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RAF IAM Report No 677

Helicopter Ditchings

British Military Experience 1972-88

by

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ABSTRACT

All ditchings involving British military helicopters were reviewed for the period 1972-1988, in which there were 94 accidents involving 243 occupants. These accidents caused 58 fatalities and 41 injuries.

Some new methods of enhancing survival in helicopter ditchings were examined and applied to the ditching data in order to quantify potential improvements.

The greatest potential in life saving was the fitment of more reliable and effective flotation systems to prevent sinking and delaying inversion. Increased buoyancy for passenger and troop carrying helicopters could arise by the fitment of inflatable passenger/troop seats. Helicopter escape hatch/door emergency lights and underwater breathing devices were also identified as potential life saving aids.

INTRODUCTION

Several new concepts for the facilitation of underwater escape from helicopters are now in development. Amongst these are escape hatch lights, breathing devices and improved escape hatch release systems. However, it is not clear what improvement in survival might accrue if all or any of these systems were installed. It was resolved that a new review of helicopter ditchings should be conducted so that the potential that these new devices might offer could be explored. All tri-service helicopter ditchings (emergency contacts/alighting on water) in the period 1972-88 were reviewed and are summarised in this report. This report should be used together with other reviews of British military helicopter accidents (Vyrnwy-Jones, 1984 and 1985; Vyrnwy-Jones and Turner, 1989; Baker and Harrington, 1988) which give additional data on each accident.

THE ESCAPE DEVICES

There are many aspects that could be addressed in an attempt to improve the chances of a successful escape from a helicopter underwater. Some of these are described below.

For passengers in the rear of a helicopter, the disorientation caused by the sudden inversion of the helicopter on water entry manifests itself by the inability to find the escape door or hatch in time. The problem can also occur for the helicopter crew. They are taught to remain in bodily contact with their adjacent door or hatch by a hand grip until all motion stops and the inrush of water has ceased. They then egress by the adjacent door or window, having jettisoned obstacles in the escape path. Aircrew are taught these escape procedures in a simple device (dunker) which simulates the internal geometry of the helicopter. The device is lowered into water and suddenly inverted and aircrew practice egress with safety divers in attendance.

However, the problem is more acute for the occupants in the rear of the helicopter as they cannot maintain contact with the escape hatch or door. They often have to travel some distance in semi-darkness, under water, against gravity, buoyancy or water flow to find the door or hatch. Having located the door, they must then operate a lever, push out the door and escape. Even in daylight, the change in illumination from above to below the water is enough to render the escape door invisible to the unaccommodated eye. At night, the problem is further compounded by poor ambient illumination. Furthermore, the change of visual acuity when water comes into contact with the eye means previously visible structures are out of focus. The further obstruction to vision by the turbidity of the water, contamination by fuel, bubbles and floating debris usually means that helicopter rear crew and passengers can only rely on feel as a method of locating the escape door.

Escape lights

It has been evident to many operators that if the escape hatch could be outlined by a self illuminating light system, location of the door and egress would be simpler. Allan et al (1989) showed, however, that the ability to see such lights can only be achieved at relatively high levels of illumination. Some systems that show promise above water, to the light accommodated eye without the panic of emergency escape, became useless under simulated emergency underwater conditions. An illuminance of 10,400 cdm^{-2} was recommended for visibility over 1.5 m in turbid water. Guided by these studies, newer systems have been designed that should be visible underwater in the dark for some distance. The door or hatch is outlined with an inverted U of lights, the missing side providing orientation to the bottom of the door. Power systems are self contained and activated by water entry or decay of the rotor speed in an emergency situation. The nature of the lights does not affect their luminance per se, but light emitting diodes have been used in this context as they can be easily sealed from water ingress and demand little power. These devices are termed helicopter emergency egress locations (HEEL) by the United States Navy (USN) who conducted the original evaluations.

Escape guide bars

The turbulence caused by the water entry and the adverse gravity and buoyancy gradients after a helicopter has inverted in the water, mean that crew and passengers in the rear of a large helicopter require some assistance to move to the illuminated escape door or hatch. The seats and seat backs may well be disturbed by the impact forces and some additional hand holds are required so that occupants can maintain their position and move towards rescue. The overhead area of the cabin has been selected as a site which is relatively unobstructed and one promising scheme (Allan, 1988) consists of a series of tubular bars fixed to, but distanced from the roof, leading to the escape doors. When these bars are made of transparent material and internally illuminated they become much easier to locate. Furthermore, the use of stroboscopically directed bands of light along the escape bars to the nearest emergency exit provides a valuable clue for the desired direction of travel. Test results (Allan, 1988) showed shorter escape times with the illuminated guide bars as compared with controls. The guide bar provided visual and tactile guidance and a practical assistance to egress.

Escape breathing devices

The ability to breath-hold while escaping depends on many factors. Cold water immersion induces hyperventilation when breathing is possible and decreases breath-hold duration. High workloads during escape produce rapid rises of carbon dioxide in the tissues which further decrease breath-hold times. Practice can increase breath-hold times, but many passengers, as distinct from crew, may not have had previous training. Re-breathing devices have been advanced as an aid to increased breath-hold times, but a recent study (Sowood, 1989) showed that re-breathing devices did not significantly lengthen breath-hold times compared to simple breath-holding at low water temperatures (11°C). However, when a small compressed air source was provided for subjects simulating escape from helicopters, breath-hold times were significantly increased (43 secs compared with 15 secs), and warmer water increased the times to 136 secs compared with 40 secs (Sowood and Higenbottam, 1989). Therefore, if compressed gas supplies could be provided, helicopter crews would be able to extend their time underwater which should enhance their chance of successful escape. There is, however, a risk of pulmonary barotrauma using compressed gas breathing devices at depths below 2.3 m, but providing the helicopter is not sinking rapidly, this depth is unlikely to be exceeded. These devices are collectively termed helicopter emergency egress devices (HEED) by the USN.

Emergency escape path clearance devices

Once having located the escape hatch or door, the release handle must be manipulated and once unlocked, the hatch or door pushed away. Occasionally trapped and pressurised air in the cabin can assist this process. However, some dexterity and force is required, and impact forces occasioned by the water impact can distort the hatch/door and its surrounds and prevent opening. Accordingly, power assistance for hatch/door jettisoning has been advanced as an aid, and pyrotechnic devices explored as a means, similar to those devices used in canopy dispersal systems of fixed wing aircraft.

There are many hazards of explosives underwater, the principal a consequence of the incompressible nature of water which transmits explosive energy from the device to the occupants with adverse results. However, with shielding and perhaps automatic activation so that the crewman is not required at the door to commence the firing sequence, these pressure effects could be diminished. Hinds and Moore (1977) used polyurethane foams to attenuate explosive forces successfully for this purpose.

Restraint systems

Incapacitation caused by the forces of impact can adversely affect the chance of survival as assistance from other crew members cannot be relied on. The forces of impact can be mitigated by efficient restraint systems which prevent secondary impact of the crew with objects in the helicopter. Pilots and other cockpit crew are usually well restrained by five point harnesses attached to strong seats. The rear crew are not so well restrained. Crewmen whose job requires them to be mobile are usually restrained only by a despatcher's harness. This consists of a broad waist belt attached to an adjustable strap arising at the mid back position which terminates in a hook for attachment to a strong point in the helicopter. The purpose of this harness is to stop crewmen falling out of the helicopter inadvertently, or their forced ejection on impact. The geometry of the harness, however, makes it possible for the crewman, so restrained, to flail around inside the helicopter cabin with attendant risks of head and other injuries. Rear crew occupants are also poorly restrained in seats which are light weight and often folding to allow a variety of cargo to be carried. Moreover, the seats are insufficiently strong to withstand high forces of impact and the harnesses attached to them often consist of lap belts which, by themselves, offer insufficient restraint. Stronger crashworthy crew seats combined with four or five point harnesses would improve survival because the risk of incapacitation on impact would be reduced.

Delethalization

Following the installation of improved restraint, another feature that would reduce the risk of crew incapacitation on impact, would be measures taken to mitigate the forces imposed on crew by contact with structures inside the helicopter cabin. Basically, this can be as simple as covering hard surfaces with energy absorbing foams and covers, or avoiding or shielding knobs and switches which could produce severe local damage if struck by the body with force. By reducing the chances of lethal damage on impact, the risk of severe head injury, and thus incapacitation, is reduced. Good cockpit design examines the possible flail envelopes of head and limbs whilst the body is restrained and removes controls, panels and other objects from these areas. The edges of panels are curved and padded, the switches recessed or shielded and coamings made frangible so that high forces are not caused by impacts of the body with cockpit structures.

Crashworthy seats

One other potential solution to the problems of high impact forces transmitted to the occupants during high speed water impacts, is the employment of crash force absorbing devices between the airframe and the occupants. In practical terms, this means the crew seat, as other devices fitted to undercarriage legs, etc. are ineffective in water impacts.

The seats can be fitted with telescoping structures such that under high impact forces, the seat support telescopes absorbing force by bending, distorting or cutting metal or composite elements. Thus, the force of the impact is absorbed by the seat structure and only a small proportion delivered to the seat occupant.

The inclusion of crashworthy seats in helicopters would mean that the forces delivered to the occupants would be reduced, the likelihood of injury lessened and the chance of escape improved.

Flotation

The current design of helicopters puts the engine(s) near the rotor, on top of the fuselage, to simplify the gear box connections. This means that the centre of gravity of the helicopter is towards the top of the helicopter, which tends to make it unstable afloat. Add the torque effects of the tail rotor, the disturbances likely if main rotor blades strike the water surface and one can see that stability of the floating helicopter is difficult to achieve even in those helicopters designed to operate from the sea surface. This is further compounded by damage likely to occur on initial contact with the water. Flotation devices consist of inflatable bags attached to aircraft strong points and inflated by compressed gases activated by water sensitive switches or by the crew. Flotation systems are designed to enhance the stability in the water, to prevent inversion and sinking, and to extend the time that crew and passengers have to egress in emergency. Older helicopters had their flotation systems added as an afterthought to the original design. Later helicopters have them built in, however, some of the later designs are no more efficient.

Flotation systems near the lower part of the helicopter increase the free board and allow escape from side doors above the water surface. However, this placement does not always prevent inversion as there is a strong overturning movement to the helicopter when it floats high in the water. Some helicopters, e.g. the Wasp, have flotation bags near the roof of the helicopter cabin. This makes for stable flotation, but the helicopter floats low in the water making downward or lateral egress less easy.

Flotation devices are by no means 100% reliable. Experience shows that some of the bags do not inflate causing assymetric flotation which usually meant the helicopter rapidly inverted. Some of the flotation bags were damaged by the water impact itself, some by blade strikes and some because the structures to which they were attached failed. Newer designs of flotation systems are needed that are not subject to these hazards. By building them in at the design stage, it should be possible to arrange a ring of flotation bags, inflated by multiple gas sources, interlinked so that gas pressure is equalised to all, arranged around the mid-line of the helicopter. This reduces the free board somewhat, but enhances stability in the water particularly in adverse sea states. The mid-line position should be less vulnerable to blade strikes, and non-return valves could retain gas pressure in the event of leakage. Colacicco and Sloane (1978) concluded that advanced flotation systems would enhance survival, providing support and shelter in the floating helicopter and considerably reduce material losses consequent upon sinking of the helicopter.

Emergency exit location

Sufficient emergency exits should be provided to ensure rapid evacuation of the helicopter in an emergency. In the case of ditching and subsequent inversion, additional hatches should be provided in floors or the roof. The types and numbers of exits required are specified in Defence Standard 00-970, Volume 2, Chapter 102. As the number of passengers increases, more exits are required, but their minimum size is less e.g. a large helicopter catering for 80 passengers must have 3 exits each side of the fuselage, one 610 x 1200 mm, one 510 x 910 mm and one 450 x 660 mm, whereas a helicopter accommodating 20 passengers need only provide one exit each side, 510 x 1120 mm.

However, as Allan and Ward (1986) pointed out, the number and placement of the emergency exits is more significant for emergency egress and survival than their size. They showed that the buoyancy of the human body under water facilitated escape from much smaller exits (432 x 356 mm) than had hitherto been considered. If exits equal to, or larger than, this size were placed at regular intervals (not > 3 m) along both sides of the fuselage of passenger carrying helicopters, more passengers would escape underwater as the location of and egress through would be made simpler by reason of proximity and congestion at the exits would be reduced.

Inflatable seats

Another concept for helicopters that could enhance survival after ditching is the use of inflatable seats. Originally, this idea arose as a multi-purpose system capable of accommodating passengers on one flight, and then bulky equipment on the next flight, without having to remove the seats from the helicopter. Basically, the seats are low pressure inflated

However, the attendant advantage as far as ditching survival is concerned, is that the inflated seats provide considerable buoyancy and, if enough inflated seats are fitted, would prevent or delay the helicopter sinking.

Rescue organisation

Having ensured that the crew and passengers can escape safely from a helicopter after ditching, a rescue organisation is required to prevent the escaped personnel from dying of exposure. Happily, in the British Services, in all theatres of operation, this service is efficient. There is little risk of fatalities once the escape from the helicopter has occurred. This could well be a problem for other services with wider areas of search.

THE ACCIDENT DATA

The data for this study were provided by records from the Royal Navy Accident Investigation Unit and the Royal Navy Air Medical School, the Headquarters of the Director of Army Aviation and the Inspectorate of Flight Safety (RAF).

Overall, the quality of the data was excellent, but some details were incomplete and medical descriptions inexact. The descriptions of injuries used in this study are as they appeared in the original reports.

The data in this report are grouped primarily by aircraft type. Tables 1, 3, 5, 7 and 9 list the date of the accident, the airframe number and the number of occupants, fatalities, injured and uninjured personnel. The time of the accident is listed as day, night (or dusk) and the principal cause is summarised. In tables 2, 4, 6, 8 and 10 the details of the escapes, the impact forces and safety equipment failures and other remarks are listed for each accident. The last 3 columns list whether aircraft flotation aids were used, an estimate of the forces of the impact with the water and, finally, a guide to the time interval between contact with the water surface and inversion of the helicopter (immediate or delayed, i.e. < or > 15 secs respectively). A list and explanation of all the abbreviations and acronyms used in the tables is at page 24.

RN Sea King

The data for RN Sea King ditchings are listed in Tables 1 and 2. Thirty four ditchings occurred and 171 personnel were at risk in them. There were 37 fatalities, 16 injured and the remaining 118 escaped without injury. There were 25 ditchings by day, 9 at night. The causes of the accidents which led to ditchings can be summarised as follows, engine failure in the hover 9, transmission oil pressure failure 5, tail rotor failure 4, mid-air collision 3, disorientation 3, excessive vibration 3, flew into the sea 2, control difficulties 2, fuel starvation 2, radar altimeter failure 1.

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The number of fatalities in RN Sea King ditchings were significantly increased by just one accident, ZA 294 produced 21 fatalities, and this accident is described in detail below. There were 16 other deaths also due to drowning, but 3 of these showed post mortem signs of severe ante mortem incapacitation.

Sea King ZA 294

The accident to Sea King ZA 294 incurred a heavy loss of life, it was unique in many respects and as it distorts any summary of helicopter emergency in which it is included and affects the recommendations arising from this study, the accident is described in detail.

The accident took place during the Falkland Islands campaign in the South Atlantic. A crew of 2 pilots and an aircrewman with 27 troops and stores were transferring at night from one ship to another. The passengers were equipped with assault troop and general service flotation devices, however, they were all heavily loaded with combat equipment. After some delay, the helicopter commenced an approach to the ship, the crew reported a 'bang' somewhere near the top of the helicopter and then the helicopter ditched. No flotation gear was deployed, the helicopter rolled starboard, instantly filled with water and sank. No emergency call was transmitted. The first pilot could not jettison his cockpit window, so he kicked a hole in the roof transparency, only to be held back by his Personal Survival Pack (PSP). He jettisoned this, swam to the surface and inflated his lifepreserver, clung to the co-pilot's dinghy and was rescued by a ship's boat. He sustained a fractured right ankle. The second pilot successfully jettisoned his window, and left the helicopter through that window taking his PSP with him. On the surface he inflated his lifepreserver and his dinghy and boarded it. He sustained a laceration to his forehead and a fracture of the 12th thoracic vertebrae. He, too, was rescued by a ship's boat. The aircrewman, in the rear cabin, sustained a severe head injury and was recovered floating dead on the surface. Of the 27 rear occupants, 20 were lost, 6 were recovered with serious injuries and one with minor injuries. The rear survivors reported a violent blow, a sudden inversion, the cabin filled rapidly with water and fuel and although the dome light was on, they could see nothing. There were beta lights marking the doors, but they had all been masked with tape for operations with night vision goggles. The tail boom broke off in the impact, but this did not simplify escape as only one soldier escaped through the hole thus produced. The survivors came from seats widely separated throughout the cabin. Many more passengers than were rescued may have escaped, but without better flotation and with the inability to jettison their equipment quickly they sank before rescuers appeared. However, as the impact was reported as severe, and few, if any, passengers were restrained, the passengers were probably incapacitated by severe injuries sustained on impact. In addition, the water temperature was 6°C and none of the passengers wore an immersion suit. All of those who were rescued hung on to the co-pilot's dinghy. The lifepreservers they wore provided inadequate buoyancy for the heavy loads they were carrying. The passengers that were rescued sustained fractured clavicles, dislocated shoulders, neck whiplash injuries, sprained shoulders and a severely bruised chest, showing that there had been severe flailing inside the cabin. The aircrewman's fatal head injury was probably caused by a machine gun which flailed at impact. The Board of Inquiry which studied the accident recommended that the cabins of Sea Kings be equipped with adequate emergency lighting, lap and diagonal harnesses for all passengers, a 'separator' between every 3 seats to prevent flailing of bodies during impact, and that troops likely to fly as passengers in RN helicopters be given dunker training. The original cause of the accident could not be determined. The pilots considered that the helicopter could have sustained a birdstrike just before impact, but, although some bird remains were discovered, the nature of the remains did not support this theory. Disorientation was thought to be more likely on a dark night, with no moon or stars, the helicopter approaching a ship darkened in a hostile zone.

In this tragic accident, it is important to realise that it was probably the injuries occurring at impact that caused the high loss of life rather than failure, per se, to escape from the ditched helicopter, although egress must have been difficult.

If the accident to ZA 294 is omitted from the Sea King series, the total number of fatalities drops to 16 and the injuries to 8 from a passenger total of 141.

The utilisation of the Sea King in anti-submarine warfare results in its spending a significant part of the operational sortie at the hover, over a suspended hydrophone, searching for submarine noise effects. This is the reason for the high incidence of ditching following engine failures in the hover. However, of the 9 helicopters that ditched in this manner, 2 were able to take off again and 2 water taxied to safety. The 5 cases of loss of transmission oil pressure all resulted in successful ditchings, without loss of life, and in 4 successful deployments of the flotation gear and no inversions. In these cases, there was adequate warning of impending disaster, and the helicopter could be prepared and ditched under control. Tail rotor failure resulted in immediate loss of control in the air, with ditching as the only course of action. However, the impacts with the sea were under partial control and caused no loss of life. Stability once on the surface, however, depended on the successful deployment of flotation devices. Mid-air collision is usually a non-survivable event as in 2 of the 3 Sea King occurrences. One helicopter could maintain control after collision until ditching. Disorientation continued to produce significant mortality as the water impact is usually severe because the helicopter is out of control.

Table 2 lists the escape and safety equipment problems in the Sea King ditchings. There were 5 accidents where there were significant difficulties in either opening or jettisoning windows or crew doors. No cases produced fatalities, but they retarded escape and were commented upon adversely. In 4 other accidents, the PSP snagged on egress, and it had to be jettisoned before egress could be effected. The lack of a dinghy can adversely affect the chances of survival, particularly if rescue is delayed.

Among the safety equipment failures, 3 crewmen lost their dinghies subsequent to successful escape with it. On 4 occasions, the dinghy either failed to inflate or inflated very slowly. Injuries were caused during ditching in two accidents by inadequate restraint, and the failure of a crew seat was associated with spinal fracture of the occupant. A life preserver was perforated by perspex from a broken window and, in another case, was slow to inflate.

The remarks column shows that successful abandonments by the crew (all but the pilot) before ditching was adopted as a method of escape in 4 cases. The deployment of the helicopter flotation system was successful in only 13 of the 34 ditchings. Three times the undercarriage (U/C) was lowered to enhance stability, but on 18 occasions, the flotation system was not used at all. The remaining 3 cases were partial failures of the system.

When the flotation system was successfully deployed, inversion of the helicopter was either delayed or prevented in all but one case. Partial deployment produced immediate inversion in 2 of the 3 cases. Failure to use the system was associated with immediate inversion and sinking in 16. Two helicopters were able to make a successful take off following the ditching and a third managed to keep its rotors turning for some 2½ hours until rescue arrived.

RN Wessex

Table 3 shows that there were 21 RN Wessex ditchings in the period, involving 82 occupants. There were 6 fatalities, 8 were injured and the remaining 68 were uninjured. All 6 fatalities were given drowning as a cause of death. One body was not recovered. In the injured category, there were 3 spinal fractures, 2 'sprained spines', one injured left arm and 2 injuries classified as slight. Seventeen accidents occurred in daylight, and 4 at night. Among the causes of the accidents, there were 10 cases of engine failure and 3 cases of tail rotor failure or strikes. Human error failures consisted of a failure to auto-rotate successfully, a case of loss of control, one accident where the deck lashings were inadvertently left connected on take off and a case of possible disorientation following a fuel computer failure at night.

Table 4 shows that there were a variety of escape problems in these Wessex accidents. In the fatal accident, (XT 477) the pilot was found floating freely in the wreckage with his harness undone. The aircraft flew into the sea under power and immediately inverted and sank, which would have prejudiced his chances to escape. The other crew member was never found. The accident to XM 884 was caused by some lashing chains left on take off. The tail rotor struck the ship and the helicopter spiralled into the sea. All escaped except the co-pilot who was drowned. It was concluded that he may have suffered from a head strike exacerbated by the night vision goggles he was wearing. In XP 156, all the crew perished as no attempt to auto-rotate was made by the pilot. The aircraft impacted the sea at high speed.

The safety equipment failures listed in Table 4, however, caused no fatalities. The dinghy only inflated partially in 2 cases,and there were 3 occasions where aircrew had difficulty in inflating their dinghies inside a relatively new survival pack. In all cases the dinghies were serviceable. Minor changes to the mechanism and re-training prevented further incidents.

Five of the 21 ditchings were so rapid that no emergency warning radio call was given. Prompt crew drills enabled doors and windows to be jettisoned before ditching in 2 cases. The flotation system in the Wessex was successfully used in 15 incidents. However, in 4 cases one bag failed and the system was not used in 2 others, thus these 6 helicopters promptly inverted and sank.

The forces of water impact were reported as light on 16 occasions, the helicopter was 'out on control' on 3 occasions and flew in on one further incident. The time before inversion was reported as immediate on 8 occasions, delayed in 6, and inversion did not occur in the remaining 8.

RN Wasp

The data for the RN Wasp ditchings are presented in Table 5. Sixteen Wasps ditched with 34 crew aboard. There were no fatalities and only 3 injuries in this series. All but 4 ditchings occurred by day. The injuries were one spinal fracture, one fractured wrist and one neck sprain. The causes of the ditchings were as follows, engine failure 9, loss of control 3, tail rotor failure 1, engine fire 1, flew in 1, oil pump failure 1.

There were few escape problems (Table 6). This is due to the limited carrying capacity, both for crew and passengers. One passenger found difficulty in jettisoning a rear door and exited through the front. One pilot had to be helped from his seat by rescuers after he sustained a spinal fracture, which was caused by the helicopter landing heavily in shallow water. There were few safety equipment failures. One liferaft only partially inflated and a crewman, restrained only by a despatcher's harness, sustained a fractured wrist.

In 6 accidents, there was no time for a warning radio call to be transmitted. Two of these were engine failures at the hover, one pilot flew into the sea guided by a defective glide path indicator light on the ship, another hit the sea during an aerobatic sequence, and the fifth lost control on the approach to a ship. The sixth aircraft suffered an engine failure at night.

The Wasp flotation system functioned correctly in 11 cases. Partial inflation occurred 3 times, a rotor blade damaged a flotation bag once, and the sudden inversion shorted out the aircraft battery before activation could be effected. The flotation system in the Wasp is mounted either side of the cockpit just below the rotor disc. Partial inflation delayed inversion in 2 cases and complete inflation prevented immediate inversion in all but one case. Six helicopters were recovered and returned to service. XS 568 and XT 427 were both recovered and repaired, only to ditch again later in the period under review.

The four heavy impacts were caused by hitting the sea during an aerobatic sequence, loss of control on the approach, following a tail rotor failure and a landing into 1 m of sea water.

RN Whirlwind

There was just one ditching of this helicopter (Table 5). A fuel computer failure caused the engine to surge. The 3 occupants escaped unharmed, but they all left their dinghies behind. No flotation system is fitted to the Whirlwind and it inverted and sank almost immediately.

RN Gazelles

The only ditchings to befall the Gazelle (Table 5) were following a mid-air collision during a formation aerobatic display. The collision was severe, non-survivable and included in this series for completeness, as the wreckage of both helicopters fell into the sea.

The newest helicopter in the RN inventory ditched 3 times in the period under review (Table 5). In the first accident a fire in the gearbox preceded a controlled ditching with a light impact. The flotation system was serviceable and all occupants egressed without injury, but one crew member's dinghy blew away after inflation.

A tail rotor failure in the second Lynx led to a very heavy vertical impact with the sea. All 4 occupants suffered spinal injuries and fractures and were lucky to survive. The cabin door release was bent during the escape and prevented subsequent door jettison. The impact damaged one flotation bag and the helicopter inverted immediately. The last Lynx ditching caused 2 fatalities as the helicopter flew into the sea on an approach at night. The flotation system operated automatically after water entry, and the helicopter floated inverted. The extensive cockpit damage trapped the crew and rescuers could not reach the helicopter in time.

Sioux

Sioux helicopters have ditched 5 times (Table 7). There was one fatality and one minor head injury sustained by the 9 occupants at risk. All the accidents except one, occurred by day. In no case was technical failure the cause of the ditching: all were due to pilot error.

There were few problems on escape. The fatality occurred when a passenger, wearing body armour and having escaped the ditched helicopter, failed to swim ashore.

All the impacts were sudden and unannounced, therefore no warning calls were given. Two occupants ditched without lifejackets and used the seat cushions as flotation aids. An assault lifepreserver failed in another accident. No flotation system is provided in the Sioux, so all the helicopters inverted and sank immediately.

Scout

The Scout helicopter is a variant of the Wasp, equipped for Army duties. Five helicopters ditched (Table 7) and 4 fatalities and one minor injury occurred in the 9 crew at risk. Two of the accidents were due to engine failure, but the other 3 were due to pilot error.

The fatalities were caused when 2 Scout helicopters flew into lakes in Northern Ireland. The first (XV 132) occurred in bad weather. The helicopter was located 10 m under water, the pilot's body was outside the wreckage. He had divested himself of the body armour he was wearing. The passenger had been knocked unconscious by the impact and was still strapped helmet and the pilot did not use a lifepreserver.

The second Scout (XW 614) accident occurred at night. Here the observer was found out of his seat, but had suffered multiple injuries from rotor blade strikes. The pilot was found still strapped in, but suffering from severe head injuries, despite his helmet. The accident was clearly non-survivable. The pilot had been using night vision goggles, but needed correcting flying spectacles which were incompatible with the goggles.

This may have contributed to the accident. No body armour was worn on this occasion.

In the accident to XN 908, the crewman was not restrained and was thrown out of the helicopter on impact, sustaining wrist and neck injuries.

In 3 accidents, the flotation system was not used and inversion was immediate, except in one case which impacted in shallow water.

Gazelle

There was one Gazelle accident (Table 8) in which the aircraft hit the sea in low level flight. All 3 occupants sustained injuries, a fractured spine, one broken leg and severe lacerations. As is usual in Gazelle accidents, the crew seats separated from the cockpit structure, but the rear passenger's harness pulled through its adjusting buckle, tore out its mount from the fuselage and allowed the passenger to be thrown clear of the helicopter. Luckily, the aircraft landed near the shore in shallow water.

Lynx

The only Army Lynx accident in this series had a fatal outcome (Table 8). The aircraft, with 2 crew, was flying at dusk in deteriorating weather. No calls were received and the aircraft was subsequently found in 25 m of water. Both bodies were still strapped to their seats and had been decapitated as the rotor swathed through the cockpit at impact.

RAF Whirlwind

Three Whirlwinds ditched in the period under examination (Table 9). Three injuries were caused, one back injury with bony involvement and 2 minor injuries (Table 9). Two of the accidents were caused by fire, although one warning was spurious. The other accident was caused by engine failure. XJ 426 was on casevac duties with 2 passengers aboard when the fire warning occurred. After a controlled impact, the crew member released one of the passengers from a Neil-Robertson stretcher and helped him and the other passenger out of the helicopter. Together with the pilot, he placed the 2 passengers in dinghies then awaited subsequent rescue.

No flotation system is fitted to the Whirlwind, so the helicopters inverted and sank almost immediately.

RAF Wessex

Two RAF Wessex helicopters ditched (Table 9). The first accident was caused by disorientation in low lying fog layers and 2 of the 3 crew, who were poorly restrained, sustained minor injuries. All egressed successfully, with minor snags, before the helicopter sank (Table 10).

The second accident was also caused by disorientation. In this flight at night, the aircraft hit the water and rapidly inverted. The pilot found he could not exit the cockpit with his PSP attached, so he released it, inflated his lifepreserver and subsequently swam some distance until rescued by a ship. It was thought that the pilot may have mis-routed his

PSP connections. The 3 occupants of the rear cabin were not so lucky. Th aircrewman, the flight nursing officer and attendant all failed to escap and sank with the helicopter, which was never recovered.

DITCHING EXPERIENCE

Having considered the ditching experience by helicopter type, the data can be summarised overall. The results of all the ditching accidents for all helicopters are listed by type in table 11. The whole series comprises 94 accidents involving 342 crew and passengers at risk, 72 of the accidents were by day, 22 at night.

An analysis of the data summarised in Table 11 was conducted to determine whether the risks of fatality or injury varied with the helicopter type. Although there were no significant differences when all the data were used, if the data from the 3 helicopters with the larger numbers of accidents were used (Sea King, Wessex and Wasp/Scout) and the levels of injury reduced to simply fatal and non-fatal, probably significant differences ($p = 0.02$) appeared in that there was a higher proportion of fatalities in the Sea King ditchings when compared to those in the Wessex and Wasp/Scout.

Table 12 summarises the incidence of fatalities by day and night. The 58 fatalities comprise 19 by day and 39 by night. These data show that there is a very significant greater ($p = 0.001$) number of fatalities at night than by day.

Causes of Ditchings

Table 13 shows the cause of the ditchings by aircraft type. By far the most frequent cause overall was engine failure and this was the leading cause of ditching in the 4 most numerous types. It accounted for a third of all the causes of ditching. The next most frequent cause was human error (HE). This included both aircrew and groundcrew error. HE factors during low level flight feature significantly in Army helicopter accidents. The next most frequent cause of ditching was transmission or transmission oil failure. This only occurred in the larger helicopters with the more heavily loaded transmissions. Tail rotor failure occurred as frequently, again featuring mainly in the larger helicopters.

Disorientation remained a significant factor in all helicopter accidents and ditchings. The other 9 causes listed constituted less than a third of all causes.

Safety Equipment

The safety equipment incidents quoted in the data are summarised in Table 14. Difficulty with dinghies, (difficulty in inflation, incomplete or very slow inflation etc.) and inadequate restraint (usually a rear crew member restrained by a despatcher's harness) were the 2 most frequent items quoted. In 7 cases, the crew either lost their personal dinghy prior or subsequent to, the escape from the helicopter. Snagging of the PSP was frequently described as a problem. In 3 of the Wessex accidents, difficulty with the dinghy was caused by unfamiliarity with a new PSP and lanyard, as all the dinghies were subsequently inflated successfully after recovery. A new lanyard design was devised that overcame the problem. The lifepreserver presented problems on 5 occasions, due to slow inflation or perforation. One of the reasons for the slow inflation can be freezing of compressed carbon dioxide as it expands to inflate dinghies or life-preservers. Other gases would not have this problem. Electrical and/or other Personal Locator Beacon (PLB) failures occurred 4 times. However, none of these safety equipment failures significantly affected survival as there were other crew nearby to assist or rescue was quickly at hand.

Escape Problems

These are summarised at Table 15. Few problems were reported overall. The 2 which were reported were difficulty in jettisoning doors and windows, and snagging of the PSP on egress, both occurring in the Sea King. Although a third of all the ditchings (34 of 94) involved the Sea King, one might have expected more escape problems from the Wessex (23 accidents), as the doors and windows are of a similar size and disposition to those in the Sea King. However, there were fewer occupants in the Wessex, 89 compared with 171, and, by and large, it is escape from the rear of the helicopter which usually produces difficulties. There were fewer rear crew members in proportion in the Wessex accidents (28%) as compared with the Sea King accidents (60%).

Inversion Times and Impact Forces

A summary of the inversion times and impact forces is presented in table 16. The inversion times are listed as immediate (< 15 secs, i.e. before the crew could egress), delayed (> 15 secs so that egress was complete before inversion) and NO (no inversion occurred at all). 15 seconds was chosen as the expected time for complete crew escape from Dunker experience. Frequently, accident reports give poor estimates of the time between ditching and inversion, so the data presented in Table 16 are best estimates from all witnesses to the scene. However, as far as survival is concerned, what is important is the orientation of the helicopter during egress and whether inrush of water or sinking hazarded that escape. Of 94 ditchings, 47 (50%) resulted in immediate inversion, 27 (28%) were delayed and 20 (21%) did not invert at all. Of those helicopters without flotation devices, all inverted immediately on ditching, except when shallow water prevented it. However, even with flotation devices, 17/34 of the Sea King, 10/21 of the Wessex and 2/3 of the Lynx helicopters inverted immediately. The Wasp was the most stable after ditching. Inversion was delayed or prevented in 12/16 of all Wasp ditchings. Clearly, in helicopters other than the Wasp, hydrodynamic stability could be improved.

In order to examine hydrodynamic stability and flotation further, the performance on ditching of helicopters fitted with flotation systems is described in Annex A (q.v.) together with recommendations for improvements.

The impact forces were estimated for each ditching as heavy or light. Light indicates that the helicopter could be controlled during ditching even with directional control lost (e.g. tail rotor failure) whereas heavy indicates the helicopter impacted severely, was out of control, or ditched in an adverse attitude. The crew always reported when the impact was heavy, but could not quantify the impact in more exact terms.

61 (65%) of all ditchings involved light impacts, therefore no impact damage should have occurred, neither should flotation devices have been damaged. In all the light impacts, slight damage to the helicopter was caused at the time of ditching, but more damage occurred in the inversions. There were 9 failures of the flotation devices in light impact accidents, all were unrelated to the forces experienced in the ditching, except one flotation bag in a Wasp which was damaged by a rotor blade.

Fatalities

Table 17 lists the accident details where fatalities occurred after ditching. These data should provide a major insight into the problems of survival from ditched helicopters. Seventeen accidents produced 55 fatalities. It is striking to note that in all these accidents, the helicopter inverted and began to sink immediately. This emphasises the considerable risk to survival when this occurs. An attempt has been made to estimate whether provision of underwater breathing devices (HEED) or underwater emergency egress location by lights (HEEL) would have affected the outcome of each accident. In this context, HEEL includes lights marking the doors and hatches and escape guide bars. For this judgement, each accident narrative was reviewed. The out of control, high speed impacts, were eliminated as being unsurvivable. All cases of severe ante mortem head injury or other severe forms of incapacitation were also excluded. Where there was at least one survivor, the ditching clearly being survivable, extra breath-holding time underwater by means of HEED or better access to doors/hatches by HEEL was applied to see whether survivability could have been improved. When this was done, 28 (50%) of the fatalities might have been saved by HEED. Of these 28, 20 (71%) were passengers from just one accident (Sea King ZA 294). A further 2 were passengers in XS 518. That leaves only 8 aircrew in the whole series that might have been rescued by HEED. The benefit from HEEL is 2 individuals less, where those 2 were clearly trapped in the cockpit (Lynx XS 243). HEEL is most likely to be of benefit at night and 4 of the 5 cases where improvement could be envisaged were at night or dusk. The data presented in Table 12 showed that there were many fatalities on ditching at night.

The doubts about survival in Sea King ZA 294 have already been expressed (pages 8 & 9). Both HEED and HEEL could have assisted escape, but with the injuries they probably sustained, the 21 occupants probably would not have survived. However, the extra breathing time underwater provided by HEED might have permitted some of the passengers to divest themselves of their equipment, and to find an exit. But, HEED is envisaged solely as an aircrew aid, and it requires some training to be used correctly, especially in an emergency. The passengers in ZA 294 would probably have not been equipped with HEED, even if it had been accepted for use and available in RN helicopters at that time.

Similarly, escape door lighting might have assisted escape from ZA 294, but with their injuries, to no avail. Therefore, HEED and HEEL cannot be justified as definite life saving devices in ZA 294. In consequence, the totals in Table 17 should exclude those from that aircraft and these are listed at the foot of the table.

When that subtraction is performed, there remain 8 individuals who could have been helped by HEED and 6 by HEEL from a total of 34 fatalities in 16 aircraft.

Table 18 lists the same accidents with fatalities, but documents the possible benefits from other underwater escape aids described earlier in this report. These are, powered door jettisoning, improved restraint (especially for mobile crewmen), delethalization of cockpit and helicopter interiors, crashworthy crew and passengers seats, more effective and reliable flotation systems, more exits, inflatable seats and better rescue services. The totals at the base of the table show the potential saving of life that could be claimed by each aid. Note the contribution to two of the columns by one accident, ZA 294. The highest scoring item in Table 18 is more efficient flotation systems. These score highly because of the unreliability of systems fitted, the deliberate or otherwise non-use of the system by the aircrew, or the absence of any flotation system at all (See Annex A). If 100% efficient flotation systems had been fitted to all the helicopters in Table 18, 36 lives could probably have been saved. Table 18 shows that the second highest number of lives that could be saved (20) is attributed to the provision of inflatable seats. This is because the seats would have prevented or delayed helicopter ZA 294 from sinking, and the buoyancy of the seats would have provided more freeboard above the surface and thus more likelihood of breathable pockets of air in the inverted helicopter. Moreover, inflatable seats would have also provided much, if not all, of the benefits of the fifth highest scoring item in this table, viz, crashworthy seats. Thus, another of the advantages of inflatable seats is that they can be made to deflate in a controlled manner during impact, thus absorbing some of the impact energy.

The major contribution for the high scores for inflatable seats and efficient flotation systems comes from ZA 294. This is because, if the helicopter had not inverted and sunk so rapidly, the injured passengers would have had more time to escape and could have clung to the wreckage until rescue arrived (see Annex A). However, because of the uncertainty of the exact sequence of events in that accident, the contribution of ZA 294 has been omitted from the last set of totals at the foot of Table 18. When this is done, more efficient flotation systems are still way beyond any of the other devices because the provision of a floating, even if inverted, helicopter would have provided significant assistance in many other fatal ditchings. Thus, any method of ensuring flotation of a ditched helicopter would produce the most significant saving of life. Colacicco and Sloan (1978) and Vyrnwy Jones and Turner (1989) came to similar conclusions.

The third highest scoring device in Table 18 is improved restraint with 6 possibilities for saving life. Improved restraint, particularly for passengers restrained by lap belts, would have increased survival considerably as the flailing that occurred on impact would have been prevented. Also, improved restraints for crewmen in the rear of helicopters, currently using only a despatcher's harness, would have reduced injuries that might have improved survival.

The fourth highest total is for assisted door/hatch jettisoning. Here 5 lives might have been saved if the doors and escape hatches could have been automatically opened or jettisoned after ditching. Despite the hazard of pyrotechnic devices underwater, it is believed that powered assistance to clear escape pathways could enhance survival. This belief is supported by the difficulties reported in opening doors and hatches in those ditchings without fatalities (Table 15). Baker and Harrington (1988) also recorded difficulties on escape from doors and hatches in 35% of survivors in RN helicopters.

Crashworthy seats are designed to absorb a proportion of the impact forces by controlled deformation. The seats for both crew and passengers of most current UK helicopters demonstrate little crashworthiness. The crew seats of newer helicopters, e.g. the Sea King and Lynx, have been made stronger so that they remain intact and attached to the cockpit structure during impact. This increased strength assists survival because it provides better restraint, however, there is little energy absorption, particularly in vertical impacts, hence the spinal injuries in XZ 249. If crashworthy seating systems had been provided, it is estimated that 4 helicopter occupants who died, might have survived.

Delethalization, the design process whereby all sharp projections, corners or objects in the occupied space that could prove injurious on impact are removed or avoided, could only have benefited 2 cases. These were the crewman who received fatal head injuries in ZA 294 and the passenger in XV 132 who was rendered unconscious in his seat and made no attempt to escape before he drowned.

The provision of more exits along the length of the helicopter cabin might only have assisted in one accident, ZA 294. Although it is believed that most of the passengers were seriously injured, more exits along the length of the helicopter cabin might have furthered the escape of some. The exit size, however, would have been critical because the small doors as permitted by Def Stan 00-970 and the smaller exits as described by Allan and Ward (1986), would probably have been insufficient to have permitted egress of those passengers in ZA 294 with all their additional equipment strapped to their bodies. In the particular case of this helicopter, it is probably more correct to conclude that extra exits would not have been a significant life saving measure.

A better rescue service would have produced no benefit at all as no fatality in the whole series was attributable to inadequacies of the existing service.

CONCLUSIONS

The following conclusions have been drawn from a review of British military helicopter ditching experience over the last 17 years.

a. The most likely cause of ditching is engine failure. Human error, transmission/oil failure, tail rotor failure and disorientation are the next four most frequent causes (Table 13).

b. Overall, there were few safety equipment problems sufficient to jeopardise survival. The problems that were reported were, in order of frequency of occurrence, problems with dinghy inflation, inadequate restraint, loss of a dinghy, difficulties with life-preserver inflation and electrical failures of location equipment (Table 14).

c. Similarly, the problems of underwater escape were few (as reported). Snagging of the personal survival pack and difficulties in jettisoning doors and windows were the only 2 repeatedly cited problems (Table 15).

d. Helicopter flotation systems should be made more reliable. Helicopters of all services should be fitted with flotation systems as role changes and combined operations often require over water flights for all services.

e. As might be expected, fatalities following ditchings are much more likely at night (Table 12). As the nature of military operations will always require helicopter flights at night, automatic lighting systems to illuminate escape pathways could enhance survival, but the improvement would be small, nevertheless worthwhile.

f. Many fatalities occur following ditching because the occupants cannot escape from the helicopter within their breath holding capability. Supplies of compressed gas to extend this period would enhance survival, but again, the improvement in overall survivability would be small but worthwhile (Table 17).

g. By far the greatest saving in life would accrue from the fitment of devices that prevent the helicopter sinking and, to a lesser extent, inverting. Even an inverted helicopter floating with significant freeboard would permit survival for most, if not all, occupants. A rapidly sinking helicopter severely jeopardises survival. Two concepts that could help here are the fitment of inflatable seats for all helicopter passengers and the application of reliable flotation systems for all military helicopters. Of these 2, the former is easier and cheaper to fit to in-service helicopters and would be more able to survive high speed water impacts. The inflatable seat provided for use in the Lynx helicopter should be used whenever roles permit. An air bag in the tail cone, or other redundant space, could also provide additional buoyancy in other aircraft.

h. Other measures that would enhance survival are improved restraint for passengers and mobile crewmen, automatic door/hatch jettison systems, crashworthy seats and delethalization of the helicopter interiors. However, these measures would produce only a modest improvement in survival.

RECOMMENDATIONS

1. All military helicopters should be fitted with an efficient flotation system that prevents the helicopter from sinking at all weights, and delays or prevents the helicopter from inverting. The system should be automatically operated on ditching by 2 or more methods of activation, or by the crew. The system should remain functional following high speed water impacts, and be resistant to perforation and have more than one inflation source. Multiple buoyancy containers should be specified to provide system redundancy. Helicopter emergency flotation should also be provided by installing inflatable passenger seats in all military passenger/troop carrying helicopters in service (especially the Lynx), and in helicopters under development. Inflated air bags in redundant spaces of the helicopter interior should be considered as sources of buoyancy in all helicopters.

2. Helicopter escape door/hatch lighting systems and door/hatch locating devices should be standard features in future, and considered as modifications to all in-service, military helicopters.

3. Helicopter underwater emergency escape breathing devices (and suitable training schemes) should be considered for all helicopter occupants.

4. Improved restraint for helicopter passengers, powered escape door/hatch jettison devices, crashworthy seats and delethalized helicopter interiors should be provided in all future military helicopters and considered as modifications for all applicable in-service aircraft.

5. Gases other than carbon dioxide should be considered for the inflation of survival aids such as lifepreservers, dinghies and helicopter flotation systems.

6. Smaller and less bulky dinghies should be developed that would permit smaller personal survival packs to be used, or other methods of dinghy carriage should be investigated.

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LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS USED IN TABLES

A/C	Aircraft	NO	Did not occur
ACM	Aircrewman	No	Aircraft Tail Number
Aeros	Aerobatics	NVG	Night Vision Goggles
Diff	Difficulty in/with	O	Observer
Eng	Engine	Pax	Passengers
Flot	Flotation	PE	Pilot Error
FNA	Flight Nursing Attendant	PLB	Personal Locator Beacon
FNO	Flight Nursing Officer	PSP	Personal Survival Pack
FOD	Foreign Object Damage	P1	First Pilot
H	Harness	P2	Second Pilot
HE	Human Error	Rad alt	Radar Altimeter
HEED	Helicopter Emergency Egress Device	S	Serviceable
HEEL	Helicopter Emergency Egress Lighting	s	Slight
HD	Wessex type	Sp	Spine/spinal
Imm	Immediate	T	Thoracic
Incap	Incapacitation	T/O	Take off
Inj	Injuries/Injured	U/C	Undercarriage
LSW	Life saving waist-coat/lifepreserver	Uninj	Uninjured
Nil	Not present	#	Bony fracture

Table 1 RN Sea King Ditchings

Date	No	Occupants	Fatal	Inj	Uninj	Day/night	Cause
31.1.72	XV645	6	-	1#T5	5	Day	Eng failure at hover
10.4.72	XV662	4	-	-	4	Day	Severe vibration at hover
30.5.73	XV706	4	-	-	4	Day	Eng failure at hover
19.11.74	XV644	4	-	-	4	Day	Tail rotor failure at hover
12.12.74	XV667	5	-	-	5	Day	Vibration in transit
19.3.75	XV699	4	-	-	4	Night	Eng failure at hover
9.7.75	XV655	4	-	-	4	Day	Eng failure at hover
17.11.75	XV695	4	-	-	4	Day	Trans oil leak
31.3.76	XV669	4	-	-	4	Day	Vibration at hover
25.10.77	XV646	4	-	3 #Sp	1	Day	Tail rotor failure at hover
30.3.78	XZ574	8	-	-	8	Day	Trans oil failure
25.8.78	XV703	7	-	-	7	Day	Trans oil failure
18.11.78	XV647	4	-	-	4	Day	Eng failure at hover
14.1.80	XV572	5	-	-	5	Day	Trans oil failure
13.10.80	XV655	4	-	-	4	Night	Eng failure at hover
21.1.81	XV665	4	-	-	4	Day	Control difficulties
18.2.81	XV701	7	-	-	7	Day	Tail rotor failure
6.3.81	XZ915	4	1	1s	2	Day))	Mid-air collision
6.3.81	XZ917	4	4	-	-	Day)	Mid-air collision
23.4.82	ZA311	2	1	1s	-	Night	Disorientation?
12.5.82	ZA132	4	-	-	4	Day	Eng failure at hover
18.5.82	XZ573	4	-	-	4	Night	Rad alt failure at hover
19.5.82	ZA294	30	21	8	1	Night	Disorientation? Bird strike?

Date	No	Occu-pants	Fatal	Inj	Uninj	Day/night	Cause
11.7.82	XV698	4	-	-	4	Day	Eng failure at hover
3.2.83	XV658	4	1	-	3	Day	PE, aeros and hit water
20.6.83	ZA130	4	-	-	4	Day	Control difficulties
26.9.84	ZA134	4	-	-	4	Day	Eng failure at hover
27.6.85	XZ919	4	4	-	-	Day	Mid-air collision with Hercules
16.10.85	XV672	3	-	-	3	Day	Fuel starvation
8.11.85	XZ918	4	-	-	4	Night	Trans oil failure
26.10.86	ZD632	3	-	1	2	Day	Fuel starvation
24.2.87	XV668	3	3	-	-	Night	Disorientation? at hover
3.2.88	XV652	4	-	-	4	Dawn	Tail rotor failure
13.10.88	XZ916	4	2	1 #leg	1	Night	Vibration distraction Flown into sea

Table 2 RN Sea King Ditchings
Details of Escape, Impact and Safety Equipment Incidents

No	Escape Problems	Safety Equipment Incidents	Remarks	Flotation	Impact	Inversi
XV645		Pilots seat collapsed	Abandoned before inversion	S	Heavy	Delaye
XV662	P2 unable to jettison window. Pax escaped with difficulty	O lost dinghy	No warning call	Not used	Light	Imm
XV706			Successful single engine T/O	Not used	Light	No
XV644			A/C abandoned before inversion	Not used	Light	Delaye
XV667			A/C abandoned before inversion	S + U/C	Light	Delaye
XV699			A/C abandoned before inversion	S	Light	Delaye
XV655			Successful single engine T/O	Not used	Light	No
XV695				Not used	Light	Imm
XV669	P1 detached from dinghy P2 disori-entated	O released harness early and flailed		Not used	Light	Imm
XV646	P2 unable to jettison window			Not used	Heavy	Imm
XZ574			Text book ditching	S	Light	No
XV703			Text book ditching	S	Light	Delaye
XV647		Dingy failure (inflation valve patch) Sonar cable cutter failed	A/C taxied towards rescue ship	S + U/C	Light	No
XV572			Windows jetti-soned before ditching	S	Light	Delaye

No	Escape Problems	Safety Equipment Incidents	Remarks	Flotation	Impact	Inversi
XV655			Crew abandoned after beaching A/C taxied to beach	S + U/C	Light	No
XV665	P2 unable to jettison door			Port bag only	Light	Imm
XV701	P1&2 diff to jettison windows			Not used	Heavy & yaw	Imm
XZ915		Aircrewman had no dinghy		Stbd sponson failed	Heavy	Imm
XZ917			Unsurviv-able	Not used	Out of control	Imm
ZA311	Poor re-collection of events by pilot	Crewman unrestrained & fatal injuries. P1 LSW damaged by perspex	No call	Not used	Heavy	Imm
ZA132	P2 couldn't jettison window	O left PSP behind		Not used	Light	Imm
XZ573		Dinghy slow to inflate	A/C later sunk by gunfire	S	Light	No
ZA294	P1 unable to jettison windown, kicked hole in roof, jetti-soned PSP		Pax injured during impact, in-adequate restraint, no call	Not used	Heavy	Imm
XV695	Difficulty with crew windows		Ditched be-side ship	S	Light	Delaye
XV658	PSP snagged on egress	Dinghy failed to inflate		Not used	Light	Imm
ZA130			A/C remained afloat 2½hrs with rotors turning	Not used	Light	No

No	Escape Problems	Safety Equipment Incidents	Remarks	Flotation	Impact	Inversion
ZA134				Stbd bag only half inflated	Light	Delayed
XZ919			Unsurvivable No call	Not used	Out of control	N/A
XV672				S	Light	No
XZ918				S	Light	Delayed
XD632	P2 unable to escape with PSP	Liferaft slow to inflate		Not used	Light	Imm
XV668	No attempt to escape		Unsurvivable	Not used	Out of control	Imm
XV652	P1 legs snagged P2 diff to jettison window	LSW slow to in-flate ACM left dinghy behind		S	Light	Imm
XZ916	P1 body trapped in wreckage		ACM heavy blow to head	Not used	Flew in	Imm

Table 3 RN Wessex Ditchings

Date	No	Occupants	Fatal	Inj	Uninj	Day/night	Cause
6.1.72	XP104	3	-	-	3	Day	Hot gas leak and fire warning
16.2.72	XS121	3	-	2#sp	1	Day	Engine surge
19.7.72	XS886	4	-	-	4	Day	Engine failure at hover
19.9.72	XS490	12	-	-	12	Day	Tail rotor strike on T/O
19.2.74	XT477	2	2	-	-	Night	Computer freeze and disorientation
15.7.74	XP138	4	-	-	4	Night	Engine surge after FOD
22.5.75	XS880	3	-	2 sprains T9-11	1	Day	Engine surge
21.8.75	XM871	4	-	-	4	Day	Tail rotor failure
17.9.75	XP112	4	-	-	4	Day	Engine fire
16.1.76	XT758	3	-	2 s	1	Day	Lost control after T/O
11.10.76	XM884	2	-	-	2	Dusk	Engine failure and fire
13.12.76	XM844	4	1	1 arm inj	2	Night	Lashings left on T/O
18.7.78	XP105	3	-	-	3	Day	Rotor blade strike on ship
13.9.78	XP110	3	-	-	3	Day	Gearbox failure
20.9.78	XP143	4	-	-	4	Day	Engine surge
22.5.80	XT763	5	-	-	5	Day	Trans oil failure
27.6.80	XP156	3	3	-	-	Day	Engine failure
11.3.81	XM872	3	-	-	3	Day	Compressor failure
15.7.81	XP118	4	-	-	4	Day	Engine failure
7.10.81	XT448	6	-	-	6	Day	Tail rotor failure
16.10.87	XT461	3	-	1#sp	2	Day	Water ingestion at hover

Table 4 RN Wessex Ditchings
Details of Escape, Impact and Safety Equipment Incidents

No	Escape Problems	Safety Equipment Incidents	Remarks	Flotation	Impact	Invers
XP104		Sarbe switch failed on		S	Light	No
XS121			Shoulder harness adjustment inadequate	Port bag failed	Heavy	Imm
XS886			No warning call	S	Light	No
XS490			All escaped on surface	S	Light	Imm
XT477	Pilots harness undone but still in cockpit		Observer not found	Not used	Fly in	Imm
XP138				S	Light	Delay
XS880	Rear crew not strapped in		Doors & windows jettisoned in descent	S	Light	Delay
XM871				S	Light	No
XP112		Intermittent Sarbre		Stbd bag failed	Light	Imm
XT758	Cabin door slammed shut	ACM on despatchers harness only	No warning call Stbd bag detached later	S	Out of control	Delay
XM884				S	Light	No
XM844	P2 lost Incapac? Blow to head?	1 sea cell failed after 1 min	No warning call	S	Out of control	Imm
XP105			Window jettisoned before impact	S	Light	No
XP110		Dinghy partially inflated		S	Light	No
XP143			Manufacturers fault in flot gear	Stbd bag failed	Light	Imm

No	Escape Problems	Safety Equipment Incidents	Remarks	Flotation	Impact
XT763			Crew escaped in low hover before ditching	S	Light
XP156	No attempt to autorotate			Not used	Out of control
XM872		O couldn't operate HD PSP (OK afterwards)	PLB defective	S	Light
XP118		All had diffs inflating dinghies (handle design)	No warning call	S	Light
XT448		Pl unable to operate HD PSP - (OK afterwards)		Port bag failed	Light
XT461		ACM LSW partially inflated, liferaft slow to inflate	No warning call	S	Light

Table 5 RN Wasp, Whirlwind, Gazelle and Lynx Ditchings

Date	No	Occupants	Fatal	Inj	Uninj	Day/night	Cause
Wasp							
29.1.72	XS534	3	–	–	3	Day	Engine failure
15.5.72	XV631	2	–	–	2	Day	Engine failure at height
17.5.72	XT418	1	–	1#T7	–	Day	Engine failure at hover
3.12.72	XS527	2	–	–	2	Night	Engine failure after T/O
5.6.73	XS568	2	–	–	2	Night	Engine failure
28.3.74	XT781	2	–	–	2	Night	Flew in, defective glide path indicator on ship
4.6.75	XT427	3	–	–	3	Day	Tail rotor failed
26.8.76	XS544	2	–	1#wrist	1	Day	Pilot error during aerobatics
29.3.77	XS531	2	–	–	2	Day	Lost control on approach
5.4.77	XV635	1	–	1 neck sprain	–	Day	Lost control in transit
3.2.79	XT441	2	–	–	2	Night	Engine fire
28.10.82	XS568	3	–	–	3	Day	Engine failure
27.5.83	XV638	2	–	–	2	Day	Oil pump failure
6.9.83	XT427	1	–	–	1	Day	Partial engine failure
13.4.84	XT794	2	–	–	2	Day	Partial engine failure
5.3.85	XT423	4	–	–	4	Day	Engine failure
Whirlwind							
16.4.73	XN310	3	–	–	3	Day	Engine surge with computer failure

Date	No	Occupants	Fatal	Inj	Uninj	Day/night	Cause
Gazelle							
13.6.77	XX415	2	2	-	-	Day)	Mid air collisio
						)	
13.6.77	XW859	1	1	-	-	Day)	
Lynx							
30.9.82	XZ247	3	-	-	3	Day	Fire in gearbox
4.5.83	XZ249	4	-	4 back inj	-	Day	Tail rotor failu
10.3.88	XZ243	2	2			Night	Hit sea on appro to ship

Table 6 RN Wasp, Whirlwind, Gazelle and Lynx Ditchings
Details of Escape, Impact and Safety Equipment Incidents

No	Escape Problems	Remarks	Safety Equipment Incidents	Flotation	Impact	Inversion
Wasp						
XS534		P operated inflation twice		Stbd bag failed	Light	Delayed
XV631		3 unsuccessful relights attempted		S	Light	Imm
XT418	P Helped out of seat by rescuers	No warning call Landed in shallow water		S	Heavy	No
XS527		No warning call		S	Light	Delayed
XS568		No warning call		S	Light	Towed ashore
XT781		No warning call		S	Light	Delayed
XT427				S	Heavy	Delayed
XS544		No warning call	Crewman in despatchers harness	Damaged by rotor	Heavy	Imm
XS531		No warning call		Sea shorted battery before activation	Heavy	Imm
XV635	P escaped via top hatch	Short Mayday call attempted	Immersion suit leaks	Port bag immersed before inflation	Light	Delayed
XT441				S	Light	Delayed
XS568	Difficult to jettison rear passenger door			S	Light	Delayed
XV638			Liferaft partially inflated	S	Light	Delayed
XT427				S	Light	Delayed

No	Escape Problems	Remarks	Safety Equipment Incidents	Flotation	Impact	I
XT794				Only port bag inflated	Light	
XT423				S	Light	
Whirlwind						
XN310			All occupants left dinghies behind	Nil	Light	
Gazelle						
XX415))		Unsurvivable		Nil	Out of contro	
XW859)				Nil	Out of contro	
Lynx						
XZ247			Dinghy blew away	S	Light	
XZ249	Cabin door release handle bent, jettison then impossible			Stbd bag damaged	V heav	
XZ243	Crew released harness but trapped in cockpit	Unsurvivable		S	Flew in	

Table 7 Army and RM Ditchings

Date	No	Occupants	Fatal	Inj	Uninj	Day/night	Cause
Sioux							
17.3.72	XT208	1	-	-	1	Day	Distraction from door opening, flew in
6.2.73	XT127	2	-	-	2	Day	Hit water in low level flight
5.5.73	XT513	1	-	-	1	Day	Tail rotor struck ship
2.1.77	XT421	2	1	-	1	Day	Wire strike at low level
26.2.77	XX409	3	-	1 minor head inj	2	Night	Flew into sea on on approach to landing
Scout							
24.3.73	XT643	1	-	-	1	Day	Engine failure
3.11.75	XT627	2	-	-	2	Day	Engine failure
10.4.78	XV132	2	2	-	-	Day	Flew in in bad weather
2.12.78	XV614	2	2	-	-	Night	Flew in at night ?Disorientation with NVG
14.8.80	XN908	2	-	1 wrist sprain & whiplash	1	Day	Tail rotor hit water in low level hover
Gazelle							
10.6.80	XX390	3	-	1 # sp 1 # leg 1 lacerations	-	Day	Hit sea in low level flight
Lynx							
4.1.84	WZ681	2	2	-	-	Dusk	Hit sea in poor weather

Table 8 Army and RM Ditchings
Details of Escape, Impact and Safety Equipment

No	Escape Problems	Remarks	Safety Equipment Incidents	Flotation	Impact	Inver
Sioux						
XT208	Minor snagging	No warning call		Nil	Heavy	Im
XT127		No warning call	No lifejackets, used cushions as flotation	Nil	Heavy	Imr
XT513	Helmet hit door frame	No warning call		Nil	Light	Imm
XT421	Passenger failed to swim ashore	Armour worn No warning call		Nil	Heavy	Imm
XX409		No warning call	One assault lifepreserver failed (servicing error)	Nil	Heavy	Imm
Scout						
XT643				S	Light	Del
XT627				S	Light	Sha wat
XV132	Pilot had released harness, found outside cockpit without body armour, passenger still strapped in seat			Not used	Heavy	Imm
XV614	Pilot found strapped in seat with head injury. Passenger out of seat - massive head injuries			Not used	Heavy	Imm

No	Escape Problems	Remarks	Safety Equipment Incidents	Flotation	Impact	Inversion
XN908	Crewman not restrained, ejected in crash	No warning call		Not used	Heavy	Shallow water
Gazelle						
XX390	Both seats separated from cockpit	Rear pax harness pulled through buckle, then thrown clear		Nil	Heavy	Shallow water
Lynx						
WZ681	Both bodies still strapped to seats - decapitated			Not used	Heavy	Imm

Table 9 RAF Ditchings

Date	No	Occupants	Fatal	Inj	Uninj	Day/night	Cause
Whirlwind							
18.1.71	XJ432	2	-	1 back sprain	1	Day	Engine fire
22.8.71	XJ426	5	-	2 minor	3	Day	Spurious fire warning
13.12.72	XP349	3	-	-	3	Day	Engine failure
Wessex							
19.4.79	XR500	3	-	2 minor	1	Day	Disorientation in fog layer
5.11.86	XS518	4	3	-	1	Night	Disorientation

Table 10 RAF Ditchings
Details of Escape, Impact and Safety Incidents

No	Escape problems	Safety Equipment Failures	Remarks	Flotation	Impact	Inversion
Whirlwind						
XJ432		Pilots seat cushion collapsed, hit rear seat bar		Nil	Light	Imm
XJ426	Pilot pulled passengers via rear hatch and put into dinghies. Passenger released from Neil Robertson stretcher			Nil	Light	Imm
XP349	Minor snagging			Nil	Light	Imm
Wessex						
XR500	Minor snagging	1 crewman on despatchers H, 1 unrestrained		Nil	Light	Imm
XS518	Pilot could not egress with PSP Misrouted connection?	ACM, FNO & FNA not recovered		Nil	Heavy	Imm

Table 11 Summary of Accident Results

	Accidents			Occupants	Fatalities	Injured	Uninju
	Total	Day	Night				
Sea King	34	25	9	171	37	16	118
Wessex							
RN	21	17	4	82	6	8	68
RAF	2	1	1	7	3	2	2
	23	18	5	89	9	10	70
Wasp	16	12	4	34	0	3	31
Scout	5	4	1	9	4	1	4
	21	16	5	43	4	4	35
Whirlwind							
RN	1	1	0	3	0	0	3
RAF	3	3	0	10	0	3	7
	4	4	0	13	0	3	10
Gazelle							
RN	2	2	0	3	3	0	0
RAF	1	1	0	3	0	3	0
	3	3	0	6	3	3	0
Lynx							
RN	3	2	1	9	2	4	3
Army	1	0	1	2	2	0	0
	4	2	2	11	4	4	3
Sioux	5	4	1	9	1	1	7
Total	94	72	22	342	58	41	243

Table 12 Fatality Incidence

	Fatalities		Total Accidents	
	Day	Night	Day	Night
ɘa King	10	27	25	9
essex	3	6	18	5
'asp/Scout	2	2	16	5
/hirlwind	0	0	4	0
;azelle	3	0	3	0
Lynx	0	4	2	2
Sioux	1	0	4	1
Total	19	39	72	22

Table 13 Ditching Causes

	Sea King	Wessex RN	Wessex RAF	Wasp	Scout	Whirlwind RN	Whirlwind RAF	Gazelle RN	Gazelle Army	Lynx RN	Lynx Army	Sioux
Engine failure	9	9	-	9	2	1	1	-	-	-	-	-
Human error	-	1	-	-	1	-	1	-	1	1	1	3
Transmission (oil) failure	5	2	-	1	-	-	-	-	-	-	-	-
Tail rotor failure	4	2	-	1	-	-	-	-	-	1	-	-
Disorientation	3	1	2	-	1	-	-	-	-	-	-	-
Loss of control	2	1	-	3	-	-	-	-	-	-	-	-
Flew in	2	-	-	1	1	-	-	-	-	-	-	1
Mid air collision	3	-	-	-	-	-	-	2	-	-	-	-
Fire (warnings)	-	2	-	1	-	-	1	-	-	1	-	-
Rotor strikes	-	2	-	-	-	-	-	-	-	-	-	1
Vibration	3	-	-	-	-	-	-	-	-	-	-	-
Fuel starvation	2	-	-	-	-	-	-	-	-	-	-	-
Radar alt failure	1	-	-	-	-	-	-	-	-	-	-	-
Water ingestion	-	1	-	-	-	-	-	-	-	-	-	-
	34	21	2	16	5	1	3	2	1	3	1	5

Table 14 Safety Equipment Incidents

Helicopter type	Lost dinghy	Dinghy difficulties	Lifepreserver difficulties	Inadequate restraint	Electrical/ PLB failure
Sea King	7	4	2	3	-
Wessex	-	5	1	4	4
Wasp/Scout	-	1	-	2	-
Sioux	-	-	2	-	-
Gazelle	-	-	-	1	-
	7	10	5	10	4

Table 15 Escape Problems

Helicopter type	Doors/windows jettison difficulties	PSP snagging/ jettisonned
Sea King	6	7
Wessex	1	1
Wasp/Scout	1	
Whirlwind		1
Lynx	1	1
	9	10

Table 16 Inversion Times and Impact Forces

Helicopter	INVERSION Immediate	Delayed	NO	IMPACT Heavy	Light	Total
Sea King	17	9	8	10	24	34
Wessex RN	8	6	7	5	16	21
RAF	2	-	-	1	1	2
Wasp	4	10	2	4	12	16
Scout	2	1	2	3	2	5
Whirlwind RN	1	-	-	-	1	1
RAF	3	-	-	-	3	3
Gazelle RN	2	-	-	2	-	2
Army		-	1	1	-	1
Lynx RN	2	1	-	2	1	3
Army	1	-	-	1	-	1
Sioux	5	-	-	4	1	5
	47	27	20	33	61	94

Table 17 Ditchings with Fatalities - Benefits from HEED and HEEL

A/C No	Fatalities	Cause	Inversion Time	Sinking Time	Benefit from HEED	Benefit from HEEL
RN Sea King						
XZ 915	1)	Mid air	Immediate	Immediate	0	0
XZ 917	4)	collision	Immediate*	Immediate	0	0
ZA 311	1	Disorientation	Immediate	Immediate	0	0
ZA 294*	21	Disorientation	Immediate*	Immediate	20	20
XV 658	1	Aerobatics at LL	Immediate	Immediate	1	1
XZ 919	4	Mid air collision	Immediate*	Immediate	0	0
XV 668	3	Disorientation	Immediate	Immediate	0	0
XZ 916	2	Distraction	Immediate	Immediate	0	0
RN Wessex						
XT 477	2	Disorientation	Immediate	Immediate	1	1
XM 844	1	Lashing left on	Immediate	Immediate	1	1
XP 156	3	No autorotation	Immediate	Immediate	0	0
RAF Wessex						
XS 518	3	Disorientation	Immediate	Immediate	3	3
Army Sioux						
XT 421	1	Wire strike/low flying	Immediate	Immediate	0	0
Scout						
XV 132	2	Disorientation?	Immediate*	Immediate	0	0
XW 614	2	Disorientation?	Immediate*	Immediate	0	0
RN Lynx						
XZ 243	2	Hit sea on approach/ disorientation	Immediate*	Delayed	2	0
Army						
XW 681	2	Hit sea/ disorientation?	Immediate*	Immediate	0	0
Totals 17	55	Disorientation 9 Human error 4 Collision 3 Distraction 1	17 Immediate *7 (fly-in)	16 Immediate 1 Delayed	28 (Aircrew 8)	26 (Aircrew 6)
* excluding ZA 294						
Totals 16	34	Disorientation 8 Human error 4 Collision 3 Distraction 1	16 Immediate *6 (fly-in)	15 Immediate 1 Delayed	8	6

			jettison	restraint	ization	seats	flotation	exits	seats	rescue
Sea King										
XZ 915	1)	Mid air	0	0	0	0	0	0	0	0
XZ 917	4)	collision	0	0	0	0	0	0	0	0
ZA 311	1	Disorientation	0	1	0	0	1	0	0	0
ZA 294*	21	Disorientation	0	0	1	0	20	0	20	0
XV 658	1	Aerobatics	0	1	0	0	1	0	0	0
XZ 919	4	Mid air collision	0	0	0	0	0	0	0	0
XV 668	3	Disorientation?	0	0	0	0	2	0	0	0
XZ 916	2	Distraction	0	1	0	0	1	0	0	0
Wessex RN										
XT 477	2	Disorientation	2	0	0	0	2	0	0	0
XM 844	1	Lashing left on	0	0	0	0	0	0	0	0
XP 156	3	No autorotation	0	0	0	3	3	0	0	0
Wessex RAF										
XS 518	3	Disorientation	3	3	0	0	3	0	0	0
Sioux										
XT 421	1	Wire strike	0	0	0	0	1	0	0	0
Scout										
XV 132	2	Disorientation	0	0	1	1	2	0	0	0
XW 614	2	Disorientation	0	0	0	0	0	0	0	0
Lynx RN										
XZ 243	2	Hit sea on approach (disorientation)	0	0	0	0	0	0	0	0
Army										
WZ 681	2	Hit sea (disorientation)	0	0	0	0	0	0	0	0
Totals	55		5	6	2	4	36	0	20	0
Totals *excluding ZA 294		34	5	6	1	4	16	0	0	0

DITCHING PERFORMANCE

SEA KING

The Sea King (Mks 1, 2 and 5) is fitted with sponsons and inflatable bags, for hydrodynamic stability and buoyancy. The sponsons and bags provide buoyancy of 5020 kg to which should be added 2700 kg from the fuel tanks and 450 kg from the gear box, tyres and other enclosed volumes. The total buoyancy of 8800 kg cannot support a Sea King at a maximum all up weight of 9525 kg, but should prolong its sinking time sufficient for successful crew escape at that weight or prevent sinking of a lighter helicopter.

Table 19 Sea King Ditching Experience

Variant	Flotation system		Inversion time			Sinking time			Total
	Serviceable	not used/ failed	Imm	Del	Indef	Imm	Del	Indef	Ditchings
Mks 1 & 2	10	-	1	7	2	1	5	4	-
	-	9	7	-	2	7	-	2	19
Mk 5	3	-	-	2	1	-	2	1	-
	-	10	10	-	-	7	2	1	13
Mk 4	-	2	2	-	-	2	-	-	2
Total	13	21	20	9	5	17	9	8	34

The ditching experience for the 3 main variants of the Sea King is shown in Table 19. The serviceability of the flotation system is listed with non use and failures grouped together. The inversion and sinking times (immediate (Imm) and delayed (Del)) are also shown with an indefinite (Indef) column where neither inversion nor sinking occurred.

Overall, Table 19 shows that, when serviceable, the Sea King flotation system delays or prevents sinking.

The flotation systems of the variants of the Sea King are similar except that the Mks 1 and 2 have no automatic activation of the system upon water immersion. In the 19 Mk 1&2 aircraft, there were 9 occasions when the flotation system failed or was not activated by the crew. Seven of these aircraft inverted and sank immediately. In the remaining 10 ditchings, the flotation system was serviceable and in 9 of those, inversion and sinking was delayed or avoided completely. A total of 7 Mk 1 & 2 Sea Kings were recovered.

In the 13 Mk 5 Sea Kings, the automatic flotation system operated successfully on only 3 occasions. In 10 ditchings, the systems either failed to operate, were damaged on impact or only partially deployed. Three aircraft were involved in mid-air collisions. Ten helicopters inverted immediately and, of these, 7 sank rapidly. Only 5 of the 13 Mk 5 Sea Kings were recovered. The automatic flotation system fitted to the Mk 5 Sea King neither delayed sinking nor enhanced recovery of the aircraft. However, if a more reliable or robust system had been devised and fitted, there would have been a potential saving of 7 aircraft.

The 2 Mk 4 Sea Kings flew into the sea. The automatic flotation systems are presumed to have functioned, but probably suffered severe impact damage. In both cases the helicopters inverted and sank rapidly. The Sea King Mk 4 is not equipped with sponsons, but has 2 large inflatable bags of 1860 kg buoyancy attached to the undercarriage legs. With the other sources of buoyancy, as in other Sea Kings, 6900 kg total buoyancy would be available against an all up weight of 9750 kg. Clearly, the buoyancy of a serviceable flotation system in the Mk 4 Sea King is less than that of the Mks 1, 2 and 5 and even if the impact damage to the flotation bags had not occurred, the Mk 4 aircraft would probably still have sunk.

The Sea King Mk 4 is used as a troop and stores carrier and can accommodate up to 28 troops in the cabin. If the troop seats were changed from their present metal and canvas construction to inflatable seats, approximately 77 kg buoyancy per man/seat would be provided which, for the whole passenger complement, would provide 2160 kg additional buoyancy. Furthermore, the change in materials would produce an additional weight saving of 63 kg for the whole aircraft. Thus, a flotation deficit of 2850 kg in the Sea King Mk 4 could be reduced to 622 kg by a change to inflatable seats. Therefore, at any weight below 9127 kg and with serviceable flotation bags, the Mk 4 Sea King should float indefinitely. The inflatable seats would not affect the stability of the helicopter after ditching, but an inverted floating helicopter provides a much safer prospect for escaping crew and passengers than an inverted rapidly sinking one. Moreover, as the inflatable seats would be carried inside the helicopter and restrained against the floor and sides of the cabin, they would be much less vulnerable to impact damage on ditching.

The case for fitment of inflatable seats to the Sea King Mk 4 is enhanced by consideration of the proposal to fit these types of seat to the US Navy V22 Osprey tilt rotor aircraft. A proof of concept study for he Osprey has been successfully conducted by the manufacturers (FPT Ltd) to show that 26 inflatable troop seats, each consisting of an inflated seat squab with a canvas seat back produced a total weight saving of 49 kg when compared with standard seats, whilst meeting full US Army Military

Specifications for crashworthiness, restraint, comfort and utility. The additional buoyancy of 1536 kg was regarded as a useful by-product. As they are inflated with air, the seats could even be made to supply emergency breathing gas underwater. The inflatable seats designed for the Osprey could be adapted for the Sea King Mk 4.

LYNX

The Lynx HAS Mk 2 was originally fitted with 2 flotation bags 1.2 m diameter with a displacement equivalent to 951 kg. Flotation tests showed that at a weight of only 2840 kg, these 2 bags were unable to stop the airframe sinking. However, when an earlier design of a 3 man inflatable seat (displacement 316 kg) was installed in the cabin, tests showed that the additional buoyancy was sufficient for a maximum weight helicopter of 4431 kg to float indefinitely.

The Lynx 3 has a greater weight of 4875 kg, so larger bags have been designed to give a displacement of 1355 kg. Although these larger bags just met the specification, they could not prevent the helicopter from sinking. The latest modification is for 4 bags to be fitted, 2 in front and 2 at the rear. These 4 bags delayed sinking of the maximum weight airframe by 11 minutes. However, the tests showed that the sponson attachments of the bags sometimes led to perforation of the bags, especially at high water entry speeds.

Inflatable seats for the Lynx were re-designed for 4 men. This configuration has a volume of 2.6 m^3 and provides an additional buoyancy of 225 kg. When fitted, this buoyancy tends to compensate for any bag failure and delays sinking. The Royal Navy possesses 55 sets of the inflatable seats for the Lynx, but few are actually installed. This is because many of the roles of the Lynx are incompatible with the inflatable seat. For instance, a Sea King rear crew seat is preferred to the inflatable seat for the instructor in the Lynx, as the seat has its own PSP and affords a better view over the pilots in front.

Up to the end of 1988, only the 2 bag system was fitted to the Lynx Mks 2 and 3. The Army Lynx (AH Mk 1) is not fitted with a flotation system.

The ditching performance of the 4 Lynx aircraft in this series is as listed below in Table 20.

Table 20 Lynx Ditching Experience

Variant	No	Flotation system	Inversion time	Sinking time
HAS Mk2	XZ 247	Serviceable	Immediate	Immediate
	XZ 249	One bag damaged	Immediate	Immediate
HAS Mk3	XZ 243	Serviceable	Immediate	Indefinite
AH Mk1	XW 681	Not fitted	Immediate	Immediate

Two Lynx helicopters immediately inverted and sank. In only one was sinking prevented. Service experience confirmed the risk of bag perforation in one case. Overall, the ditching performance has been poor.

The fitting of the inflatable seat, when not incompatible with other equipment, would assist flotation on ditching and should be adopted as a standard procedure even when the 4 bag system is installed.

WESSEX

The Wessex has a maximum weight of 5727 kg and 2 flotation bags, each of 1860 kg displacement on immersion. In the tailcone, there is a permanently inflated airbag (1.2m^3) which provides a further 400 kg of buoyancy. The total buoyancy of the system (4130 kg) coupled with other sources of buoyancy in the airframe (fuel tanks, tyres and other enclosed volumes) ensures that at all weights (except maximum) the Wessex will float for some time before sinking.

The ditching performance of the RN Wessex is listed in Table 21. (The flotation system fitted to the different variants is identical).

Table 21 Wessex Ditching Experience

Variant	Flotation system		Inversion time			Sinking time			Total
	Serviceable	not used/ failed	Imm	Del	Indef	Imm	Del	Indef	Ditchings
RN Wessex	15	-	3	6	6	2	12	1	15
	-	6	6	-	-	3	3	-	6
Total	15	6	9	6	6	5	15	1	21

This table shows that 6 Wessex ditched without a serviceable flotation system and they all immediately inverted then sank. In these 6, 4 suffered single bag failures and the system was not armed for automatic function in the other 2. All 3 bags are required for flotation.

On the other hand, when supported by 3 flotation bags, 12 of 15 Wessex neither inverted nor sank rapidly on ditching. Two of the 3 that did, followed uncontrolled water impacts. The Wessex flotation system when functioning correctly was very effective in both delaying inversion and sinking.

The Wessex is the only British helicopter to be fitted with a permanently inflated air bag in the tailcone, which is inflated for all flights except those involving flight above 8000'. The excellent ditching performance of the Wessex must be due in a small part to this tailcone bag. It requires little maintenance, no aircrew action, occupies an otherwise wasted space and withstands severe water impacts. It is recommended that this bag concept be applied to other helicopters either in-service or in the future.

Table 22 Wasp/Scout Ditching Experience

Variant	Flotation system		Inversion time			Sinking time			Total
	Serviceable	not used/ failed	Imm	Del	Indef	Imm	Del	Indef	Ditchings
Wasp	11	–	1	8	2	–	5	6	11
	–	5	3	2	–	2	3	–	5
Total	11	5	4	10	2	2	8	6	16
Scout	2	–	–	1	1	–	–	2	–
	–	3	2	–	1	2	–	1	–
Total	2	3	2	1	2	2	–	2	–

The ditching experinece of the RN Wasp is listed above in Table 22. The flotation system functioned in 11 ditchings and, of those, only one helicopter inverted immediately. In all 11, sinking was either delayed or prevented. In the ditchings where the flotation system was either not activated, armed or it failed, all 5 inverted and sank. When serviceable, the Wasp flotation system is effective.

There were 5 ditchings in the Scout group, the flotation system was not used on 3 and functioned in two. Two ditchings occurred in shallow water where neither inversion nor sinking was possible. The 3 others all inverted and 2 sank.

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