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The Ergonomics of Jettisoning Escape Hatches in a Ditched Helicopter

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The first formal investigation of the problem of location, operation and jettison of escape windows and hatches of helicopters following ditching has been conducted in a new simulator. There were 48 aircrew who attempted 298 escapes using a variety of 24 escape routes and 9 different types of escape hatches. Overall results, while superficially indicating that the task was easy, in fact revealed many unforeseen problems. Specifically, there was no standardization of hatches and levers, there were problems with location and operation of levers principally due to poor design, and an ergonomics study has not been conducted to investigate the problem. Underwater escape training with hatches in position must be mandatory for all who fly off-shore or over water for a living, and further research should be conducted to design a better standard hatch and jettison system.

WHEN A HELICOPTER accident occurs over water, it happens suddenly. The helicopter sinks very rapidly, either upright or inverted. Commonly, aircrew and passengers are disoriented and have to make their escape in cold water from a flooding or flooded cabin.

The escape route may not resemble the pre-accident condition; it can be seriously blocked by debris, personal possessions or panicking survivors or, as a result of the accident, it can be seriously damaged. Even if the survivors can negotiate their way to an escape aperture, they must then locate the mechanism for jettisoning the door, hatch or window, usually by touch rather than vision due to poor lighting, to enable escape from the fuselage. This last challenge, unfortunately, often defeats those who are at the limit of their breath-holding ability, or who have been injured in the accident. They are part of the 25–35% mortality rate associated with helicopter ditching accidents (1,3–8).

In 1973, Rice and Greear (9) recommended that more hatches be provided both overhead and in the deck, and that water-pressure-activated charges be fitted to remove the hatches automatically in the event that the crew could not release them manually. Subsequent to this, in 1983–85, the U.S. Navy (5,6) reported 33 cases in which personnel had difficulty or found it impossible to open the escape hatch. No further action has taken place on Rice and Greear's original recommendations, but, as a partial solution to the problem, most military and civilian operators of helicopters now insist on underwater escape training in an approved facility.

The problem has not gone away, however, and although examples reported in the literature are very sparse, the following extracts from the investigation of the ditching of the S61N G-BDES inbound from SEDCO 703 in the UK sector of the North Sea demonstrate typical examples of the problem (2):

> "*The Captain* found himself upside down in his seat underwater; he could not find the emergency exit handle (probably because he was suspended on his harness and therefore some inches further away from the handle than he thought). He released his harness and surfaced (at this time some air must still have been trapped in the cockpit). . . . He looked into the cabin and saw passengers who were calm. The captain attempted to open the cargo door but could not; when he surfaced for more air he found the air bubble had disappeared. He found a window, pulled the beading out, punched the window out and left the cabin. . . . *The Co-pilot* also had difficulty finding his emergency exit handle and decided to go out his sliding window; this was tight but successful."

Generally, helicopter underwater escape training establishments teach the survivor to escape only from an open hatch in the simulator. As a result of the above observations, one of us responsible for training reasoned that once students were trained to this level of expertise, the training should be extended to include location and jettison of windows and doors. One year ago, Survival Systems Limited in Dartmouth, Nova Scotia, constructed a Helicopter Underwater Escape Trainer: the Modular Egress Training Simulator

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(METS) (Fig. 1). As in other training establishments in Australia, the Netherlands and Norway, a very wide range of escape apertures, doors, windows, and associated jettison methods could be simulated. This includes all those in the Canadian Air Forces inventory of helicopters—Sea King (Sikorsky H-3), Kiowa (Bell Twin CUH-IN), Huey (Bell OH-58), and Labrador (Boeing Vertol).

After commissioning the METS, an initial course was prepared to train the instructors to operate all the mechanisms on the windows and hatches. Surprisingly, the highly experienced instructors found that not only was the task of locating the jettison devices difficult, in some cases, but so was operating the jettison levers. What appeared to be a very simple procedure to execute in the upright position on dry land became an extraordinarily difficult task to do when one was inverted underwater, breath-holding, excessively buoyant and without gravitational references. As a result, it took 4 weeks of extra training for the instructors to develop reliable techniques for teaching how to safely locate and operate their jettison mechanism. To illustrate the point, the following example is given.

The Sea King Helicopter has what appears to be a very easy escape route for both pilots. The window jettison lever is located on the bottom sill approximately one-third of the way from the forward edge. By simply reaching down with the right hand (right seat), or left hand (left seat) and rotating the handle from the 9 o'clock position to the 1 o'clock position in the RH seat and the 3 o'clock to the 11 o'clock in the LH seat, the whole window is unlocked. When pushed by the pilot's elbow, it should fall out leaving a large escape aperture. When this was tested underwater, however, it was noted that the instructors and, later, the early groups of students consistently missed reaching the handle by 5–10 cm. In the inverted position with no gravitational reference, poor underwater depth perception and underwater magnification effects, the subjects apparently had a misperception of where the handle was located, and if they failed to find the lever for some unknown reason, the response always followed a similar curious

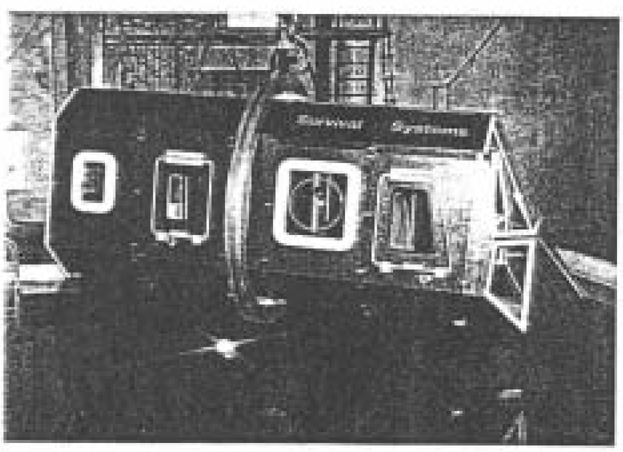

Fig. 1. Helicopter underwater escape trainer—the Modular Egress Training Simulator (METS) at Survival Systems, Dartmouth, Nova Scotia, Canada.

pattern. The shaking arms became outstretched and the trembling hands searched aimlessly around the upper half of the window/door frame. However, once the escapee's hand was placed on the handle by one of the underwater observers, he did not have great difficulty in operating the jettison lever, although many of the students first attempted to rotate the handle in the wrong direction (a classic reversal error). As testing continued, it became apparent that extraordinary mental effort was required to conduct any manual task underwater more than 25 cm away from the fingertips while in a normal sitting position with elbows flexed (i.e., while controlling cyclic and collective). Subjects consistently missed reaching their jettison mechanisms by 5–10 cm.

The solution to this specific problem was relatively simple. Using the example of a pilot in the right seat, the student was instructed to adopt the traditional ditching position (5–7). Post crash, once all motion had stopped, he was instructed to keep his left hand on the seat to maintain a primary reference, as is taught in the basic course. The new technique taught the student to proceed as follows: (a) spread the legs 45° apart and try to fixate the right leg against the fuselage to give further reenforcement of position; (b) place the right hand on the pubic symphysis, which automatically flexes the right forearm; and (c) with the right hand physically trace a path from the pubic symphysis along the inside of the right thigh continuing past the right knee. This path has not been completed until the right elbow rests on the right knee with the right forearm in the line of the thigh. At this point, the student's right hand would be essentially touching the jettison lever. If students followed this routine *rigidly*, they were guaranteed to be very close to the handle every time. If they attempted other techniques, they commonly missed the handle and failed to escape without assistance.

The many different types of escape hatches lack uniformity in types and placements of mechanisms: the Sea King alone has four. Apparently, no thought had been given to designing them for operation underwater without gravitational or visual references; nor had any consideration been given to the fact that survivors may be seriously injured, disoriented, having possibly only one useful hand, being at the limit of their breath-holding ability and close to drowning. A literature search revealed only the single recent pioneering attempt by Bohemier et al. (4) to investigate the relative difficulties of mechanisms used for jettison of windows and hatches. Four types were studied: a mechanical pull, a mechanical rotate, a push-out, and a tear-away bead. No other work on the problem could be found, and it would appear that this problem has been entirely neglected by the aerospace engineering community.

Our instructors' initial opinions were that helicopter escape hatch jettison mechanisms had in fact been poorly designed for underwater escape. Therefore, it was decided to use the results of the performance of the first 49 students to qualify from the new METS to determine if this were the case. If true, preliminary recommendations would be made on how to improve the mechanisms, both in the short and long term.

METHODS

Commencing in summer of 1992, the first 48 of 49 experienced aircrew to complete the standard underwater escape training course (Phase I) were asked to participate in additional training (Phase II)—to include jettison of the escape hatch. The aircrew were a mixture of 23 fit pilots, 12 Airborne Equipment Sensor Operators (AESOP's), one Sonar Operator, 2 Observers, 6 Flight Engineers, and 4 Search and Rescue Technicians. Coming from a variety of backgrounds, they were currently flying in either the CH124 Sea King, CH135 Huey, CH136 Kiowa, or CH113 Labrador helicopter. A common denominator was that none of them had previously attempted an underwater escape course, although the Search and Rescue Technicians were qualified divers.

In Phase I, each student was instructed in the procedures for underwater escape from the METS using the standard training syllabus. These procedures were completely satisfactory and required no modification. The first objective was to learn the basic principles of underwater escape through an open hatch. Each student wore a cotton-ventile immersion suit, lifejacket, helmet, and gloves. The students were required to conduct: (a) one hover evacuation (escape from an open hatch approximately 6 ft above the water); (b) two surface evacuations (escape from an open hatch with the METS floating on the surface of the water); and (c) one underwater escape from an open hatch in the inverted position. Occasionally, if the instructor believed the student was not very confident with the underwater escape, a second attempt was conducted. Of the 49 students who reached this standard, 6 needed the extra coaching. One student never succeeded in making a successful escape without assistance in spite of extra coaching, and was therefore not included in the next phase.

In Phase II, the METS was configured to the helicopter type being flown by the subject. The subjects were then required to attempt to make two successful escapes underwater in the inverted position using their primary escape routes, with the windows or hatches initially in place for both escapes. They wore the same clothing and equipment as in Phase I. Each subject was shown how to find and jettison the closest window or hatch. After making two successful escapes, and further training, they were asked to escape twice using a secondary escape route. Both tests were voluntary and the aircrew could discontinue at any time. Nine different types of escape hatches/mechanisms in the four helicopter types were tested (Fig. 2–6), and a total of 24 different primary or secondary escape routes were examined.

At the end of the course, all students were requested to fill in a simple questionnaire which asked them to subjectively rate locating and jettisoning primary and secondary hatches as either easy, moderately difficult or difficult, and to offer any recommendations for improvement. Additional data on each subject's escape was provided by one instructor designated to observe every immersion. Both he and an additional instructor were also positioned to aid any student who had difficulty. There was also a safety diver in the pool at all times when the METS was in operation.

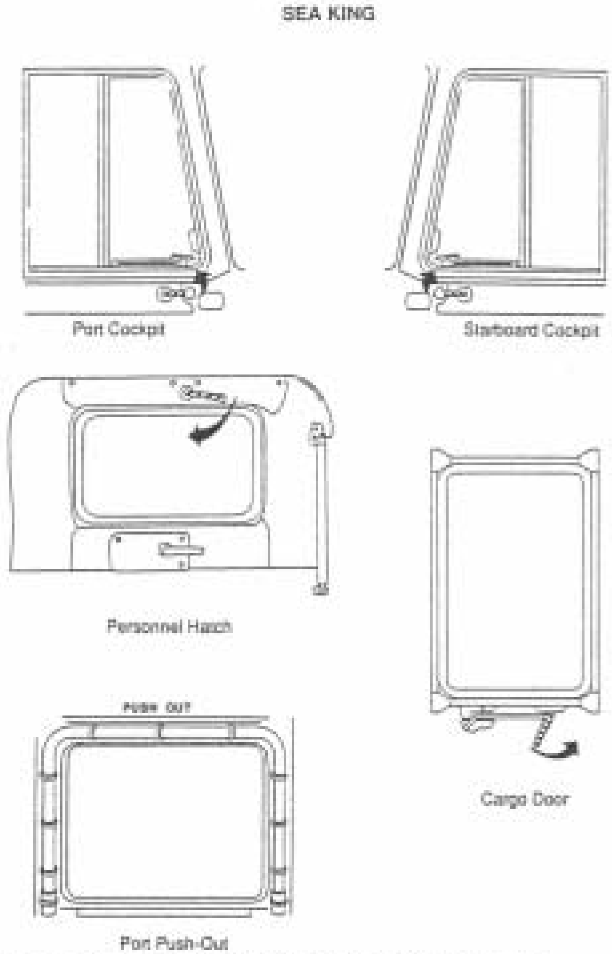

Fig. 2. Hatches and windows in the Sea King helicopter.

RESULTS

Out of 49 aircrew, 48 completed Phase I and experienced a similar level of difficulty as personnel in previous courses. Five percent of pilots and fifteen percent of other aircrew needed extra coaching to become confident and competent in doing an inverted underwater escape from an open hatch. The difference in the rate between the two groups is attributed to greater difficulty of escaping from the positions aft of the cockpit than from the cockpit positions. For the second phase, the 48 aircrew attempted at least 2 escapes using their primary escape route and, wherever possible, 2 escapes using a secondary route for a total of 24 conditions and 298 escapes. The results of the 298 phase II trials are tabulated by aircraft type in Fig. 7. Ten attempts were judged to have been unsuccessful; i.e., would have resulted in a fatality in a true accident. The subjects were using the primary exit in all cases except one.

Sea King

Pilots: Seven pilots attempted two escapes from both the left-hand seat (primary route) and the right-hand seat (secondary route) or vice versa. One pilot attempted an escape through the upper personnel hatch (5

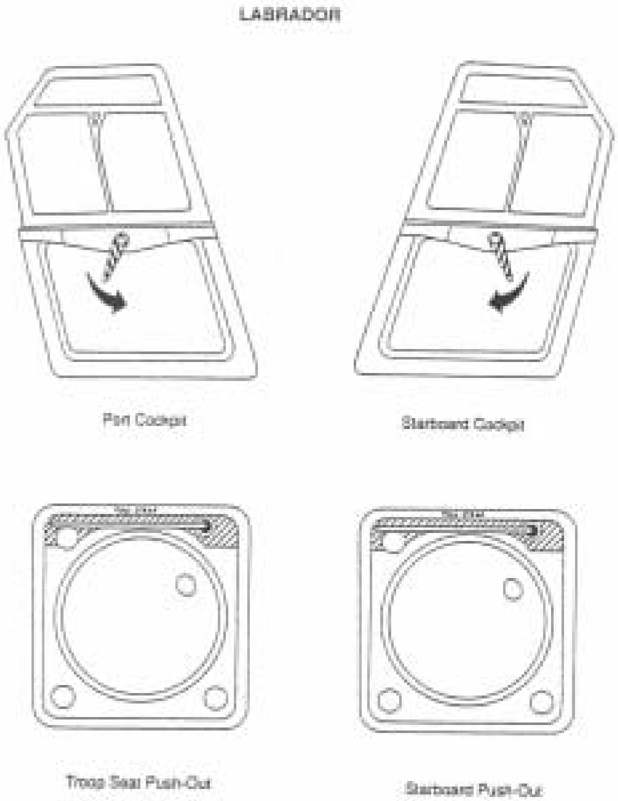

Fig. 3. Hatches and windows in the Labrador helicopter.

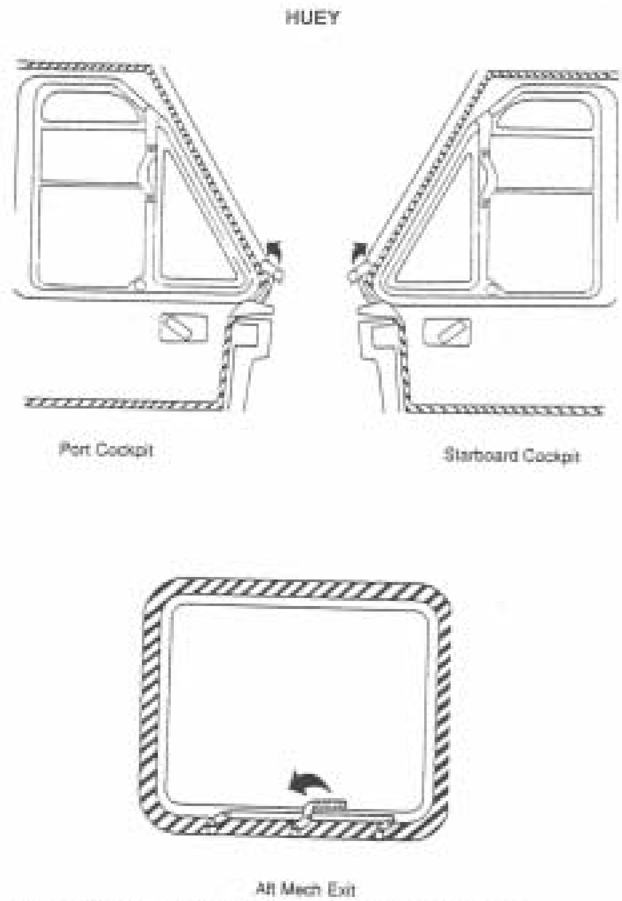

Fig. 4. Hatches and windows in the Huey helicopter.

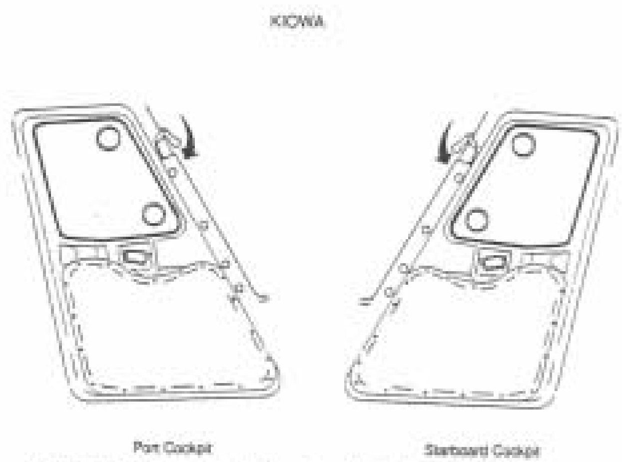

Fig. 5. Hatches and windows in the Kiowa helicopter.

conditions and 58 escapes). All reported no difficulty finding and jettisoning the window using the technique described previously, but the pilot who attempted the escape through the upper personnel hatch found it more difficult because he was not as familiar with its operation. Underwater, two pilots forgot to use the technique that had been taught to locate the lever, and in the first escape, the instructors had to redirect their hand to it. On their questionnaires, they reported no difficulty in location and operation!

Five observations were made by this group. First, it was common for the students to make reversal errors and try to unlock the window by pushing the lever forward (in the opposite direction) rather than pulling it towards them. Second, several people remained in their seat and continued to push on the lever furiously even after the window had jettisoned; the instructors had to direct them to this fact. (In the Sea King, the knob is attached to and remains on the fuselage and does not jettison with the window). Third, the levers operated by their left hand were often more difficult to actuate than the levers operated by their right hand. Fourth, with the window jettisoned, two pins protruded from the upper edge of the window frame and, in underwater (inverted) escapes, snagged every time on clothing around the chest, abdomen and legs of the escapee. This would increase the likelihood of an escape being hung up and drowned, and/or the chance of damage to either or both the lifejacket and immersion suit.

Other aircrew: One Sonar Operator and twelve Airborne Equipment Sensor Operators attempted escapes using the upper personnel hatch as their primary escape route (1 condition and 26 escapes). These crewmen sit athwartship looking outboard to the starboard bulkhead to operate their equipment; their escape hatch is behind and forward of them. It is by far the most difficult of all positions from which to escape because, unlike the pilot's position, their escape hatch is not adjacent to either their left or right hand. In Phase I they had already been taught the best technique to find their way to the escape hatch. Eleven reported finding or jettisoning the

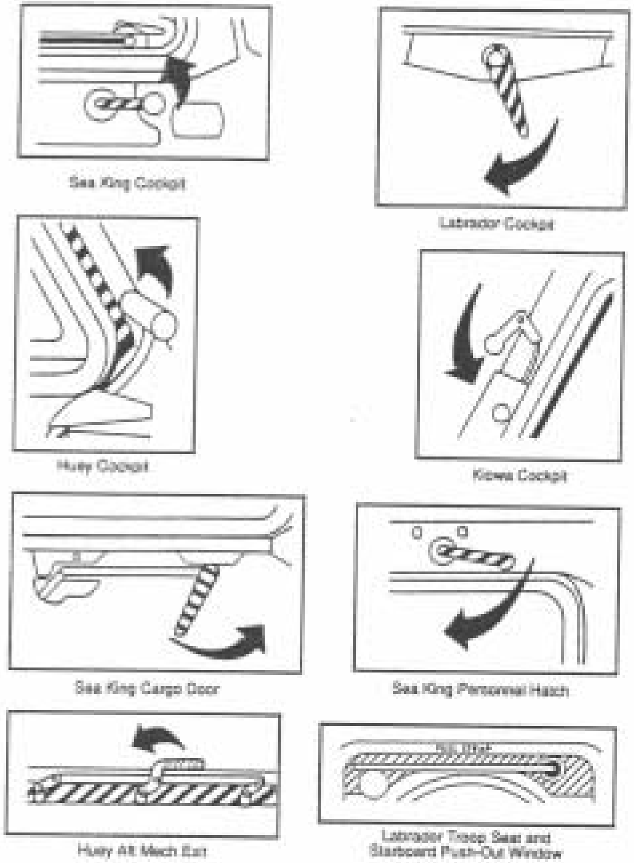

Fig. 6. Mechanisms to jettison hatches or windows in the Sea King, Labrador, Huey, and Kiowa helicopters.

hatch easy and two reported finding and jettisoning the hatch as moderately difficult. The instructors noted that the jettison handle was positioned too high up, so that in the inverted flooded condition, the escapee had to dive down against his buoyancy towards the roof of the helicopter to locate the handle. They also noted that, in the process of trying to rotate the handle, there was a tendency for the escapee to rotate around the handle, increasing disorientation. The two subjects who reported moderate difficulty needed assistance to locate the handle during the first run. On their first run, two others needed assistance in obtaining direction to the hatch; however, on their questionnaires they reported no difficulty in location and operation! One subject specifically reported that it was easier to jettison the hatch because the handle was part of the door, thus confirming that expectancy plays a positive part in the jettison procedure (i.e., that the handle normally jettisons with the hatch).

In addition, 8 AESOP's attempted the following secondary escape routes: 7 through both the port and starboard cockpit windows and 1 through the starboard cockpit window only (2 conditions, 30 escapes). Four subjects reported it was easy, two reported moderately difficult, one reported a mixture of difficult and moderately difficult and one reported difficult (this was the subject who only tried the starboard cockpit window). The reasons given for difficulty were: a) unfamiliarity and tendency to want to pull the lever rather than push it, not having a lever that could be pushed or pulled from a central detent; and b) the need for the handles to be enlarged to improve the grasp underwater, particularly if travelling any distance.

Six of the AESOP's attempted the cargo door (1 condition, 12 escapes). One person reported escape as easy. Four reported moderate difficulty and one reported difficulty. These subjects indicated that it was not easy to locate the release mechanism and, even when the lever was grasped, the hand slipped off it because of the shape of the lever, specifically its much narrower distal end. When underwater there was also no indication as to direction of rotation.

Finally, one AESOP attempted the port push-out window (1 condition and 2 escapes). He was the only subject to attempt to escape from all five routes in the Sea King Helicopter. He reported difficulty with this window because there was no guide to it, and the survivor could quite easily swim by and miss it. He also reported that it was difficult to locate the push-out mechanism for the window because, in fact, it was designed to function without a specific mechanism! A simple push on the center of the window jettisons it outboard and, although it was easy to push-out, it was difficult to escape through it.

Kiowa

Three pilots who normally sit in the right-hand seat attempted escape by both their primary route through the starboard window and their secondary escape route across the cockpit through the port window (2 conditions and 12 escapes). Two observers who normally sit in the left-hand seat attempted escapes by their primary (port window) and secondary (starboard window) routes (2 conditions and 8 escapes). These aircrew were taught a modified technique to locate the forward edge of the door frame which leads up to the handle because the handle is on the frame at the 2 o'clock or 10 o'clock position, respectively. Four out of five subjects reported that the mechanism was easy to operate, but that it was not all that easy to locate (one pilot needed instructor assistance during the first run to locate it, but still reported no problem on his questionnaire). One pilot reported moderate difficulty escaping through both starboard and port windows. He expressed the opinion that the release handle should extend farther out from the frame, so that it was easier to grasp with the gloved hand.

Huey

Twelve pilots attempted escape by both the port (primary) and the starboard (secondary) window or vice versa and one of these pilots made an additional escape by the aft window/door (3 conditions and 98 escapes). Seven of them reported it was easy; four reported moderate difficulty; and one reported difficulty (he required assistance in his first run in both seats to locate the handle). In three cases, the collective interfered with the release lever when escaping from the left-hand seat. In two cases, the direction of pull and shape of the lever were criticized. The pilot that attempted the escape

SEAKING	Starboard Cockpit		Port Cockpit		Personnel Hatch		Cargo Door		Port Push-Out	
	Loc & Op	JETT	Loc & Op	JETT	Loc & Op	JETT	Loc & Op	JETT	Loc & Op	JETT
Pilot 1	○	○	○	○						
Pilot 2	○	○	○	○						
Pilot 3	○	○	○	○	▲	○				
Pilot 4	○	○	○	○						
Pilot 5	○XX	○	○	○						
Pilot 6	○XX	○	○	○						
Pilot 7	○	○	○	○						
SONAR 8					○	○				
AESOP 9					○XX	○				
AESOP 10					○XX	○				
AESOP 11	○	○	○	○	○	○	■	○		
AESOP 12	■	○			○	○	▲	○		
AESOP 13	▲	○	▲	○	○	○	▲	▲		
AESOP 14	▲	▲	▲	▲	○	○	▲	▲		
AESOP 15					○	○				
AESOP 16	○	○	○	○	○	○				
AESOP 17					▲XX	▲	○	○		
AESOP 18	○	○	○	○	○	○	▲	○	■	○
AESOP 19	■	○	▲	○	▲XX	▲				
AESOP 20	○	○	○	○	○	○				

LABRADOR	Starboard Cockpit		Port Cockpit		Starboard Push-Out		Troop Seat Push-Out	
	Loc & Op	JETT	Loc & Op	JETT	Loc & Op	JETT	Loc & Op	JETT
Pilot 44	○	○	○	○				
SAR Tech 45					○	○	○	○
SAR Tech 46					○	○	○	○
SAR Tech 47					○	○	○	○
SAR Tech 48					○XX	▲	○	▲

HUEY	Starboard Cockpit		Port Cockpit		Aft Mech Exit	
	Loc & Op	JETT	Loc & Op	JETT	Loc & Op	JETT
Pilot 26	○	○	○	○		
Pilot 27	○	○	○	○		
Pilot 28	▲	▲	▲	▲		
Pilot 29	▲	○	▲	○		
Pilot 30	▲	▲	▲	▲		
Pilot 31	○	○	○	○	○	○
Pilot 32	○	○	○	○		
Pilot 33	○	○	○	○		
Pilot 34	■XX	■	■XX	■		
Pilot 35	○	▲	○	▲		
Pilot 36	○	○	○	○		
Pilot 37	○	○	○	○		
F.Eng. 38					○	○
F.Eng. 39					○	○
F.Eng. 40					○	○
F.Eng. 41					○	○
F.Eng. 42					○	○
F.Eng. 43					○	▲

KIOWA	Starboard Cockpit		Port Cockpit	
	Loc & Op	JETT	Loc & Op	JETT
Pilot 21	○	○	○	○
Pilot 22	▲	○	▲	○
Pilot 23	○XX	○	○	○
Observer 24	○	○	○	○
Observer 25	○	○	○	○

○ Easy
▲ Moderately Difficult
■ Difficult
XX Needed assistance - considered unsuccessful in real accident

Fig. 7. Performance of 48 aircrew attempting 24 conditions of simulated helicopter underwater escape.

through the aft mechanical window/door thought the mechanism in the METS worked more smoothly than the mechanism in the helicopter.

Six flight engineers attempted escape through the aft window/door (1 condition and 12 escapes). Most reported that it jettisoned easily; one subject commented that the mechanism felt stiff and ratchety, and another indicated moderate difficulty jettisoning it. Contrary to basic and universal principles of escape, it jettisons inwards! The escapees in general had to apply their entire strength to the combined effort to unlatch and pull it in. The force required to overcome water pressure on it in the flooded fuselage, once released, then sent it sailing across the inside of the flooded cabin! This resulted in risk of injury to following escapees who cannot see it coming. For these trials the door was tethered by rope to the inside of the METS before jettisoning to limit its travel, and no other students were allowed to occupy the stern of the underwater escape trainer when this configuration was tested.

Labrador

One pilot attempted escapes from the left seat by both primary (port) and secondary (starboard) routes (2 conditions and 4 escapes). He also used the modified technique to find the lever. He reported that it was easy to operate both port and starboard jettison levers which mount on the center of the portion that jettisons. Four Search and Rescue technicians attempted escapes through both the starboard push-out window and the starboard troop seat push-out window, which are of similar design (2 conditions and 16 escapes). Three technicians reported that it was easy to operate both the pull-out tape and jettison the window and the fourth person reported that a large force was required to jettison it (all were qualified divers). This latter technician needed assistance during the first run to orient him in front of the window, but commented he had no difficulty on his questionnaire!

One of the four technicians reported that it was not easy to find the pull-out tape to release the mechanism that held the window in place, and that the pull-out tape was too long. This was also noted by our instructors. Pulling the tape caused the subject to rotate out of position, thus enhancing disorientation. This group suggested all jettison mechanisms and apertures should be designed alike, so that the escapee does not have to guess what type of escape hatch is in the escape path.

DISCUSSION

Escape from a flooded inverted helicopter is extremely hazardous. Currently, worldwide statistics show that over 30% of crew and passengers may perish during such escape. How much inability to find and jettison the escape hatch contributes to the fatalities is unknown. In this study, 48 aircrew current on 4 different Canadian Air Force helicopters attempted 24 simulated underwater escape routes. Each escape included location, operation and jettison of the windows/hatch and evacuation from the inverted fuselage. The overall results from these trials, while superficially indicating that the task was easy, also revealed many unforeseen problems. The subjects were fit, uninjured professional aircrew, already trained in basic underwater escape, and familiar with their helicopter, who had already been prepared and were ready for the simulated emergency. The ditching was a controlled vertical water entry into still, clear water, with no damage incurred to any of the fuselage. Even under these conditions, in 10 of the 298 escapes, the aircrew needed assistance and would most likely have not survived a true accident.

The size, shape and location of jettison levers may appear to be ergonomically well located, to be the correct size and to rotate or to push/pull in the "right direction" for emergency ground egress; however, buoyancy, disorientation, and an inverted position make otherwise simple operations very difficult indeed. Poor depth perception, magnification effects underwater, and disorientation require great eye-hand coordination and a very strong presence of mind to execute physical actions more than 25 cm ahead of the hand.

These difficulties are exacerbated by the lack of uniformity in placement and operation of the levers. It is clear that helicopter designers have not considered this problem. More specifically, even though the window jettison levers are adjacent to the pilot's side, in four cases, a pilot subject had difficulty locating the handle. They would probably not have managed to escape without assistance unless they had received training. Left-handed operation was more difficult than right-handed operation. Several specific problems with the levers were noted: (a) the Sea King pilot's jettison lever should rotate both forward and aft (in its current form the pilot is prone to make a reversal error); (b) the cargo door handle is tapered the wrong way causing the wet gloved hand to slip off; (c) the jettison handle on the upper personnel hatch is at the highest point of the door and is, thus, the deepest underwater when the helicopter is inverted and free floating, and the subjects tend to rotate around the lever when operating it; and (d) the Kiowa pilot's lever does not allow the gloved hand to fit completely around the lever; thus, it should be set further out from the window frame. The Huey cockpit, unlike the others, has a T-handle that requires pulling in an unnatural direction. It was observed first, that the mechanism is orientated too close to vertical; second, that the lever is not large and easy enough to grasp; and third, that the direction of the pull is not directed towards the pilot. Confusion can also occur when the jettison lever does not match the task and does not push out with the door or window, but remains mounted on the fuselage. This results from the psychological phenomena of expectancy; that is, when turning a knob/lever or handle, the handle is expected to move out or in with the window or door in the direction that it operates.

Solutions require both standardization and improvement to design. All the jettison levers and escape latches throughout the helicopter should be the same shape and size, and be located in the same position. They should be lighted to aid final placement of the hand. For those severely disoriented, levers at the top and bottom are required for all helicopter cockpits; this would be particularly helpful for those flying in the left-hand seat where several instances of interference with the collective were reported. A grab bar installed around the periphery of the escape window or hatch would assist the survivor to overcome water pressure often preventing release, provide mechanical purchase, prevent the tendency to rotate around the levers, and provide positive feedback in the correct direction of escape.

There were mixed opinions among the subjects over the preference of method to jettison their window or hatch and no conclusions could be drawn from their comments. However, the instructors all preferred a simple push-out window which did not use a retaining tape. The principle of a retaining tape on such a window was considered very poor. Under the threat of drowning, mechanical actions made underwater are very deliberate and very forceful. The pull-out tape may require little force to release it in air, but underwater in potentially extreme danger and likelihood of injury, the survivor can't gauge this. The response is all or nothing, and the survivor, for want of a better expression, gives it a furious tug, which certainly unlatches the window. However, because the survivor is free floating in the cabin with no mechanical purchase or means to hold on to anything when he/she pulls the tape, the ultimate result is to spin the survivor around out of position still holding the 25 cm of tape. This only compounds the disorientation problem. It is only with luck that the survivor can re-orient and determine in which direction to proceed to the now open hatch. Paradoxically, the one AESOP who tried the push-out window in the Sea King was noted by the instructors to be feeling around underwater trying to find a mechanism in order to release it, when in fact a simple push on the center of the panel would jettison it. This was again due to expectancy; subconsciously, his basic knowledge of the world told him to look for a lever even though he had been taught that one did not exist. Finally, in the real situation, specifically for this same Sea King push-out window, it is unlikely that anyone could escape through it because a high frequency antenna has been installed across the aperture approximately 1 ft from the fuselage.

The Huey mechanical aft exit jettisons inboard, which is contrary to basic principles of escape. For AESOP's, Sonar Operators, SAR Technicians, and Flight Engineers, without training and/or diving experience, it is unlikely that they could locate and jettison their hatches and then make a successful escape. This study confirms that there has been no standardization of escape hatches/windows and jettison methods.

CONCLUSIONS AND RECOMMENDATIONS

The Survival Systems Ltd. helicopter underwater escape simulator was modified to replicate the windows and hatches of four Canadian Air Force helicopters. This permitted us to conduct what we believe to be the first formal investigation of the problem of location, operation, and jettison of escape windows and hatches following ditching. The following conclusions and recommendations are drawn from the work:

1. There is no standardization of doors/hatches or windows and escape routes. Both primary and secondary routes underwater can be extremely tortuous. Therefore, all aircrew and passengers who fly in helicopters over water for a living must have underwater escape training. The final portion of the course should teach the techniques for locating and jettisoning emergency egress windows and hatches.

2. Inversion, the loss of gravitational references, increased buoyancy with trapped air in the immersion suit, poor depth perception and magnification effects of the water make reaching to grasp a jettison lever underwater very difficult, particularly if it is more than 25 cm from the resting hand position. This must be taken into account in the design of new helicopters.

3. Current levers, even if easily located, can be difficult to operate for the following reasons:

a. there is no standardization, with complete lack of uniformity in shape and placement;

b. they work through pushing, pulling or rotation; hence, they are prone to reversal errors, and there is no obvious indication to the underwater survivor regarding actuating direction, or how much force is required to operate the mechanisms;

c. the direction of pull to activate the mechanisms is often set up at an unnatural angle. If there is any doubt in the survivor's mind whether mechanisms should be pushed, pulled, or rotated, backwards or forwards, then they are not designed to operate both ways from a central detent;

d. the arc or range of action is not obvious to the escapee and may differ, not only between helicopter types, but also between escape hatches in an individual helicopter;

e. attempting to actuate a rotating lever underwater tends to rotate the escapee rather than the mechanism;

f. the shape allows a wet gloved hand to slip off the end of the lever;

g. some levers are fitted too close to the bulkhead to allow the hand to grasp them, and soundproofing material also narrows the space;

h. some mechanisms are positioned at the upper margin of the hatch, which is the deepest part of the cabin underwater when the helicopter is inverted, making the task of diving down to operate the lever very difficult due to immersion suit buoyancy from trapped air;

i. mechanisms do not match the task and do not always depart the fuselage with the window or hatch, leaving the survivors wondering whether their mechanical action has had any effect;

j. for aircrew in the left-hand cockpit seat, there is interference with the collective, and there is no alternative release mechanism;

k. right-handed people have difficulty underwater with left-hand operated levers;

l. none of the escape mechanisms are lighted to aid final location; and

m. some are located too far away for survivors to easily put their hand on them.

4. Irrespective of the type of jettison method, there is not a grab bar around the periphery of the escape hatch which could provide primary anchorage and purchase from which to operate the mechanism and jettison the window or hatch.

5. When the hatch jettisons, there should be no protruding pins in the open aperture which can hang up or snag the clothing or equipment of an escapee.

6. The Huey helicopter aft mechanical exit jettisons inboard, which is contrary to basic principles of escape: all windows or hatches should jettison outboard.

7. No perfect escape hatch appears to have been designed, but a push-out window (with no retaining tape to pull) surrounded by a lighted grab bar appears to be best; this would also eliminate the right-handed/left-handed problem.

8. As this was a preliminary study, a further in-depth study should be conducted to examine the options.

9. The ergonomics of emergency egress in a helicopter underwater, particularly the ability to locate and jettison windows and hatches, does not appear to have been studied.

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