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EASA.2022.C02. HELICOPTER UNDERWATER ESCAPE #2

Helicopter Underwater Escape (HUE2): Summary Report

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Scope

This report is a summary of a study undertaken to address Safety Recommendation (SR) 2016-016 from the UK Air Accident Investigation Branch report AAR 1/2016 (AAIB, 2016) in relation to the accident to helicopter G-WNSB on 23 August 2013. The SR called for a programme of research that would provide realistic data to better support regulations relating to evacuation and survivability of occupants in commercial helicopters operating offshore, quantifying the characteristics of underwater escape under conditions representative of actual offshore operations and passenger demographics.

The work was split into two tasks covering exit operating forces and the time needed for underwater escape.

Task 1 investigated the forces that human test subjects must apply to successfully operate an underwater emergency exit when they are inside a flooded and inverted helicopter cabin. Maximum permissible operating/jettison forces were established for both a lever handle operated Type III exit and a 'push-out' Type IV exit. These forces were compared to the average and individual load limits defined in FAA AC 29.809 (FAA, 2008) and referred to in EASA CS-27 AMC 27.807(d)(b)(8) (EASA, 2023a) and CS-29 AMC 29.809(b)(3) (EASA, 2023b). A detailed report covers the work undertaken in Task 1 (CAAi, 2024a).

Task 2 investigated how long it would take for all the occupants of a helicopter to complete an underwater escape under conditions that were as realistic as possible, with consideration given to modern seating configurations and exits representative of the current European offshore helicopter fleet. The results of Task 2 were used to validate the escape time that has been used as the basis for regulations to underpin the assumptions in the design and operating rules. They were also used to validate the requirements introduced under Amendment 5 to the Certification Specifications for Rotorcraft (CS-27 and CS-29) (EASA, 2018a, b) which are aimed at maximising the likelihood of occupant egress and subsequent survivability in the event of a capsize. A detailed report covers the work undertaken in Task 2 (CAAi, 2024b).

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ABBREVIATIONS

ACRONYM	DESCRIPTION
AAIB	Air Accidents Investigation Branch (UK)
AAR	Aircraft Accident Report
AMC	Acceptable Means of Compliance
CAAi	CAA International (Part of UK Civil Aviation Authority)
CA-EBS	Compressed Air Emergency Breathing Systems
CS	Certification Specification
EASA	European Union Aviation Safety Agency
FAA	Federal Aviation Administration
HOFO	Helicopter Offshore Flight Operations
RFM	Rotorcraft Flight Manual
SR	Safety Recommendation
UK CAA	United Kingdom Civil Aviation Authority

DEFINITIONS

For the purpose of this report the following definitions apply:

TERM	DEFINITION
Ditching	An emergency landing on water, deliberately executed in accordance with RFM procedures, with the intent of abandoning the rotorcraft as soon as practicable.
Double ellipse exit	A large exit providing an unobstructed area that encompasses two ellipses of 0.48 m x 0.66 m (19 in x 26 in).
Handhold	A device provided to facilitate an occupant in generating the opening force required operate an underwater emergency exit.
Helicopter	A rotorcraft that, for its horizontal motion, depends principally on its engine-driven rotors.
Maximum permissible operating force	The highest force required to operate/eject an underwater emergency exit that could be achieved by all members of a group of test subjects representative of the offshore workforce.
Type III exit	A rectangular opening of not less than 0.51 m (20 inches) wide by 0.91 m (36 inches) high, with corner radii not greater than one-third the width of the exit, in the passenger area in the side of the fuselage.
Type IV exit	A rectangular opening of not less than 0.48 m (19 inches) wide by 0.66 m (26 inches) high, with corner radii not greater than one-third the width of the exit, in the side of the fuselage with a step-up inside the rotorcraft of not more than 0.74 m (29 inches).
Underwater emergency exit	An emergency exit designed and installed to facilitate rapid occupant escape from a capsized and flooded rotorcraft.
Water impact	Unintentional contact with water or exceeding the demonstrated ditching capability for water entry.

1. Introduction

1.1 Background

Following the 2013 accident to helicopter G-WNSB on approach to Sumburgh Airport, Shetland, UK, when twelve occupants escaped and survived while four occupants died, the UK AAIB (2016) raised concerns about a lack of research relating to helicopter underwater escape. Those passengers who escaped from the cabin used the escape windows as exits. A number of escape windows were displaced during the initial impact; others were removed by the passengers. The majority of passengers who removed escape windows reported that this "*was not easy and was significantly harder than they experienced during training*". The accident investigators concluded that one of the passengers died as a result of being unable to successfully escape from the cabin. Both crew members had problems locating the door emergency jettison handle and had to resort to using the normal handle to open the doors and escape.

The UK AAIB made a safety recommendation that the European Union Aviation Safety Agency (EASA) should instigate "*a research programme to provide realistic data to better support regulations relating to evacuation and survivability of occupants in commercial helicopters operating offshore. This programme should better quantify the characteristics of helicopter underwater evacuation and include conditions representative of actual offshore operations and passenger demographics*" (Safety Recommendation 2016-016). They were concerned that research undertaken to date, of which they were aware, had been too specific and only investigated certain aspects of escape rather than looking at the escape process as a whole, and that little work had been done which realistically simulated actual offshore operations and passenger demographics.

This led to a review of the published literature relating to helicopter underwater escape research, undertaken by the UK CAA on behalf of the European Union Aviation Safety Agency (Coleshaw & Howson, 2020). This report made recommendations for further research covering gaps and shortfalls in knowledge identified in the published literature. A number of priority areas for further research were proposed. One of the highest-priority recommendations was the establishment of a maximum operating force for underwater emergency exits. A second priority was a study of underwater escape from the passenger cabin with a full complement of passengers and, in particular, the time required to complete an evacuation.

The review of exit operating forces showed that some research work had been undertaken previously using an underwater emergency exit representing a single helicopter type (Taber and Sweeney, 2014; Taber et al, 2017a; Taber et al, 2017b; King et al, 2018). This research had suggested that high forces were required to jettison this type of exit, raising serious concerns regarding the ability of helicopter occupants to operate exits when required. No research on other helicopter types had been published. The research had often involved more than one variable being studied, making it difficult to achieve a clear interpretation of the results relating to operating forces.

The Acceptable Means of Compliance (AMC) to CS-29 and CS-27, at AMC 29.809 (b)(3) iii (EASA, 2023b) and AMC 27.807 (d)(b)(8) iii (EASA, 2023a), state that underwater emergency exits are considered to be non-compliant if the exit does not meet the opening effort limitations set by FAA AC 29.809 (FAA, 2008). This Advisory Circular in turn states at (b)(1) that "*If the effort required to open the exit is in the range of 40 to 50 pounds, it is recommended that a person of slight stature, such as a female in the 90 to 110 pound weight range, be used for the exit opening demonstration/test. In any case, the average load required to operate the exit release mechanism and open the exit should not exceed 50 pounds, and the maximum individual load of a test series should not exceed 55 pounds*".

The above research suggested that the 245 N (25 kg/55 lb) maximum individual load limit to operate a standard over-wing exit in aeroplanes was much lower than the forces required to operate certain helicopter underwater emergency exits. In addition, it was not known whether the 245 N (25 kg/55 lb) maximum individual load limit was appropriate for occupants inside a flooded and inverted cabin. Work was therefore needed to define an acceptable maximum jettison force for underwater emergency exits.

The review of helicopter underwater escape research (Coleshaw & Howson, 2020) identified just one study which investigated the simulated evacuation of a full passenger cabin (Brooks, Muir and Gibbs; 1999, 2001). In this case, a helicopter simulator was configured for 15 and 18 passengers. With the 18-seat configuration and a slow 180˚ capsize, participants took between 43 s and 109 s to escape, with the last person out being underwater for 92 s. Faster escapes were found following a rapid capsize, conducted under light and dark conditions. These trials were all conducted using highly trained rather than naïve test subjects. It is recognised that the most rapid escape times will be achieved by occupants seated next to an underwater emergency exit. Longer escape times will be found if the occupant has to wait for someone else to escape through the exit, if the occupant must cross the cabin or if the occupant has to move longitudinally through the cabin to a different exit row to find an escape route. In 1990, Bohemier et al investigated ease of underwater escape from three different seat positions; escape from a seat across the aisle from the designated exit took a mean time of 49 s while escape following a route that either required the participant to turn to an exit behind the seat, or to move down the fuselage to an exit on the opposite side took 60-62 s. Since then, efforts have been made to ensure that, for the offshore fleet, exits align with seating, and that underwater emergency exits are of sufficient size for large occupants to escape (EASA, 2017, 2023c). It is not known how long it would take for all occupants to escape with modern seating configurations, and representative exits.

AMC1 SPA.HOFO.165(h) for air operation rules relating to helicopter offshore operations (EASA, 2017, 2023c) refers to an expectation that, in the event of capsize, all passengers shall be able to escape from the helicopter within an underwater survival time of 60 s.

While the 60 s escape time criterion being used in the rules corresponds to the time taken for individuals to complete a cross-cabin escape in Bohemier's study (1990), there is a mismatch between this time and the 92 s escape time measured in the Brooks, Muir and Gibbs study (1999; 2001) which measured the time for the last person to escape from a fully occupied helicopter cabin. It is therefore considered important to validate the escape time used as a basis for regulations and ensure that valid assumptions are being made when specifying design and operating rules.

1.2 Aims and objectives of Task 1

The overall aim of Task 1 was to determine the forces that human test subjects must apply to successfully operate an underwater emergency exit when they are inside a flooded and inverted helicopter cabin to establish an appropriate maximum permissible operating/jettison force.

Trials were undertaken using a helicopter simulator, first under 'dry' conditions, followed by further assessments under 'wet' (underwater) conditions. The objectives were to:

- Establish the optimum point of application of force for a real AW189 'push-out' Type IV underwater emergency exit (dry);
- Compare the performance of the real AW189 'push-out' window with the simulated Type IV 'push-out' window (dry);
- Compare the effectiveness of different 'push-out' ejection techniques (hand push, hand strike, elbow strike);
- Establish the maximum permissible operating force for a Type IV 'push-out' underwater emergency exit (dry);
- Establish the maximum permissible operating force for a Type III lever operated underwater emergency exit (dry);
- Determine the worst case seat position (unstroked or stroked) (dry);
- Confirm the optimum location of handholds to aid exit operation underwater;

- Establish the effect of wearing gloves on the exit operating forces;
- Establish the effect of using each hand (or elbow as appropriate) when operating the exit;
- Establish the maximum permissible operating force for a Type IV 'push-out' underwater emergency exit (wet);
- Establish the maximum permissible operating force for a Type III lever operated underwater emergency exit (wet);
- Establish the effect of capsize upon exit operating forces.

1.3 Aims and objectives of Task 2

The overall aim of this study was to determine how long it would take for all the occupants of a submerged helicopter cabin to complete an underwater escape.

Trials were undertaken using a helicopter simulator, with seating configurations and exits representative of the current European offshore helicopter fleet and a group of test subjects representative of the offshore workforce.

The objectives of the research were to:

- Measure the escape time for a full complement of occupants from a capsized helicopter simulator cabin.
- Validate the 60 s escape time for a full helicopter cabin.
- Measure the time for individuals to escape from different seating configurations.
- Determine escape routes and exits used.
- Assess difficulty of escape.
- Consider whether the orientation of a large double ellipse exit ('portrait' versus 'landscape' orientation) influences ease of escape.
- Validate whether two occupants can escape through a large double ellipse exit at one time.
- Determine the effect of blocking certain exits.

2. Summary of Task 1

2.1 Description of work

2.1.1 Overview

A review of helicopter underwater emergency exits was initially undertaken to ensure that the exit designs selected for the experimental work were representative of the European offshore helicopter fleet.

Based on the findings of the review and the requirements within the CS regulations, two designs of exit were simulated for Task 1. They were:

- a 'push-out' Type IV exit with the dimensions 0.48 m x 0.66 m (19 in. x 26 in.);
- a lever operated Type III exit with the dimensions 0.51 m x 0.91 m (20 in. x 36 in.).

A load cell was used to measure exit operating forces.

Representative seating was fitted with a four-point harness, with the possibility for some seating to be in a fully stroked position with the seat base 250 mm lower than the standard seat or at an intermediate (50 % stroked) position.

Trials were run by the Fleetwood Test Laboratory. The trials were performed at the helicopter underwater escape training facilities of Blackpool and The Fylde College, at their Fleetwood Nautical Campus. Their helicopter simulator was modified slightly to allow the required exits and seating to be fitted.

Test subjects covered a range of sizes similar to those required by the technical standards for rotorcraft constant wear lifejackets (EN 4862 (CEN, 2023a)) and immersion suits (EN 4863 (CEN, 2023b)), with one additional 'large' size category subject.

A series of trials were devised, initially under dry conditions followed by further wet execises with the helicopter submerged but not inverted. These were followed by wet exercises with a capsize immediately prior to exit operation. The general approach taken when measuring exit operating forces was to start at or above the maximum force defined in AMC 29.809 (b)(3) iii (EASA, 2023b) and AMC 27.807 (d)(b)(8) iii (EASA, 2023a) and then make staged reductions until all the test subjects were able to operate the exit.

2.1.2 Dry trials

The optimum point of application of force for each Type IV exit was first established. This was undertaken using three jettison techniques, a hand push, a hand strike and an elbow strike, applied to a real AW189 Type IV exit fitted in the helicopter simulator. Three test subjects were asked to apply force to the exit at the following locations:

- lower corner;
- halfway along short side;
- halfway along long side;
- in the middle of the window.

The experiment was then repeated using the simulated Type IV exit, set up to have the same operating force as the AW189 exit at the optimum point of application for the hand push technique (lower corner). The results were compared with those using the real AW189 exit to demonstrate that they were representative.

Maximum permissible operating forces for the simulated Type IV (push-out) exit were then established, using the optimum point of application established in the previous exercise, using each of the three jettison techniques in both the unstroked and stroked seat position. Similarly, the maximum permissible operating forces for the simulated Type III lever exit were established, reducing the operating force until all test subjects were able to jettison the exit.

2.1.3 Wet trials

For the wet trials, a handhold was located near to the lower corner of each exit.

Maximum permissible operating forces for the simulated Type IV (push-out) exit and Type III lever exit were established. Using the three different jettison techniques, the exit was operated first with the test subject in the worst case stroked seat, and then free-floating in the cabin (moving to the exit from the opposite side of the submerged cabin) both with and without use of the handhold. These exercises were undertaken with and without gloves and in both forward and rear facing seats to assess use of the opposite hand or elbow.

A final series of exercises was completed with operation of the exits attempted immediately following capsize of the helicopter simulator, using the worst case (lowest) operating forces previously established, to determine whether inversion affected the maximum permissible operating force.

2.2 Results

2.2.1 Test subjects

Eighteen test subjects took part in the Task 1 'dry' trials, aged from 16 to 71 years. Height ranged from 1.54 m up to 1.91 m, while weight ranged from 55 kg to 123 kg. Nine test subjects took part in the wet trials. Three (small, medium and large) test subjects participated in the AW189 exit comparison. These three subjects did not participate in the dry or wet trials.

2.2.2 Dry trials

Pilot trials identified that the test subjects were unable to apply force to the nearest lower corner of the exit as it was too close to the person. As a result, with the exit to the left of the body, test subjects were asked to apply force to the far lower corner (hand push) and far side of the window (hand strike) with their right hand and use their left elbow for the elbow strike. Some test subjects were then unable to reach the required point of application with the four-point harness secured. The trials were therefore undertaken with a two-point waist harness only.

For the AW189 exit, when using the hand push technique, the lowest operating forces were found at a point halfway along the long side of the exit window and at the corner of the exit. For the hand strike technique the lowest operating forces were measured when applied to the lower corner. For the elbow strike technique the lowest operating forces were measured when applied to the point halfway along the long side of the exit. Overall, operating forces measured using the hand push technique were significantly lower than those measured when either the hand strike or elbow strike technique was used. This was the case for both the AW189 exit and the simulated Type IV exit. The variability of the results was much higher for the hand and elbow strike techniques. It was considered much more difficult for the test subjects to control the force applied with a strike, so in many cases the force applied was likely to be higher than the force needed to jettison the exit. There was also concern that the load cell was measuring the force applied as opposed to the minimum force needed to jettison the exit.

When assessing the maximum permissible operating force for the simulated Type IV exit (i.e. the highest operating force where all test subjects could successfully jettison the exit), exercises started with the exit set at an operating force of 299 N (31 kg/67 lb). At this operating force, all test subjects were able to successfully operate the exit when using the hand strike and elbow strike techniques at the optimum points of application, from the unstroked and stroked seat positions. Table 2-1 shows that a lower maximum permissible operating force of 204 N (21 kg/46 lb) was measured when test subjects operated the exit using a hand push. For a given operating force, there were more failures when operating the exit from the stroked seat position. At an operating force of 204 N (21 kg/46 lb) all test subjects were able to operate the exit from the unstroked seat. At this operating force, five test subjects were still unable to operate the seat from the stroked seat position, but were able to operate the exit when the degree of stroking was reduced to 50 %. These test subjects came from the lower size categories who would have been much less likely to experience full stroking of the seat in a real helicopter impact accident.

Table 2-1 Dry trials: Maximum permissible operating forces for the Type IV exit

Operating technique	Operating condition	Maximum permissible operating force	Less than 245 N limit*
Hand push	**Unstroked seat**	**204 N (21 kg/46 lb)**	**Yes**
Hand strike	Unstroked seat	> 299 N (31 kg/67 lb)	No
Elbow strike	Unstroked seat	> 299 N (31 kg/67 lb)	No
Hand push	**100 % or 50 % stroked seat****	**204 N (21 kg/46 lb)**	**Yes**
Hand strike	Stroked seat	> 299 N (31 kg/67 lb)	No
Elbow strike	Stroked seat	> 299 N (31 kg/67 lb)	No

* The current AMC to CS-29 and CS-27 states: "*the average load required to operate the exit release mechanism and open the exit should not exceed 50 pounds* [23 kg/222 N]*, and the maximum individual load of a test series should not exceed 55 pounds* [25 kg/245 N]".

*** As appropriate for the test subject.*

For the Type III exit, the lowest maximum permissible operating force was found when the exit was operated with the left hand from a fully stroked or 50% stroked seat (Table 2-2).

Table 2-2 Dry trials: Maximum permissible operating forces for the Type III exit

Operating technique	Operating condition	Maximum permissible operating force	Less than 245 N limit*
Right hand	Unstroked seat	> 236 N (24 kg/53 lb)	Yes
Left hand	Unstroked seat	209 N (21 kg/47 lb)	Yes
Right hand	Stroked seat	> 236 N (24 kg/53 lb)	Yes
Left hand	**100 % or 50 % stroked seat****	191 N (19 kg/43 lb)	Yes

* The current AMC to CS-29 and CS-27 states: "*the average load required to operate the exit release mechanism and open the exit should not exceed 50 pounds* [23 kg/222 N]*, and the maximum individual load of a test series should not exceed 55 pounds* [25 kg/245 N]".

*** As appropriate for the test subject.*

Based on the exercises using the left hand, when comparing the two seat positions, operation of the exit from the stroked seat position was found to be the worst case across the range of forces assessed.

2.2.3 Wet trials

These exercises were conducted with the helicopter simulator fully submerged but upright, using a stroked seat as the worst case from the dry trials, and a two-point harness to secure the test subjects. The far lower corner was used as the optimum point of application of force for the hand push and hand strike exercises, while the point halfway along the near long side of the exit was used as the optimum point of application of force for the elbow strike exercises.

Table 2-3 shows that, for a Type IV exit from a stroked seat, the lowest maximum permissible operating force was found when test subjects used the hand push technique, while the highest maximum permissible operating force was found when test subjects used the elbow strike technique. Slightly lower forces were achieved by all on the opposite side of the cabin, i.e. when using the opposite hand or elbow. When free-floating and moving across the cabin to operate the exit, test subjects had few problems when operating the exit while holding onto the handhold. Lower maximum permissible operating forces were found when a handhold was not available. Test subjects found that, without any points of contact after leaving the seat, on releasing the harness there was an immediate tendency for buoyancy to cause them to float upwards and away from the exit. This prevented them from applying force to the exit. In some cases, sufficient momentum was achieved by pushing away from the seat to reach the exit. Some test subjects, but not all, who were unable to operate the exit unaided by the handhold, did achieve a successful jettison when holding onto the seat back. Some cases were seen when the test subject pushed their feet against the helicopter simulator frame to apply force and eject the exit. These results were rejected.

Table 2-3 Wet trials: Maximum permissible operating forces for the Type IV exit

Operating technique	Operating condition	Maximum permissible operating force	Less than 245 N limit*
Hand push	**Stroked seat (forward-facing)**	**190 N (19 kg/43 lb)**	**Yes**
Hand strike	**Stroked seat (forward-facing)**	**206 N (21 kg/46 lb)**	**Yes**
Elbow strike	Stroked seat (forward-facing)	> 293 N (30 kg/66 lb)	No
Hand push	**Stroked seat (rear-facing)**	**180 N (18 kg/40.5 lb)**	**Yes**
Hand strike	**Stroked seat (rear-facing)**	**180 N (18 kg/40.5 lb)**	**Yes**
Elbow strike	Stroked seat (rear-facing)	> 291 N (30 kg/65 lb)	No
Hand push	Cross-cabin/free-floating/ with handhold	> 293 N (30 kg/66 lb)	No
Hand strike	Cross-cabin/free-floating/ with handhold	273 N (28 kg/61 lb)	No
Elbow strike	Cross-cabin/free-floating/ with handhold	> 293 N (30 kg/66 lb)	No
Hand push	**Cross-cabin/free-floating/ without handhold**	**190 N (19 kg/43 lb)**	**Yes**
Hand strike	**Cross-cabin/free-floating/ without handhold**	**231 N (24 kg/52 lb)**	**Yes**
Elbow strike	Cross-cabin/free-floating/ without handhold	273 N (28 kg/61 lb)	No

* The current AMC to CS-29 and CS-27 states: "*the average load required to operate the exit release mechanism and open the exit should not exceed 50 pounds* [23 kg/222 N]*, and the maximum individual load of a test series should not exceed 55 pounds* [25 kg/245 N]".

*** As appropriate for the test subject.*

With the Type III exit, wet exercises were conducted with both the right and the left hand, both with and without gloves. All were conducted using a stroked seat. Table 2-4 shows that, from a forward-facing stroked seat, with the exit to the left of the test subject, the maximum permissible operating force was 156 N (16 kg/35 lb) both with and without gloves, well below the FAA 245 N limit. Similar results were found when the test subjects were free-floating and operating the exit with gloves. Without the use of gloves a higher maximum permissible operating force was found, although this was still lower than the 245 N limit.

Table 2-4 Wet trials: Maximum permissible operating forces for the Type III exit

Operating technique	Operating condition	Maximum permissible operating force	Less than 245 N limit*
Right hand	Stroked seat (forward-facing) - without gloves	156 N (16 kg/35 lb)	Yes
Left hand	Stroked seat (forward-facing) - without gloves	156 N (16 kg/35 lb)	Yes
Right hand	Stroked seat (rear-facing) - without gloves	199 N (20 kg/45 lb)	Yes
Left hand	Stroked seat (rear-facing) - without gloves	154 N (16 kg/35 lb)	Yes
Right hand	Stroked seat (forward-facing) - with gloves	156 N (16 kg/35 lb)	Yes
Left hand	Stroked seat (forward-facing) - with gloves	156 N (16 kg/35 lb)	Yes
Right hand	Cross-cabin/free-floating/with handhold - without gloves	179 N (18 kg/40 lb)	Yes
Left hand	Cross-cabin/free-floating/with handhold - without gloves	179 N (18 kg/40 lb)	Yes
Right hand	Cross-cabin/free-floating/with handhold - with gloves	156 N (16 kg/ 35 lb)	Yes
Left hand	Cross-cabin/free-floating/with handhold - with gloves	156 N (16 kg/ 35 lb)	Yes
Right hand	Cross-cabin/free-floating/without handhold - without gloves	179 N (18 kg/40 lb)	Yes
Left hand	Cross-cabin/free-floating/without handhold - without gloves	156 N (16 kg/35 lb)	Yes
Right hand	Cross-cabin/free-floating/without handhold - with gloves	156 N (16 kg/35 lb)	Yes
Left hand	Cross-cabin/free-floating/without handhold - with gloves	156 N (16 kg/35 lb)	Yes

* The current AMC to CS-29 and CS-27 states: *"the average load required to operate the exit release mechanism and open the exit should not exceed 50 pounds* [23 kg/222 N]*, and the maximum individual load of a test series should not exceed 55 pounds* [25 kg/245 N]".

*** As appropriate for the test subject.*

2.3 Key outcomes

- Similar behaviour was observed with the AW189 aircraft Type IV exit and the simulated Type IV exit; the simulated Type IV exit was consequently considered to be sufficiently representative.
- The optimum point of application of force when using the hand push or hand strike technique was found to be the lower corner of the exit.
- The optimum point of application of force when using the elbow strike technique was found to be halfway along the long side of the exit.
- Maximum permissible operating forces were established for a Type IV push-out underwater escape exit under dry and wet conditions, using three operating techniques (hand push, hand strike and elbow strike) and the corresponding optimum points of application of force.
- The maximum permissible operating forces established take account of any differences between operation e.g. with the left and right hands, with/without gloves, seat position, i.e. where there was a difference, the lower force is adopted.
- The maximum permissible operating force established for a Type IV push-out underwater escape exit under wet conditions, using the hand push and hand strike techniques, of 180 N (18 kg/ 40.5 lb), was lower than the maximum average and individual load limits defined in FAA AC 29.809 (FAA, 2008) and referred to in EASA CS-27, AMC 27.807(d)(b)(8) and CS-29, AMC 29.809 (EASA, 2023a,b) of 222 N (23 kg/50 lb) and 245 N (25 kg/55 lb) respectively.
- The maximum permissible operating force established for a Type IV push-out underwater escape exit under wet conditions, using the elbow strike technique, of 273 N (28 kg/61 lb), was higher than the maximum average and individual load limits defined in FAA AC 29.809 (FAA, 2008) and referred to in EASA CS-27, AMC 27.807(d)(b)(8) and CS-29, AMC 29.809 (EASA, 2023a,b) of 222 N (23 kg/50 lb) and 245 N (25 kg/55 lb) respectively.
- The elbow strike exit operating technique (resulting in dynamic loading) is recommended as the means of operating a Type IV push-out exit in a capsized and/or submerged helicopter in the interests of maximising the probability of successful operation. In this case, the appropriate location for a decal marking the point of application of operating force would be halfway along the vertical edge of the exit.
- The hand push exit operating technique (resulting in static loading) is recommended as the operating technique of choice for certification testing in the interests of controllability and repeatability. In this case, the appropriate location for a decal marking the point of application of operating force would be a lower corner of the exit.
- Maximum permissible operating forces were established for a Type III lever operated underwater escape exit under dry and wet conditions. The maximum permissible operating forces established for the wet condition were lower than in dry conditions.
- The maximum permissible operating force established for a Type III lever operated underwater escape exit under wet conditions of 154 N (16 kg/ 35 lb) was lower than the maximum average and individual load limits defined in FAA AC 29.809 (FAA, 2008) and referred to in EASA CS-27, AMC 27.807(d)(b)(8) (EASA, 2023a) and CS-29, AMC 29.809 (EASA, 2023b) of 222 N (23 kg/50 lb) and 245 N (25 kg/55 lb) respectively.
- It is recommended that ’wet’ values for maximum permissible operating forces be used for certification. The ‘wet’ values are clearly more representative of the real world scenario and are also lower than the ‘dry’ values and therefore conservative.
- Exit handholds were found to be of significant benefit in assisting the operation of Type IV push-out exits when the test subject was not secured by a harness.

- The optimum position for an exit handhold may vary with helicopter design, but should be accessible to a person who is free-floating underwater in the capsized helicopter to help overcome buoyancy forces, supporting the guidance given in AMC 29.809 (EASA, 2023b).
- The use of gloves did not have any significant effect on the maximum permissible exit operating force. This aspect was only evaluated for the Type III lever operated exit.
- Inversion did not increase the difficulty of operating either type of exit.
- Consideration should be given to reducing exit operating forces in CS-27 and CS-29 and the associated AMC 27.807 (d)(b)(8) iii and AMC 29.809 (b)(3) iii (EASA, 2023a; EASA, 2023b) for push out exits where the hand push or hand strike techniques are intended to be used. Alternatively, occupants should be instructed to use the elbow strike technique.
- Consideration should be given to reducing exit operating forces in CS-27 and CS-29 and the associated AMC 27.807 (d)(b)(8) iii and AMC 29.809 (b)(3) iii (EASA, 2023a; EASA, 2023b) for lever operated exits.

3. Summary of Task 2

3.1 Description of work

A review of passenger seating layouts was undertaken to ensure that the seating layouts used in this study were representative of the European offshore helicopter fleet. It was found that in some cases, a single seat was found next to an exit on one side of the cabin, while in many other cases two seats served each exit, with a maximum of four seats in a row across the cabin. A single row of four seats was either made up of four seats in a row or two sets of two seats with an aisle space between. These different configurations were included in the seating layouts used for the full cabin escape trials.

Trials were run by the Fleetwood Test Laboratory. A full risk assessment was undertaken before conducting the trials. Ethical approval was gained from the Blackpool and Fylde College Ethics Committee.

Test subjects covered a range of sizes similar to those required by the technical standards for rotorcraft constant wear lifejackets (EN 4862 (CEN 2023a)) and immersion suits (EN 4863 (CEN 2023b)), with one additional 'large' subject size category. Effort was made to ensure that the selected subjects covered a wide range of ages (representative of the offshore workforce). Test subjects wore an immersion suit system similar to those used by members of the UK offshore workforce, fitted with an approved Category A compressed air emergency breathing system (CA-EBS).

Large exit validation trials were conducted to determine whether two occupants (with shoulder widths greater than 500 mm) could escape through a large double ellipse exit with the dimensions of 0.66 m x 0.96 m (26 in x 38 in), as described in AMC1 29.807(d)(b)(3) (EASA, 2018b). This aperture is larger than the minimum size of 0.51 m x 0.91 m (20 in x 36 in) for a Type III exit. This assessment was undertaken with the exit in two orientaions, 'portrait' and 'landscape', with ease of escape assessed in each case.

In preparation for the full cabin escape trials, seating arrangement trials were undertaken, where time to escape was measured with test subjects seated in the range of different configurations established by the seating review (all seats unstroked). A combination of simulated Type III, large double ellipse and Type IV exits were used in the helicopter simulator, with pull-out strips simulated around the exits. The optimum jettison technique identified in Task 1 (CAAi, 2024a) for the Type IV exit (elbow strike) was used, and the exits were set to the corresponding maximum permissible operating force.

For the full cabin escape trials, the helicopter simulator was fitted with seating for thirteen test subjects in the cabin; one row of four seats at the front on the cabin facing back and three rows of 2+1 seats facing forwards. Four of the seats were fitted in a stroked position. An additional four test subjects were positioned at the back of the cabin, who were instructed to move into the cabin as soon as possible after inversion or capsize and escape through any available exit. This gave a total compliment of 17 test subjects. Test subjects were instructed to deploy their EBS prior to submersion. The time that could have been taken to deploy the EBS underwater was taken into account when analysing full cabin escape times.

Three full cabin exercises were undertaken; a submersion, a capsize and a capsize with the forward port-side Type III exit blocked.

The trials were conducted in light conditions to allow filming of the escape process. No attempt was made to undertake the trials in dark conditions due to safety concerns.

3.2 Results

3.2.1 Large exit validation

Two sets of two large test subjects, all with shoulder widths ≥ 500 mm, were able to successfully escape simultaneously through the large double ellipse exit in both the landscape and portrait orientations. In each case, the escape process was not considered to have been hindered by the size of this exit.

Three out of the four subjects reported that the escape through the exit in the portrait orientation was more difficult than escape through the exit in the landscape orientation. This was largely due to the buoyancy of the test subjects and the challenge of getting into position with one on top of the other while undertaking the simultaneous escape.

3.2.2 Seating arrangement trials

Tables 3-1 and 3-2 summarise the data for the mean time for the last subject to escape from each seating configuration, equivalent to the total escape time for each seating configuration.

Comparing the first and third rows in Table 3-1, it took approximately 25 to 32 seconds on average for test subjects to escape from their nearest exit where each two subjects had a single exit available for use (two subjects escaping through one exit and four subjects escaping through two exits). Comparing the second row in Table 3-1 where the port exit was blocked, with the first row, it took approximately 8 to 10 seconds for an additional subject to cross the cabin and escape from the same exit (three subjects escaping through one exit).

Table 3-1 Summary of time to escape from a single row of seats

Seating configuration	Total escape time Mean ± SD (s) (without handhold)	Total escape time Mean ± SD (s) (with handhold)
Single row, 2 subjects, 1 Type IV exit	25.2 ±5.9	26.4 ± 6.0
Single row, 3 subjects, 1 Type IV exit	34.8 ± 4.4	34.8 ± 4.4
Single row, 4 subjects, 2 Type IV exit	32.5 ± 5.0	28.3 ± 5.0

The first three rows of Table 3-2 show that test subjects took a mean time of between 35 seconds and 40 seconds to escape from a double row of seats, with seats facing each other in a 'club' configuration. This is longer than the mean time to escape from a single row of seats (Table 3-1). While the double ellipse exit was large enough for two subjects to escape simultaneously this was not seen under trial conditions, with subjects tending to escape through the exit in turn. Following capsize in a real water impact accident it is more likely that occupants would attempt to compete and escape simultaneously.

The mean escape time of 30 seconds for the layout comprising two rows of three seats in 2+1 configuration (six test subjects) is within the range of 25 to 32 seconds measured for two subjects using a single exit as would be expected.

The final double seating configuration assessed was one row of three seats in 2+1 configuration and one row of four seats across the cabin, all facing forwards. It took a mean time of 31 s for the 7 test subjects to escape through the two Type IV exits in the runs without a handhold available. In the two runs when a handhold was present the mean time for all 7 test subjects to escape was 39 s. One subject in an aisle seat had problems releasing the harness and received help from a safety diver before making his escape. This subject took 49.5 seconds to escape, having a significant effect on the mean time for the last person to escape (two runs).

In this case, the time for the 6th test subject to escape was 27.8 seconds, while the 7th test subject escaped in 27.9 seconds in the second run.

Table 3-2 Summary of time to escape from a double row of seats

Seating configuration	Total escape time Mean ± SD (s) (without handhold)	Total escape time Mean ± SD (s) (with handhold)
Double row (club), 4 subjects, 1 Type III (double ellipse) exit	38.8 ± 7.0	-
Double row (club), 6 subjects, 2 Type III (1 double ellipse) exits	35.5 ± 2.7	36.0 ± 1.1
Double row (club), 8 subjects, 2 Type III (1 double ellipse) exits	39.9 ± 3.1	37.8 ± 2.7
Double row, 6 subjects, 4 Type IV exits	29.6 ± 2.1	35.5 ± 7.1
Double row, 7 subjects, 4 Type IV exits	30.7 ± 0.8	38.7 ± 15.3

3.2.3 Full cabin escape trials

Different seating plans were used for each of the full cabin escape trials. Figure 3-1 shows the helicopter simulator fully loaded with test subjects immediately before the submersion trial took place. The additional test subjects can be seen at the rear of the cabin, ready to enter the cabin once the simulator was submerged.

Figure 3-1 Helicopter simulator loaded with test subjects prior to the 'submersion' trial

Under the conditions of this study, the escape of 17 individuals from a submerged but not inverted helicopter cabin took 35 seconds. The escape of 17 individuals from an inverted helicopter cabin took 65 seconds (first capsize). With one exit blocked, it took a little longer, 70 seconds, for all the occupants to escape.

If the first full cabin capsize is considered, the last seated test subject to leave the cabin took 51.3 seconds to escape (this particular test subject had some problems releasing their seat belt before they were able to escape). It therefore took an additional 13.8 seconds for the four test subjects who had entered from the rear of the cabin to escape, moving between the aisle seats one-at-a-time, and in some cases having to wait for others to escape. Similarly, in the second capsize exercise, with a Type III exit at the front of the cabin blocked, the last seated test subject to leave the cabin took 51.5 seconds to escape. In this case it took an additional 18.7 seconds for the four test subjects who had entered from the rear of the cabin to escape. Aisle width was reported to have hindered their escape. This suggests that the total time for all occupants to escape will be increased if any occupants need to move along the cabin to a different seat row to make their escape.

There were a number of instances where individuals had problems releasing their seat harness, delaying their escape. This was considered realistic and is likely to be observed in a real accident.

Another factor that slowed the escape of some individuals, was found to be waiting in turn to escape through their nearest exit, particularly in the second capsize with the blocked exit. This wait was noted to have been mitigated by the use of EBS which allowed the test subjects to stay calm and allowed them the time to wait rather than competing to escape. It is unlikely that helicopter occupants in a real accident, with poor visibility, would remain so calm even with EBS.

Test subjects were instructed to deploy their EBS prior to submersion. In a water impact accident resulting in immediate capsize, the EBS would most likely be deployed underwater following inversion but prior to escape. The time taken to deploy EBS underwater must therefore be taken into account when estimating the time needed to escape. The mean time to deploy this particular design of EBS in air is 7.4 ± 1.4 seconds (Coleshaw, 2013). The European technical standard for EBS (CEN, 2023c) requires approved EBS to be fully deployable using one hand in 12 seconds, while it must be possible to deploy the mouthpiece in 10 seconds (any nose clip may or may not be deployed). If the 10 second deployment time is used for underwater deployment, then the escape times measured in the current research should be increased by 10 seconds to allow for underwater deployment of EBS prior to escape.

The use of EBS during these trials provided noticeable benefits to the test subjects, with few signs of panic. Test subjects were seen to take their time to escape, in some cases waiting for others to escape before releasing their seat harness and moving to the exit.

When considering helicopter operations not covered by the offshore operation regulations, undertaken over water at temperatures below 15˚C, the risk of drowning due to the breath-hold/escape time mismatch is likely to be increased considerably if EBS is not carried by the occupants. This risk could be mitigated by ensuring that all occupants are sat immediately next to an openable underwater emergency exit, i.e. middle seats are not occupied. An air pocket within the passenger cabin (Dart, 2024; EASA, 2016) could also mitigate this risk.

3.3 Key outcomes

- In the event of capsize, an underwater escape time of 60 seconds is considered to be appropriate for escape under good environmental conditions without any of the required underwater emergency exits blocked. This is based on the full cabin escape times recorded for seated occupants only of 51 seconds.
- The blocked exit increased overall escape time.
- Escape times were also increased by the test subjects entering from the back of the cabin, and by test subjects who either forgot to release their seat harness or had problems when attempting to release their seat harness.
- Seating arrangements with a maximum of two individuals escaping from one exit resulted in rapid escape times.

- An exit which provides an unobstructed area that encompasses two ellipses of 0.48 m x 0.66 m (19 in. x 26 in.) is large enough to permit the simultaneous egress of two broad shouldered passengers.
- The use of compressed air EBS allowed the test subjects to stay calm and escape without signs of panic. An underwater deployment time of up to 10 seconds would have maintained the full cabin escape time close to the suggested 60 seconds (51 seconds + 10 seconds).
- Where provided, the width of any aisle will affect the difficulty of escape for passengers having to move between rows due to a blocked exit(s).

4. Review of Regulations and Associated Material

Table 4-1 provides a summary of the review of the suitability of the relevant current CS 27, CS 29 and CS 26 requirements and associated AMC material and air operating regulations (HOFO) based on the analysis of the trials.

Table 4-1 Suitability of relevant current Regulations and associated AMC material

Regulation	Current requirement	Suitability of current CS-27 and CS-29 requirements and associated AMC material
Exit operating forces		
CS-27: AMC 27.807 (d)(b)(8) iii CS-29: AMC 29.809 (b)(3) iii	"*Designs with any of the following characteristics (non-exhaustive list) are considered to be non-compliant: ….* *(iii) the exit does not meet the opening effort limitations set by FAA AC 29.809*".	The 222 N and 245 N average and individual load limits (FAA, 2008) found in the current regulations were higher than the forces that could be achieved by some individuals (representative of the user population) when attempting to operate an underwater emergency exit inside a submerged and inverted helicopter cabin under a range of conditions. If the hand-push technique is used for the certification testing of openable ('push-out') exits, then a load limit of 180 N would be needed to cover all conditions and passenger sizes. In the case of lever operated exits, a load limit as low as 154 N would be required to ensure that all occupants are able to operate such an exit underwater. A number of regulatory options are possible: 1. Lower the maximum operating force limits as appropriate below those defined in FAA AC 29.809 (FAA, 2008), in line with the maximum permissible operating forces measured in this study. 2. Maintain the current operating force limits, accept the risk but provide mitigation. For some operations such as offshore oil & gas support flights, this could take the form of operational restrictions such as requiring a minimum size/weight of occupants sitting next to an exit (see section 8.1 of the Task 1 report (CAAi, 2024a)). For 'push-out' exits only, one option could be for occupants to use an elbow or hand strike action to jettison the exit. 3. Maintain the current operating force limits, accept the risk but provide no mitigation.
FAA AC 29.809 (FAA, 2008)	"*In any case, the average load required to operate the exit release mechanism and open the exit should not exceed 50 pounds* [23 kg/222 N]*, and the maximum individual load of a test series should not exceed 55 pounds* [25 kg/245 N]".	

Regulation	Current requirement	Suitability of current CS-27 and CS-29 requirements and associated AMC material
		Option 1 is preferred as it could increase the likelihood of survival in a post ditching capsize or water impact accident, without the need for any operational interventions (Option 2). Option 3 would not offer any improvement in survivability.
Exit handholds		
CS 27.807(d)(3) CS 29.809(j)(3) AMC 29.809(b)(5) AMC 29.809(a) (Also covered by AMC 27.807(d)(b)(7))	"*… each underwater emergency exit must meet the following: … a suitable handhold, or handholds, adjacently located inside the cabin to assist passengers in locating and operating the exit, as well as in egressing from the exit, must be provided*". "*Handholds, as required by CS 29.809(j)(3), should be mounted close to the bottom of each underwater emergency exit such that they fall easily to hand for a normally seated occupant*". "*Openable windows might require an appreciable pushing force from the occupant. When floating free inside a flooded cabin, and perhaps even if still seated, generation of this force may be difficult. An appropriately positioned handhold or handholds adjacent to the underwater emergency exit(s) should be provided to facilitate an occupant in generating the opening force. Additionally, in the design of the handhold, consideration should be given to it assisting in locating the underwater emergency exit*	For Task 1 and 2 trials, handholds were provided (as appropriate) close to the bottom of each simulated Type IV exit and the simulated Type III exit in accordance with the AMC guidance. It was noted that by positioning the handholds close to the bottom of each exit, there was potential for the handhold to obstruct the knees of a seated passenger, requiring some adjustment of the handhold position. Task 1 demonstrated that, when handholds were provided and used, test subjects were able to apply higher forces to operate a Type IV exit compared to the case without handholds, validating the requirement for handholds. This was found for each of the three operating techniques. The greatest benefit was found when the hand push technique was used. Exit handholds were found to be of significant benefit in assisting the operation of Type IV push-out exits when the test subjects were not secured by a harness but were free-floating (Task 1). Without the handhold, buoyancy caused the test subjects to float upwards and away from the exit. In this free-floating condition a much higher maximum permissible operating force was therefore found when a handhold was provided, validating the requirement for handholds close to the bottom of each underwater emergency exit. In Task 2, exit operating forces were based on the maximum permissible operating forces established in Task 1. With operating forces set at 200 N (push-out exit) and 180 N (lever operated exit), those operating the exits were secured by a harness. Under these conditions, limited use of the handholds was observed.

Regulation	Current requirement	Suitability of current CS-27 and CS-29 requirements and associated AMC material
	and in enabling buoyancy forces to be overcome during egress".	
CS 27.807(d)(5) (EASA, 2023a) CS 29.811(h)(2) (EASA, 2023b)	"*Each operational device (pull tab(s), operating handle, 'push here' decal, etc.) of underwater emergency exits provided for flight crew or passengers must be marked with black and yellow stripes*".	The current trials were conducted under light conditions to allow the underwater escapes to be filmed. The potential benefits of the black and yellow stripes to improve conspicuity of the handholds were largely negated by the light conditions. Handholds are not explicitly required to be marked with black and yellow stripes but it is recommended that such marking should be required.
CS 26:	"*... any operating handle or control can be gripped using*	During Task 1, the use of gloves was not found to affect the maximum permissible operating forces.

Regulation	Current requirement	Suitability of current CS-27 and CS-29 requirements and associated AMC material
GM1 26.415(c) (EASA, 2022a)	*either a bare or a gloved hand*".	The lever handle simulated in this study could be operated with and without gloves.
Position of seat in relation to exit		
CS 29.813 (d)(1) (EASA, 2023b) AMC 29.813 AMC 27.807(d)	"*passenger seats must be located in relation to the underwater emergency exits provided in accordance with CS 29.807(d)(1) in a way to best facilitate escape with the rotorcraft capsized and the cabin flooded …*". Seats to be "*positioned relative to the exits in a favourable manner*". "*passenger seats to be located relative to these exits in a way to best facilitate escape*"	In Task 1, some test subjects had problems reaching the exit when secured by a four-point harness. It is recommended that further detail is added to the AMC to consider whether the exit is in a position where it can be reached and jettisoned by the occupant with the seat harness secured.
Aisle width		
CS 29.815 (EASA, 2023b)	In a helicopter with a seating capacity of 11 to 19, the main passenger aisle width between seats must equal or exceed 0.30 m at a height of less than 0.64 m from floor and 0.51 m at a height of 0.64 m or more from floor.	In the regulations, minimum aisle width is set to allow evacuation of the aircraft (on the ground). The aisle width used in the trials (0.43 m) was found to limit speed of underwater escape for those test subjects who needed to move down the aisle to find an exit available for underwater escape. An increase in the minimum aisle width could improve underwater escape times.
Large (double ellipse) exits		
CS 29.807(d)(1) (EASA, 2023b) CS 27.807(d)(1) (EASA, 2023a)	"*… the passenger seat-to-exit ratio may be increased for exits large enough to permit the simultaneous egress of two passengers side by side*".	Trials undertaken during Task 2 demonstrated that two large test subjects with shoulder widths ≥ 500 mm were able to simultaneously escape through an exit encompassing two ellipses of 0.48 m x 0.66 m. When using an exit of this size in combination with a second Type III exit, eight test subjects were able to escape in under 60 seconds. It is considered that these results validate the option which permits a seat-to-exit ratio of 4:1 when a large 'double ellipse' exit is provided. The results of the trials suggest that a 'side-by-side' orientation is not essential and that the rule
AMC1 29.807(d)(b)(3) (EASA, 2023b)	An example of a large exit is described as "*an unobstructed area that encompasses two ellipses of 0.48 m x 0.66 m (19 in. x 26 in.) side by side*".	

Regulation	Current requirement	Suitability of current CS-27 and CS-29 requirements and associated AMC material
		and CS text should be amended accordingly.
Escape time		
AMC1 SPA.HOFO.165(h) (EASA, 2017, 2023c)	"*In order for all passengers to escape from the helicopter within an expected underwater survival time of 60 sec in the event of capsize*" provisions are required relating to emergency underwater exits.	The results of Task 2 validated the expectation of an overall escape time of 60 seconds cited in AMC1 SPA.HOFO.165(h). This is based on escape occurring in favourable conditions without problems such as a blocked exit or a passenger having problems releasing the seat harness. With underwater escape exits meeting the requirements of the current CS 27 and CS 29, and operating forces set at the maximum permissible operating forces established in Task 1, test subjects sat in seats adjacent to an available (unblocked) exit were able to escape in less than 60 seconds. Those test subjects who were not sat next to an available exit took a little longer to escape. In a real underwater escape scenario, there are many factors that could extend overall escape time including passenger injury, blocked exits and darkness.
CS 29.807(a)(d) (EASA, 2023b) (Also covered by CS 27.807(d)(1) (EASA, 2023a)	For a helicopter with ditching provision it shall be demonstrated that it has "*one underwater emergency exit in each side of the rotorcraft, meeting at least the dimensions of a Type IV exit for each unit (or part of a unit) of four passenger seats*" allowing rapid escape.	

5. Other Recommendations

5.1 Recommendations for training

The results of the Task 1 and Task 2 studies provided evidence to support a range of recommendations in relation to best practice for helicopter escape training.

- Training should be conducted using exits that are as realistic as possible to present realistic operating forces.
- The underwater emergency exits provided in helicopter simulators should not significantly exceed the minimum size requirements covered by CS 29.807(a)(4) (EASA, 2018b) i.e. equivalent to the minimum size for a Type IV exit (0.48 m wide by 0.66 m high (19 in. x 26 in.)). If a Type III exit is simulated and used for underwater escape, this should not significantly exceed the minimum size requirements of 0.51 m wide by 0.91 m high (20 in. x 36 in.).
- Trainees should receive training in the different types of exit found in the current helicopter fleet. As a minimum, helicopter underwater escape training should include exercises using realistic 'push-out' exits. If exits are in use that require a lever action to function, this type of exit should also be operated during training.
- Trainees should be taught to jettison 'push-out' underwater escape exits using an elbow strike to either a lower corner or the long side of the window where resistance will be least in a real exit.
- While exit sizes have often been unrealistically large in the past, the current certification specifications mean that exits used in the current fleet are similar to the exit sizes found in many helicopter simulators.
- The removal of an exit pull-out strip should be simulated as this action is required for the majority of 'push-out' exits in the current helicopter fleet. The exit cannot be jettisoned if this action is omitted. The removal of the pull-out strip takes time, meaning that escape times will be shorter without this action being completed. The removal of pull-out strips from around push-out windows would thus provide more realistic training.
- Seating arrangements provided in helicopter simulators should meet the requirements of CS 29.809(j)(2) and AMC 29.809(b)(3) (EASA, 2018b) i.e. passengers to be able to egress through a nearby underwater emergency exit which is simple to operate with one hand (lever operated) or using an elbow strike (push-out exit).
- Trainees should be given the opportunity to escape from a stroked (attenuated seat). In a water impact accident, forces are likely to be sufficiently high to result in some seat heights being lowered; resulting in a change to the relative position of the exit, and a more cramped seating position. This could lead to potential difficulties such as problems when attempting to release the seat harness.
- Trainees should be given the opportunity to undertake a cross-cabin escape. This requires a different skill set; the trainee would preferably learn to move across the cabin and remove an exit while free-floating.
- If and when available in the helicopter fleet, handholds and their use should be included in helicopter underwater escape training and pre-flight briefings. If provided, these should be marked with black and yellow tape. The location and benefits of these handholds should be discussed, particularly in relation to cross-cabin escapes when the passenger is free-floating.
- Helicopter underwater escape training should be undertaken using approved EBS. The study showed that for all but one test subject, use of EBS allowed the test subjects to stay calm while completing the escape process. Use of EBS would allow training to be carried out under more realistic conditions, and allow cross-cabin escapes to be undertaken.

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