breathing system by one single operation using one hand.

In 2003, a review of the implementation and use of various types of EBS identified the need for a technical standard to ensure that minimum acceptable levels of performance and health and safety standards were met (Coleshaw, 2003). As a result an "*Example draft technical standard for helicopter emergency breathing systems*" was published as an appendix to this CAA report. The draft technical standard contained a number of suggested requirements:

- Limits for work of breathing, respiratory pressure and hydrostatic imbalance;
- Deployment using one hand only;
- Use whilst manoeuvring in different orientations;
- Deployment and use during a helicopter underwater escape exercise - assessment of snagging hazards and compatibility with other equipment;
- Maximum additional buoyancy (applicable to hybrid systems);
- Cold water performance.

At the time of publication, the UK CAA decided not to produce a formal specification as they considered that there was no compelling case to mandate the use of EBS, and it was not normal practise to produce a formal specification for non-mandated equipment. However, use of EBS is seen by the UK CAA as a short-term solution to the problem of post-capsize survival, pending availability of the side-floating helicopter scheme (see section 3.2.5). As a result, work was commissioned in 2008 to complete the technical standard, filling gaps in the requirements and investigating areas where there was insufficient published data to allow performance criteria to be set. This study has considered issues such as speed of deployment, underwater deployment and performance in cold water. Deployment trials demonstrated the benefits of a simple system, where the mouthpiece could be located easily and without error. When stored in a pouch, it must be easy to remove the EBS. Nose clips were beneficial, but could be 'fiddly' to put on. (In a real situation, the nose clip could be deployed once first breath from the EBS had been achieved). Cold water trials demonstrated reduced endurance, with high variability between individuals. The results of the trials are currently being analysed to allow test requirements and methods to be further developed. The revised standard will then go through a consultation process, with the work due for completion later in 2010. The technical standard will be published in the public domain for the industry to use on a voluntary basis, and will be offered to EASA for adoption as an ETSO (see section 3.2.4).

2.6 Personal locator beacons

Personal locator beacons (PLB) have recently been provided to helicopter passengers as an additional aid to location, in addition to the use of retroreflective tape and lights on the suit or lifejacket. PLBs are radio beacons used to alert the emergency search and rescue (SAR) services and allow both aircraft and marine vessels to home in and locate those in distress. PLBs carried on helicopters generally transmit on two frequencies; 406 MHz and/or 121.5 MHz. Beacons using the 406 MHz frequency send out a distress signal which is picked up and can be uniquely identified by satellite, providing information about the location of the beacon. The 121.5 MHz frequency is used for homing, allowing SAR aircraft and surface vessels to come to the aid of the aircraft or personnel.

All helicopters operating offshore in the UK offshore sector are equipped with at least one emergency location transmitter. Each helicopter liferaft also has a beacon operated manually by the occupants in the liferaft. Helicopter pilots and co-pilots all carry a PLB which transmits on 406 and 121.5 MHz. By mid 2010, all passengers will carry a PLB that transmits on 121.5 MHz only. All crew and passenger PLBs can be activated automatically or manually when submerged in water. The PLB models carried by passengers in the UK sector are turned off once the passenger reaches the liferaft to reduce the number of transmitting beacons, improving the likelihood that those remaining in the water will be located.

3.0 SHOULD THE C-NLOPB MORE DIRECTLY INVOLVE ITSELF IN STUDIES AND RESEARCH INTO THE PREVENTION OF INVERSION OF DITCHED HELICOPTERS AND ENHANCEMENT OF PASSENGERS' ABILITY TO ESCAPE?

3.1 The need for helicopter flotation systems

Whilst considerable consideration has been given to the use of personal protective equipment (PPE) such as survival suits and EBS, the provision and use of PPE should always be the last step in the risk reduction process. The first consideration should be to reduce the risk of exposure, in this case to the hostile environment.

Whilst it is almost inevitable that occupants will be immersed in cold water in the event of a helicopter water impact, means of keeping the helicopter afloat and upright will reduce the risk of occupants being submerged and having to make an underwater escape. In so doing, the risks of cold shock and drowning should be greatly reduced. Thus, whilst there will still be a need to use an immersion suit to provide thermal protection, the likelihood of needing to use EBS for underwater escape could be reduced.

The need for a helicopter to remain stable and upright on the water following ditching is thus fundamental when considering the probability of passengers and crew successfully evacuating from the helicopter. Over the years many reports have suggested that improvements to the flotation system are needed to achieve improvements in occupant survivability (e.g. CAA, 1984; Chen et al, 1993; Benham, Redman & Haywood, 1995; Clifford, 1996). Following a review of helicopter ditchings and water impacts published in 1993, Chen et al concluded that "*flotation equipment performance was generally found to be inadequate in keeping the rotorcraft upright and afloat, in both ditchings and water impacts*".

With an effective flotation system, in a ditching situation in calm seas, it should be possible for the helicopter to stay upright. (N.B. A ditching is defined as a controlled landing on water). In the best case situation, occupants are able to use the emergency exits and transfer into liferafts, without any prolonged immersion in cold water. The longer the helicopter stays upright, the greater the chance that occupants can safely evacuate into a liferaft. It has been estimated that the helicopter must remain afloat and upright for about 5 minutes to allow all occupants to escape.

That said, even following a controlled ditching, there are conditions where the helicopter will invert after a variable period of time. This is due to helicopters being top-heavy, with a high centre of gravity. Certain conditions will increase the likelihood of capsize. Sea state is a critical factor. In some areas of the North Sea, helicopters need to have ditching capability in conditions up to Sea State 6 (with significant wave heights of 4 to 6m) to minimise the risk of capsize in the event of a ditching at any random time during the year (winter months generally being most critical). Steep, breaking waves pose the highest risk for capsize, which can be exacerbated by the risk of a rotor strike.

If the helicopter does capsize either immediately or a little time after a controlled ditching, an undamaged flotation system should ensure that the helicopter at least stays afloat despite being inverted. In this situation, any occupants within the helicopter will be forced to make an underwater escape. Likelihood of survival is reduced further if damage causes the flotation to fail, with the helicopter then sinking. It goes without saying that escape will be much more difficult if the helicopter sinks below the water surface. The provision of effective and undamaged flotation systems is thus essential if occupants are to have a reasonable chance of survival.

In a controlled ditching where the helicopter remains afloat, the risk of drowning is relatively low (Clifford 1996). Survival probability will be greatly reduced in the event that the helicopter inverts or sinks; accident data demonstrate that this occurs in about 60% of all water impacts (Rice & Greear, 1973; Brooks, 1989; Clifford 1996). Clifford reported that drowning accounted for more than 50% of the fatalities in accidents where cause of death was known. He considered that this reflected the scale of post crash survival problems. Improvements to flotation systems could help to reduce this high incidence of drowning.

A recent review demonstrated a significant positive relationship between the presence of flotation systems and the helicopter staying on the water surface, and a relationship between the helicopter staying on the water surface and occupant survivability (Taber and

McCabe, 2007). The study failed to show a relationship between installation of flotation devices and occupant survivability. This may reflect a need to improve flotation systems.

As previously mentioned, the term ditching is used to describe the situation where there is still some control of the landing. In many water impacts, there is only limited or no control of the impact, involving much higher impact velocities and forces. Current flotation systems are located low down on the helicopter where it is most susceptible to damage. For flotation systems to be fully or partially effective under this wider set of circumstances, it is necessary for the emergency flotation equipment to be crashworthy, whilst recognising that there will be some high impact events where flotation systems will be ineffective. Currently, emergency flotation systems are designed to withstand controlled ditching loads only.

3.2 UK CAA/EASA research into the prevention of inversion of ditched helicopters and enhancement of passengers' ability to escape

3.2.1 Background

An extensive programme of work into the mitigation of helicopter ditchings and water impacts has been ongoing in the UK for many years. In 1984, as the disappointing safety record of helicopters in transporting passengers to North Sea installations became evident, a committee was set up to look at improvements in airworthiness, resulting in the publication of the 'HARP' report (CAA, 1984). Amongst the many recommendations from this proactive report were several relating to crashworthiness and ditching:

- "*Recommendation 7 - A study should be initiated forthwith to identify suitable requirements for an improved standard of crashworthiness of the structure as a whole, landing gear, seats and possible restraint systems ...*".
- "*Recommendation 10 - We propose that resolution of the problems of stability of a ditched helicopter be urgently pursued*".

They also stated "*the need for stability is emphasised by the very limited practicability of escape from a capsized helicopter. The conditions on which the stability of the helicopter should be demonstrated must take account of realistic wind speeds accompanying severe sea states. Special consideration needs to be given to conditions in the very inhospitable areas such as the northern North Sea.*" These recommendations led directly to the programme of research into ditching and crashworthiness funded by the UK CAA along with industry partners.

The HARP Report was followed some 11 years later by the RHOSS Report (CAA, 1995). This further review of helicopter offshore safety and survival was published following the helicopter accident close to the Cormorant Alpha platform in 1992, when 5 out of 17 occupants failed to escape from the inverted helicopter. In this uncontrolled water impact, the crew did not have time to manually activate the flotation system.

The RHOSS report recognised that efforts should be placed on "*safety measures related to heavy impacts as opposed to ditching*", based on the high survivability record related to ditching, but cautioned against "*prejudicing ditching survival in an unrealistic attempt to help the victims of non-survivable crashes*".

Of the many recommendations within this report, Recommendation 14.2 (g) stated "*The CAA should accelerate and/or coordinate current studies into helicopter crashworthiness, flotation and stability parameters and the automatic activation of flotation gear ... Particular account should be taken of the need to improve provision for flotation after a severe impact, including the possibility of installing extra flotation devices specifically to cater for a crash*".

Research into the stability of helicopters and the prevention of inversion has been ongoing since the 1980s. This work is summarised in CAA Paper 2005/06 "Summary Report of Helicopter Ditching and Crashworthiness Research" (CAA, 2005), covering work conducted up to 2005. The following section further summarises some of the key issues that have been investigated within this research programme.

3.2.2 Stability and capsize of ditched helicopters

In 1992, BMT were commissioned to review work undertaken into ditching performance, looking at the characteristics of waves that would capsize a helicopter, and the probability of experiencing such a wave. They identified the need for more work to characterise the wave, to allow improved performance in a seaway. In almost all cases, the helicopter was capsized by a breaking wave, at a point when the lower float 'dug in' and the upper float was out of the water. Factors such as a large range of static stability and a low above-water profile were considered beneficial in preventing inversion.

Sea anchors

BMT noted that in model tests fewer capsizes occurred in wind, due to the helicopter turning into the wind and waves. It was therefore suggested that a device such as a sea anchor, that would help to turn the helicopter nose in to the wave, would be beneficial. There was some evidence that sea anchors were difficult to deploy, potentially taking too much time to be effective.

'Wet floor' approach

In the mid 1980s the British Hovercraft Company investigated two possible means of improving the static stability and capsize performance of a ditched helicopter. The first looked at the level at which a helicopter floats. At that time helicopters were required to float with the sill of any exit above the calm water flotation line. Studies were undertaken to investigate whether stability could be improved by allowing the helicopter to sit lower in the water with a 'wet floor'. Results were inconclusive, with very variable results dependent upon the helicopter weight, type and test conditions. Whilst raising the floats could improve stability in some circumstances, the lower float position increased the risk of rotor/blade strike on the wave, and there were concerns about the flotation system impeding escape routes and increased exposure of the occupants to cold water. The 'wet floor' approach was not pursued.

Float scoops

The second study conducted by the British Hovercraft Company demonstrated the potential benefits of float scoops similar to those used to improve the stability of inflatable liferafts. In all cases the scoops improved stability. In some cases this was partially attributed to the tendency to keep the helicopter more head to the waves, but the improvement was mainly due to increases in righting moment and roll damping. The CAA then commissioned BMT and Westland Helicopters to examine the additional load forces and weight penalties. The float scoops were shown to increase the helicopter's capsize threshold by about one sea state; i.e. a helicopter with ditching capability in sea state 4 could be increased to sea state 5. It was considered that the risk of capsize would be significantly reduced following a ditching at minimal cost and weight.

Means to prevent total inversion

Research was conducted to look into means of preventing total inversion following a ditching, with the aim of mitigating the consequences of capsize. When helicopters capsize on the water surface they tend to fully invert, turning through an angle of 180˚. Occupants trapped inside must make a rapid escape through exits and escape windows that are under the water. If the capsize occurs immediately after water impact, the occupants are likely to be still strapped in by their harnesses. Inversion results in severe disorientation that makes the location of escape routes yet more difficult. The risk of drowning is high in this situation.

In 1997 BMT was commissioned to investigate novel flotation systems. The aim was to develop a system that would result in a floating attitude where one set of exits and windows remained above the water surface. A panel of experts was first brought together to consider different flotation options. Three potential systems were shortlisted:

- Foam filled engine/gearbox cowling panels - inherent buoyancy fitted in to the airframe high up on the helicopter.
- Long buoyancy bags along the upper cabin wall, above the windows.
- Tethered inflatable flotation bags.

The first two options proved to be effective. The most effective was the buoyant engine cowling panel. The second most effective was the long buoyancy bag system. In calm conditions, most of the cabin was clear of water, with one set of exits above the water surface. In waves, occasional large waves swept in through the doors and windows.

One concern with both of these systems was that the helicopter could roll into two positions. A single wave turned the helicopter to a position with the exits on the lee side, away from the oncoming waves. The helicopter remained stable in this position for some time until hit by another large wave, which resulted in a further rotation of the aircraft so that the opposite side of the helicopter was now above the water with the exits facing the waves. No further rotations were observed. There were concerns that this double rotation could make it much more difficult for the occupants attempting to escape from the cabin.

This problem was solved by an asymmetric configuration. A combination of the buoyant engine cowling panel plus a single long flotation bag on one side of the helicopter resulted in a single stable flotation position in waves.

The main advantage of this 'side-floating' system is that, following a capsize, there is the potential to create a large air pocket in the cabin and cockpit, with doors and exits on one side of the helicopter above the water. The hypothesis was that this would give occupants a much better chance of escape from the capsized helicopter. The next step was to investigate any problems that might be experienced by occupants escaping from the partially inverted helicopter.

One further advantage of the proposed system was that it provided additional flotation to the helicopter, creating some redundancy. This could be beneficial in severe impacts if the traditional flotation system were to incur damage. Current flotation systems are located low on the airframe where they are likely to be exposed to damage. The proposed additional flotation would be positioned high up where it would be at lower risk of damage, thereby potentially improving the overall crashworthiness of the emergency flotation system.

Human Factors Study - Escape from side-floating helicopter

RGIT Limited were commissioned to investigate escape from a side-floating helicopter, developing an appropriate technique and associated training procedures for escape from a partially inverted helicopter. Benefits and problems associated with the system were assessed by comparison with escape from a fully inverted cabin. A helicopter underwater escape trainer was configured to invert through angles of either 150˚ or 270˚, with buoyancy bags fitted above the escape windows to simulate the asymmetric additional flotation system.

Different escape procedures were first investigated using trained personnel. It was established that escape could best be achieved if, following partial inversion, the lowest edge of the window was close to the water surface. In a series of trials conducted with naïve subjects the majority (90%) preferred escape from the side-floating helicopter to underwater escape from the fully inverted helicopter. Overall, escape was found to be easier and subjects were more satisfied with the way they coped. Levels of disorientation and the difficulty of finding their exit were rated much higher in the fully inverted underwater escape, particularly in a cross-cabin exercise. In the side-floating helicopter, time spent with the head underwater was much shorter, requiring much shorter breath-holds (no EBS used). On surfacing within the cabin, subjects had time to assess the situation and plan their escape route once they had reached the air pocket in the cabin.

Some further work was recommended to look at uneven loads on the seat harness, as occupants in some seats would be above the water and fall a short distance to the water surface. This caused some problems with harness release. Consideration must also be given to the effects of large waves that may wash into the cabin. Overall, the benefits of escaping from the partially inverted helicopter were considered to outweigh any problems, giving the occupants a much better probability of escape and survival.

Type-specific design study

The most recent research in this area has been undertaken by Eurocopter and Aerazur and was funded by the European Aviation Safety Agency (EASA). Design objectives for an additional emergency flotation system were considered for both a light (AS355) and heavy (EC225) helicopter. Designs were based upon floats along the top of cabin walls, foam filled cowling panels, and a combination of the two.

For the EC225, five different additional flotation systems were tested using scale models in a wave tank, with irregular waves (sea state 5). Both symmetrical and asymmetrical designs were considered. In each case, a stable flotation position following capsize was achieved with a rotation of between 150˚ and 160˚. Additional flotation system designs incorporating the buoyant cowling panel proved to be the most effective, with respect to stability and the number of windows remaining above the waterline following partial inversion. Both the asymmetrical design (cowling panel + flotation bags on one side of the upper cabin), and the symmetrical design (cowling panel + flotation bags on both sides of the upper cabin), remained effective when one of the standard (lower) flotation bags was damaged. This demonstrated the benefits of buoyancy redundancy.

The authors cited a number of reasons for preferring the symmetrical flotation configuration over the asymmetrical one:

- The volume of the inflatable flotation on each side of the cabin was lower compared to the asymmetrical design with floats on only one side;
- The airspace inside the cabin was larger with the symmetrical design, due to a higher inclined flotation position following capsize;
- The asymmetrical design suggested a different level of safety depending upon which side of the helicopter the occupant was seated;
- When one standard lower float was damaged, better buoyancy redundancy was achieved, with the helicopter stabilising at a 45° angle whichever side the damage occurred.

Future work included the need to develop new fabrics for the floats to withstand high temperatures in the upper part of the helicopter. Further analysis was needed regarding the interaction between the blades and the additional floats, as well as some consideration of the effects of blade damage during helicopter capsize.

3.2.3 Crashworthiness research

This work focussed on crashworthiness issues that specifically relate to water impact. It should be recognised that flotation systems are likely to be much less effective when a helicopter crashes into water due either to the floats being damaged by impact or due to the fact that the crew are unable to manually activate the system.

The review of UK military and world civil helicopter water impacts from 1971 to 1992 (Clifford, 1996), previously descrbed, was part of this programme. Clifford found that, in fatal accidents where cause of death was known, drowning was the major cause of loss of life. This was particularly true of vertical descents with limited control and fly-in accidents. Fatalities due to impact injuries only predominated in the category of uncontrolled impacts. (Crashes considered to be non-survivable were excluded i.e. where forces exceeded human tolerance and/or where the airframe did not stay sufficiently intact to permit survival). This was likely due to the fact that the helicopter inverted or sank in more than 50% of cases before the evacuation of occupants could be completed.

Structural loads and the probability of occupant injury in helicopter water impacts were found to depend on both the impact velocity and the behaviour of the structure on water entry. Designing the airframe to withstand water pressures without excessive deformation and without water entering into the internal structure or occupied areas, was seen to be the key issue for water impact resistance. There were no requirements calling for the airframe to be so designed at the time the study was undertaken.

The major factor for improving occupant survival was considered to be design techniques for increasing the capability of the helicopter structure to remain afloat after water impact for long enough for occupants to escape.

The CAA then commissioned two studies investigating means of improving the crashworthiness of helicopter emergency flotation systems. The first, conducted by WS Atkins, looked at the crashworthiness of both the airframe and the flotation system. They recommended several design modifications to the emergency flotation system that would improve performance following a severe impact, including automatic arming and deployment of the system. A number of these modifications have been implemented in modern designs, but it is understood that they have not been addressed in the requirements and advisory material.

An associated study by BMT looked at water impact loading on typical flotation system components. They looked at various scenarios relating to horizontal and vertical impact forces, angles of water entry and sea states. Their studies showed that additional redundant flotation, of the type described for preventing complete inversion, will reduce the probability of a helicopter sinking following a high-impact crash. They considered that with conventional flotation systems, with buoyancy low down on the airframe, substantial increases in design loads would be needed to improve survivability. They highlighted the benefits of flotation redundancy, where additional floats are positioned high on the cabin wall, where they are protected from all but side impacts (CAA, 2005).

3.2.4 EBS research

Initial study of implementation and use

During the early years of the ditching research programme, RHOSS (1995) considered that there was no clear advantage to be gained from introducing emergency breathing systems (EBS). However, in 2000, a workshop on EBS was set up in response to the wide and increasing deployment of EBS by the UK offshore industry. One of the key issues explored was that the time to escape from an inverted helicopter (estimated as 45 to 60 seconds) was greater than the average breath-hold time in cold water (mean values vary from 20 to 30 seconds, but values may be as little as 10 seconds in some cases). As a result of this workshop, the CAA, on behalf of Joint Aviation Authorities' Helicopter Offshore Safety and Survivability (HOSS) working group, commissioned a study into the implementation and use of EBS (Coleshaw, 2003).

The study aimed to establish the extent of knowledge and testing performed on various EBS designs. Clifford's (1996) data on water impacts was reviewed, with the high incidence of drowning accounted for by the effects of cold shock. The effective use of EBS would allow users to overcome cold shock and allow them time to make an underwater escape, extending underwater survival time.

Whilst it was considered that reliance on EBS for escape should be minimised, it was reported that successful use of EBS can reduce levels of stress experienced during helicopter escape under simulated conditions. Satisfactory performance of EBS was considered to depend on good design, reliability of the equipment, ease of use and performance on demand. Other key factors included individual human capabilities, training, environmental conditions, helicopter design, and the circumstances of the helicopter accident.

The author felt that in-water training was required to maximise the benefits of EBS and minimise the risk of human error during deployment and operation. It was considered important that competence be maintained to prevent any failure of deployment.

An example draft technical standard was also prepared (see also 2.5.2), identifying minimum performance requirements to ensure that equipment is manufactured to consistent and satisfactory standards, and that basic health and safety requirements are met. Compatibility with other personal protective equipment was also considered to be an important issue that a technical standard would address.

The main conclusions from the study were that EBS could provide a viable solution to bridge the gap between breath-hold time and escape time, but that careful attention would have to be paid to equipment design and user training. The study recommended that a technical standard should be produced for EBS, and highlighted the knowledge gaps that would need to be filled.

Development of full technical standard

A follow-up study was commissioned in 2008 with the aim of completing the technical standard for EBS. To achieve this aim, gaps in the draft standard needed to be filled, whilst further research was needed to deal with knowledge gaps in areas such as realistic emergency deployment times and cold water performance. This work, which is ongoing at the present time, has looked at three generic designs of EBS; a compressed air device, a rebreather and a hybrid (rebreather with additional air). The results of the research will be used to develop the test methodology and set performance criteria. The completed standard will then be circulated to interested parties for review, before being submitted to EASA for possible publication as an ETSO (European Technical Standard Order).

3.2.5 Overview of research

At the time of writing this report the UK CAA/EASA programme of research is ongoing, with responsibility for future work having been transferred to EASA. The research has provided a much better understanding of the problems, particularly in relation to helicopter flotation, allowing design improvements to be made.

Following personal communication with the UK CAA, the CAA consider that "*there is a fundamental mismatch between the certification standards in terms of ditching stability and the wave climate in the North Sea, and between escape times from an inverted helicopter and realistic breath-hold times in typical sea temperatures.*

Measures for improving the sea-keeping performance of helicopters such as float scoops do exist and could provide a worthwhile improvement; unfortunately the present certification standards do not drive the industry to improve ditching stability. However, it is recognised that there is a practical limit to what can be achieved with helicopters (probably Sea State 5), which could be inadequate for areas such as the northern North Sea where the previous UK standards recommended Sea State 6. Furthermore, capsize during ditching could occur due to imperfect alighting on the water (e.g. due to limited control caused by tail rotor failure or some other mechanical defect), or due to the rotor striking a wave. Means to mitigate the consequences of a capsize are therefore considered to be necessary and could take the form of EBS or modification of the emergency flotation system to allow a reversionary side-floating attitude.

In addition, accident experience indicates that in almost all cases the helicopter will invert immediately in the case of a (survivable) water impact. CAA believes that the case has been made for automatic float arming and deployment, and for the provision of emergency flotation system redundancy at a flotation unit level (rather than the present 'critical' float compartment level). An additional hazard in the case of water impacts is that the helicopter may sink, further reducing the chances of successful escape and survival. Studies have indicated that the additional floatation needed for the side-floating scheme considered for post ditching capsize would provide the redundancy required to prevent sinking and, in many cases, retain an air gap within the cabin. EBS is less likely to be effective in water impacts due to the likely increased difficulties associated with deployment (e.g. impact injuries, underwater deployment), and the reduced probability of survival in the event that the helicopter sinks.

In view of the above, CAA believes that a properly designed EBS could provide a satisfactory short-term solution to the problem of post capsize survival pending availability of the side-floating scheme. The side-floating scheme is, however, considered to present the optimum solution and the CAA is not aware of any insurmountable problems that would render the scheme impractical or ineffective at least for new build/design helicopters. Should the side-floating scheme prove impractical to retrofit, however, it may be possible for EBS to provide a degree of long-term mitigation.

CAA and its industry partners are completing work on a technical standard for EBS. This will be published in the public domain for the industry to use on a voluntary basis, and will be offered to EASA for adoption as a formal standard (ETSO). As regards the side-floating scheme, EASA currently proposes to establish a workshop in 2011 to review all of the helicopter ditching and water impact requirements, advisory material and research. It is hoped that the good consensus for the adoption of the side-floating scheme achieved within the JAA HOSS Working Group (formed to consider the recommendations of the RHOSS report), and the FAA/JAA Joint Harmonisation Working Group on Water Impact and Ditching Design will prevail (see Appendices F and G of CAA Paper 2005/06)" (CAA, 2010).

If the C-NLOPB were to more directly involve itself in research of this kind there would be benefits, in particular, an improved knowledge base relating to helicopter safety in the offshore transport sector. The support of a wider audience could also help this work to progress, with the hope that further improvements to flotation systems will be realised.

4.0 WHAT ARE THE APPROPRIATE STANDARDS OF HELICOPTER SAFETY TRAINING TO ENSURE THAT THE RISK TO PASSENGERS IS AS LOW AS REASONABLY PRACTICABLE, BOTH DURING TRAINING AND HELICOPTER TRANSPORT?

4.1 The need for training

Helicopter underwater escape training (HUET) has been developed over many years in response to helicopter crew and passengers having great difficulty escaping or being trapped inside the helicopter following submergence or capsize, with many fatalities due to drowning.

In-rushing water, disorientation and an inability to reach or open exits have all been cited as problems experienced when attempting to escape the helicopter (Rice and Greear, 1973), resulting in a recommendation for realistic underwater escape training. Ryack et al (1986) reviewed helicopter crashes at sea and reported data from the US Naval Safety Centre showing that 92% of those who had received training in the 'Dilbert Dunker' survived such crashes, compared to a 79% survival rate for those who were untrained. They considered that the training provided individuals with familiarity with the crash environment and confidence in their ability to cope with the emergency situation, recommending HUET training for all navy helicopter crew. Others have reported the benefits of HUET training. Hytten (1989) described one particular accident where HUET training was believed to have been critical to those who escaped. Training provided reflex conditioning, provided a behaviour pattern to follow, reduced confusion and reduced panic. The real situation was said to have been different to the training scenario but nonetheless, their training was considered to have been very important in their survival.

Training has been said to develop a positive expectancy for future coping (Hytten, Jensen & Vaernes, 1989). Thus, individuals who cope well with training develop some confidence that they will be able to cope with a real emergency, gaining more confidence in helicopter transport. Hytten (1989) has also reported how individuals can adapt to stressful situations over time, stating "*when fear is confronted and coped with at one intensity, it is probable that one will cope with a new fear-provoking situation of greater intensity*". Thus, coping with a training situation allows the individual to develop coping mechanisms and thus manage a real life-threatening event more effectively.

In real emergencies, victims show a range of behaviours in response to the threat. Muir (1999) described a number of behavioural responses experienced by passengers involved in transport accidents. These included fear, anxiety, disorientation, depersonalisation, panic and inaction. Inaction or 'freezing' is a real problem in the helicopter emergency situation. If a person seated next to the exit freezes, they are less likely to make a rapid escape and will effectively block the exit for someone seated on the inside. Leach (2004) suggested that 'freezing' could be accounted for by time constraints on the cognitive processing of information in a rapidly unfolding, real-time environment. This is at the other extreme to panic where the individual reacts very quickly but perhaps inappropriately. Training should aim to reduce the likelihood of such behaviours, through familiarisation with typical scenarios, familiarisation with equipment and practise in the procedures that must be carried out.

4.2 Fidelity of training

There is much debate regarding the fidelity of training. This may be applied to the similarity of the environmental conditions, the similarity of equipment, and the similarity of tasks undertaken. For example, disorientation is known to be one of the most difficult factors that individuals must learn to cope with in an inverted helicopter. By experiencing disorientation in a controlled environment its impact in a real event can be diminished. However, in a real emergency it might be dark, there could be oil floating on the water, and there may well be damage to the helicopter structure in all but controlled landings on the water. It would therefore not be sensible or practical to recreate all aspects of this environment in training. Whilst some military and crew training takes place in the dark, this would be a much more difficult for training organisations to control, and the risks of training would increase. The stress of training would undoubtedly increase and this would be undesirable.

When trying to achieve physical fidelity of equipment, success will depend on the number of different helicopter designs that trainees may be exposed to in reality. Different helicopters have different designs of exits and escape windows, and many different exit release mechanisms. Thus, if only one helicopter design were to be used by a particular occupational group it might be possible to achieve reasonable physical fidelity. Where different helicopters are used, the best that can be achieved is some fidelity with, for example, a typical exit release. What is most important is that each trainee does get the opportunity to at least operate a generic exit mechanism and have some idea of the types of mechanism that might be experienced (this needs to be backed up by pre-flight type-specific briefings).

That said, it has been argued that exact physical fidelity is not needed. Summers (1996), in a study of procedural skill decay and optimal retraining periods in helicopter underwater escape training, considered that physical fidelity was not necessarily required for effective transfer of training from the simulator to the real environment. She considered that task analysis was more important when identifying the information needed for learning i.e. it was more important to physically go through the actions required to locate an exit and operate the exit mechanism than for the exit door to look like a real exit door. Summers stated that the most important factors in simulator training were operational realism and functional similarity. As an example Summers cited a study where training in a plywood aircraft cockpit mock-up produced transfer of training that was similar to that achieved with a high fidelity, sophisticated and expensive cockpit simulator. To back up this contention, several accident reports have suggested that even if a helicopter simulator bears little physical resemblance to the cabin of a real helicopter, the training will still have positive benefits when it comes to surviving a real accident (Hytten, 1989; AAIB, 1993).

When considering the fidelity of escape procedures it is therefore important that each step in the escape process is covered by the practical training. Trainees need to be familiar with their personal protective equipment (PPE), and know what, if any, actions have to be taken to make the PPE ready for use in the event of an emergency (such as doing up zips or locating and donning hoods). Release of the seat harness must be experienced and practised, whether this be with a four-point or two point harness. With a two-point harness, confusion can be caused if direction of release is different to the commonly used car seat harness. Release of the less familiar four-point harness must be learnt, but there is less likelihood of confusion (and this will be practised under non-emergency conditions when flying offshore).

Issues have been raised about the number of delegates in the HUET at one time, and the possibility of practising escape from seats other than those next to an exit. In the past, in UK training centres, higher numbers of delegates were seated in the HUET for each exercise, with some seated next to exits and others on inside seats, having to wait for the person seating next to them to escape before they could then move to the exit and escape. This regime resulted in some injuries to delegates, when someone in an inside seat panicked and went to escape ahead of the person sitting next to the exit, kicking that individual as they escaped. (This occurred at a time when no EBS was used during training, so that trainees were having to breath-hold during escape). The training procedures now stipulate a maximum of 4 delegates in the HUET to reduce the risk of injuries (and to allow competence to be assessed). This means that no 'cross-cabin' escape is undertaken. The advent of EBS use could make this feasible in the future without unduly increasing the risks of training.

Another issue in the UK has been the requirement to physically remove an exit/escape window when escaping from the HUET, this being a task that was not included in training until recently (see Coleshaw, 2006b). A study of HUET by Muir and Mills (1999) concluded that delegates must be given training and practice in the operation of representative exits if they were to meet minimum competency levels and adequately simulate the real environment. It was found that higher fidelity training including the operation of exits caused more stress but individuals were more confident as a result of their training. The authors also supported the need for "*part-task learning whereby trainees skills are built up in an incremental fashion*" (Mills and Muir, 1999).

A more recent study (Kozey et al, 2006) also investigated the effects of training fidelity and practice on egress performance. They found that participants who had experienced use of push-out windows once during training had a greater success rate (81%) during a test HUET escape 6 months after the training than those who had no experience of pushing out windows during training (54% success). A further group who, during training, undertook four HUET inversions during which a window had to be pushed out, demonstrated a 96% success rate when carrying out the test HUET escape. This work clearly demonstrated the combined benefits of including the operation of exits during training and of practicing underwater escape using exits. The results also demonstrated that if sufficient training in a task is given, the learning will be retained for at least 6 months.

4.3 Stress in training

When it was first proposed that the operation and removal of exits be introduced into the basic and further offshore emergency response training in the UK, concerns were raised regarding the levels of stress and anxiety that may be experienced by some course delegates, the possibility that stress levels may be increased by the introduction of exit operation and the potential health risks associated with such a change. OPITO therefore funded a project to assess the impact of the proposed changes (Coleshaw, 2006a). Previous studies had identified high levels of anticipatory anxiety in some individuals undergoing HUET training (Harris, Coleshaw & Mackenzie, 1996). Anxiety levels were higher in those participating in training for the first time, and in younger age groups, possibly suggesting that older, more experienced individuals who had attended training on multiple occasions knew what to expect and had developed coping strategies. The work of Muir and Mills (1999), which aimed to develop a training standard for underwater survival, found that higher fidelity training (including operation of emergency exits) caused more stress, although trainees were more confident as a result of the training.

Whilst some stress can be advantageous, helping the individual to react to a challenge or threat, too much can have negative effects on health. As part of the OPITO study (Coleshaw, 2006a) registered occupational physicians were consulted and they identified a number of issues. They discussed both the potential threat posed by stress in some individuals, but also the fear that job security depended upon successful completion of the HUET training. The personal view of one medical officer was that emergency response training was much less stressful than it had been 10 to 15 years previously, related to continuous changes and improvements to the training and the way it was delivered (e.g. less machismo attitudes). The physicians supported a strategy of minimising stress in training where possible.

When considering changes to HUET training it is therefore necessary to balance the need for training fidelity against the stress that may be induced in some individuals when making training more and more realistic. Concerns have also been raised that offshore medicals are enhanced due to the need to be fit for emergency response training, over and above the needs of fitness to work. Again, a balance must be achieved.

4.4 Training frequency

Skills decay and the frequency of training is another area of ongoing discussion. In the UK, further training must be taken within four years, though many repeat the training after three years. The study by Summers (1996) looked at training frequency. She pointed out that procedural skills, that are infrequently practised, decay rapidly, and she considered that a two year training interval was too long. The Association of Oil & Gas Producers (OGP) recommend a 3 year goal for frequency of training, but recognise that this may vary according to the operation, exposure, identified threats and the quality of training given. Offshore workers who have been in the industry for many years tend to complain about having to come back and repeat training every few years. This requires a sense of personal responsibility on their part, to acknowledge the benefits of refresher training, and recognition that while they may think that they know what to do, some skills may have been forgotten.

4.5 Training standards

It is considered that helicopter safety training should include a positive message about helicopter safety in addition to practical skills training. Helicopter flight has been included in a list of stressors experienced by offshore workers. It is therefore necessary to limit fears about helicopter travel and provide a balanced and realistic view of helicopter safety.

Training needs to cover the different types of water impact that could occur, recognising that a controlled ditching is more likely to occur than a fly-in or uncontrolled impact. To cover the different scenarios that could be experienced, a number of different training scenarios are needed:

- Evacuation from a floating helicopter, leaving the cabin in a controlled manner, using an emergency exit, and exiting into a liferaft.
- Underwater escape from a submerged helicopter.
- Underwater escape from a capsized/inverted helicopter.

Within these exercises, a number of issues and essential procedures need to be covered within either the classroom or practical training:

- Familiarisation with personal protective equipment that is likely to be worn;
- Preparation for water impact;
- The possible impact of in-rushing water;
- Use and release of harness;
- Importance of locating exits;
- Awareness that it might be necessary to cross the cabin in a real accident;
- Effects of buoyancy;
- Liferaft deployment;
- Actions to take once in the liferaft e.g. turn of PLB, find survival bag etc.;
- Inflation of lifejacket (if used);
- Actions to take in the water whilst awaiting rescue.

In the UK and many other parts of the world, HUET training is conducted to the standards laid down by OPITO (2008). Their standards lay down learning objectives, a detailed and prescriptive training programme, competence assessments and optimum contact time with delegates.

The Basic Offshore Safety Induction and Emergency Training (BOSIET) incorporates more exercises than the Further Offshore Emergency Training (FOET). The BOSIET includes 7 HUET exercises (dry evacuation including removal of exits; three submersions and three capsize exercises, each including one escape on a breath-hold, one escape using EBS, and one escape using EBS and removal of exits). The FOET includes 4 exercises (dry evacuation including removal of exits; one submersion with EBS; one submersion with EBS and exits; plus one capsize with EBS and exits). Some exercises are still conducted without the use of EBS to ensure that subjects practise taking a deep breath and escaping as quickly as possible on a breath-hold. This may still be the best option in an accident without warning and with no time to deploy EBS before submersion, if the helicopter occupant is next to an escape window and can escape quickly. Repeated exercises are also conducted with EBS. If sufficient preliminary EBS training has been given the delegates should be able to practise rapid deployment of the EBS and then concentrate on the escape process during these exercises. Exits are removed in three exercises with both the BOSIET and FOET courses, providing a reasonable level of practise.

It is understood that the Canadian offshore workforce complete some of their training under real sea conditions, in cold water. This has some merit as a process that will familiarise trainees with what might be expected in a real emergency, and perhaps reinforce the need to wear an immersion suit that is correctly fitted and sealed. However, this is a very uncontrolled environment in which to conduct training. The severe distracting effects of cold water are likely to limit the learning process. Procedures such as liferaft boarding are more likely to be learnt well if they are practised in a controlled pool environment. In the UK, pool training in water as cold as 20˚C, was stopped following action by the Unions (Spiller, 1997), with most training facilities now operating HUET training in water temperatures close to 25˚C. The disadvantage of this cool rather than cold water temperature is that some delegates can develop a misconception regarding just how cold water temperatures may be in the real environment.

4.6 EBS Training

In-water training is recommended for all types of EBS. Emergency deployment should be practised with the trainee in an aircraft seat with two or four-point harness as appropriate (both if both types could be encountered). Deployment should be attempted with both the left and right hands, as the best hand for deployment will depend on seating position and the location of the exit. Single-handed deployment is seen as the worst case scenario, and allows one hand to remain locating the exit.

Users must be trained to breathe normally when using compressed air systems, to overcome the distraction of the exhalation bubbles and to learn that they must not hold their breath at any time with this type of device. With rebreather systems, some breathing resistance will be experienced, particularly when swimming face down. Most users should be able to rebreathe for more than a minute without feeling the effects of a rising carbon dioxide level.

It is recommended that users learn to breathe from the EBS in a shallow water area, being given enough practise for each to breathe from the EBS with confidence. Only then should the EBS be used in a helicopter simulator.

5.0 SHOULD OFFSHORE WORKERS HAVE A LEVEL OF PERSONAL ACCOUNTABILITY FOR THEIR OWN SAFETY IN HELICOPTER TRANSPORT?

There are a number of areas where offshore workers can take personal responsibility for their own safety. RHOSS (1995) reporting on the evidence given by two survivors of the Cormorant Alpha accident, suggested that their survival was in part due to "*their own stamina and presence of mind*". It was considered significant that both were strong and confident swimmers "*who were able to remain clear-headed and in control of their breathing when underwater*", having an effect both during escape from the cabin and afterwards when coping with heavy seas whilst awaiting rescue. In his testimony to this Inquiry, Robert Decker, the survivor of Flight 491, described how he had had previous experience of being thrown into cold sea water, that he felt some of his reactions were therefore instinctive and that this helped him to stay calm and not panic. In the study of stress during offshore survival training, non swimmers demonstrated higher levels of anxiety during training (Harris et al, 1996) resulting in a recommendation for water confidence classes for this group prior to training, to reduce pre-course anxieties and improve coping skills.

These comments support the view that confidence in water is likely to increase the chance of survival in a helicopter ditching. Those who are familiar with the sensation of being immersed in water and having the head underwater are more likely to cope well than those without this experience. Training every three to four years may not be sufficient to provide this familiarity with the water environment. The issue of exposure to cold water is problematic. Whilst exposure would increase familiarity with the environment, and could result in some habituation to cold shock if repeated on a regular basis, it would not be recommended for all. Older members of the workforce are more likely to have undetected cardiovascular disease, and sudden immersion in cold water, without the protection of an immersion suit, could put this group at some risk.

Personal accountability is also important when considering the use of personal protective equipment. Section 2.2 of this report considered the issues of immersion suit sizing and fit. Members of the workforce must take responsibility for ensuring that they are issued with a well fitting suit. There is also a need to check seals at the face and wrists, to ensure that there is no damage to seals, whilst care must be taken to ensure that seals sit on the skin, and that there is no hair or clothing trapped under the seals that would allow water to track into the suit. There are times that zips are not fully done up as the end of the zip feels uncomfortable digging into the face. Some level of discomfort may be necessary to ensure a good seal when used in an emergency.

Comfort will also be dependent upon the level of clothing worn under the suit. This will affect the overall insulation of the suit. In the UK, clothing policies have been instituted in an attempt to put some control on the level of clothing worn under the suit; either two layers or three layers dependent upon the time of year. The problem comes when sea temperatures are cold but air temperatures in the cabin are hot. It may not be in the best interest of the individual to strip down to a minimum layer of clothing under the suit. As previously mentioned, this is a balance between thermal comfort in the cabin and protection from cold in the event of immersion. Again, the passenger must accept some level of discomfort.

A positive attitude to survival training is recommended. Those who achieve this are more likely to learn skills and complete training with a positive outcome than those who do not want to be there and resent the time spent on the training. This carries across into helicopter transport. Those with a positive attitude to safety are more likely to build up their own survival strategy, taking time to check escape routes and exit mechanisms in the particular helicopter used for flights. Those individuals will be better prepared in the event of an accident, providing positive benefits.

Some oil and gas operators now operate policies where the workforce must take responsibility for the safety of themselves and those they work with, speaking up if they see an unsafe act. This aims to reduce preventable accidents but also gets the workforce to think about personal safety.

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