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IAM REPORT No 648

A REVIEW OF ROYAL NAVY HELICOPTER ACCIDENTS 1972 - 1984

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ABSTRACT

This review considers the fatalities and injuries received by the crew and passengers of Royal Navy helicopters involved in accidents during the period 1972 to 1984. During this period there were 121 major accidents, which resulted in 51 fatalities.

The majority of accidents were found to be caused by aircrew error (51%), technical defects accounted for 44.6%. The higher helicopter accident rate for the Royal Navy, in comparison to the Royal Air Force and Army Air Corps, is attributed to the harshness of the maritime environment.

The high incidence of spinal injury (50%) is due to the nature of water impact; energy absorption seating systems are urgently required to reduce this figure. Underwater escape from an inverted helicopter remains a particular risk and considerable work is still required to minimise this hazard. The most cost effective modification to RN helicopters would appear to be greatly improved flotation gear.

A REVIEW OF ROYAL NAVY HELICOPTER ACCIDENTS 1972 - 1984

**For want of a nail the shoe was lost;
for want of a shoe the horse was lost;
and for want of a horse the rider was lost;
being overtaken and slain by the enemy,
all for want of care about a horseshoe nail.**

Franklin - Poor Richards' Almanac.

HISTORICAL NOTE

The first recorded use of aerial transport by Royal Navy (RN) personnel is the ascent of Admiral Sir Edward Vernon in Count Zambeccaris' balloon on the 23rd of March 1785. The ascent took place from an enclosed space in Tottenham Court Road, London. There was to have been a third passenger, a Miss Grist, who was persuaded to forgo this novel experience; there being insufficient lift for all three. The Count and the Admiral travelled a distance of 35 miles and achieved an altitude of approximately 10,000 ft.

The advantage to the Royal Navy of aerial power was appreciated from an early date and the advent of the helicopter brought the ability to operate aircraft from a limited deck space. In 1942, the British Director of Naval Development, Captain Caspar John, set up a mission in the USA to study the feasibility of using helicopters in the anti-submarine role. This resulted in the first shipborne helicopter trials in 1944 when two Sikorsky XR4 helicopters were employed in convoy duties on board the SS Daghestan.

The event that, to the public at least, confirmed the importance of the helicopter, was the dramatic rescue of over 600 people by Dragonflies of 705 Squadron and other Dragonfly operators in February 1953 when the sea breached the coastal defences of Holland. Early helicopters were difficult to handle and were unreliable by modern standards. Fig. 1 illustrates the consequences of mishandling the controls. This took place on HMS GLORY in 1952 off the Korean Coast. Unfortunately the pilot was killed.

INTRODUCTION

The last major review of RN helicopter accidents (Day, 1972) covers the period 1960-1969 and is, in the main, concerned with the advantages of providing assisted escape to helicopter aircrew. It is now appropriate to review more recent data; especially as the next few years will see the introduction of the EH101. Reviews of Army Air Corps (AAC) and Royal Air Force (RAF) helicopter accidents have already been published (Vyrnwy-Jones, 1984 & 1985).

This review is concerned with RN helicopter accidents which occurred between 1972 and 1984. Helicopters in service with the RN for the review period were the Whirlwind, Hiller, Wessex, Wasp, Sea King, Gazelle and Lynx. During this period the RN completed 854,940 rotary flying hours and there were 121 major accidents and 51 fatalities. Fig. 2 affords a brief summary of the accident data. A list of definitions is included at Annex A to this paper, as is a list of abbreviations used. The sources of data for this paper are the detailed accident reports held by the then Director of

Naval Air Warfare, and the medical reports located at the RN Air Medical School. All accidents involving RN helicopters during the period 1972-1984 are summarised in Tables 1-7. Data concerning the Wessex, Wasp, Whirlwind and Hiller have been included in this review, although these aircraft are no longer in service with the RN. Certain accidents, such as those involving only winching operations, have been excluded from consideration. As the data were collated from several sources it is possible that a few accidents may have been inadvertently omitted, but this number would be small and unlikely to influence the final conclusions.

ACCIDENT AND FATALITY RATES

Terminology. Accident and fatality rates in this paper refer to the number of accidents and fatalities occurring per 10,000 flying hours. This is the system commonly employed in Europe for aircraft accident statistics. The USA uses statistics based on the number of events per 100,000 flying hours; so any comparisons have to be analysed with care. A major confusing factor when comparing RN accidents to those of other operators is the often trivial nature of the malfunction in many of the maritime accidents. For instance, a forced ditching due to an engine oil feed malfunction may result in severe damage or the total loss of a Naval helicopter; due to the inability of most current helicopters to remain afloat in any but the most clement of seas. A similar problem affecting a helicopter operating over land would usually only result in a precautionary landing and would not feature as an accident statistic.

Accident rates. The RN flies an average of 71,245 rotary-wing hours per year and during the course of the Falklands Campaign achieved far more than this. A graphical representation of accident rates from 1965-1983 is presented in Fig. 3. As can be seen, there has been a gradual decline, but this is not as clear cut as in the other two Services (Vyrnwy-Jones, 1984 and 1985). The high accident rate in the early years was associated with the operation of fairly primitive helicopters such as the Dragonfly (Fig. 1). The present generation of RN helicopters is considerably more sophisticated, for example the Sea King (Fig 4). The overall accident rate during the period of study averages 1.08 per 10,000 flying hours, though since 1980, this has declined to 0.6 per 10,000 flying hours.

Fatality rate. Fatality rates have been treated in exactly the same way as accident rates and the trend since 1965 is displayed graphically in Fig. 5. The sharp increase in the fatality rate in 1982 is due to the losses incurred during the Falklands Campaign. The overall fatality rate for the period studied is 0.57 per 10,000 flying hours. If the fatalities due to the Falklands Campaign are excluded, then the overall rate becomes 0.32 per 10,000 flying hours.

DISCUSSION

Table 8 compares the accident and fatality rates in RN helicopters with those in the AAC and the RAF. At first sight the comparisons are not favourable, but this is entirely due to the maritime nature of most of the Naval accidents. For instance, if one adjusts the RN fatality rate by discounting the fatalities due to drowning, then the fatality rate is reduced by one half, to 0.27 per 10,000 flying hours, a figure almost exactly equal to the AAC and only marginally higher than the RAF. There is no doubt that the RN operate in a more demanding environment than the two sister services.

FEATURES OF RN HELICOPTER ACCIDENTS

MAJOR CAUSES

The major listed causes of RN helicopter accidents are as follows:-

a. Aircrew error - 51%

b. Mechanical failure and technical defects - 44.6%

c. Groundcrew error - 4.4%

The accident rate in the AAC, RAF and US Army has tended to stabilise over the last few years. This stabilisation is due to the decrease in the number of accidents caused by mechanical failure or technical defects. Efforts to reduce the number of accidents ascribed to aircrew error have proved more difficult. The relatively high mechanical and technical defect rate in the RN does, however, leave some scope for future improvement.

TYPE OF TERRAIN IMPACTED

The ratio of terrain impacted is as follows:-

a. Water 47% (57 accidents)

b. Land 37% (44 accidents)

c. Deck 16% (19 accidents)

A more detailed review of the type of terrain impacted for each helicopter type is included at Table 9. Not all the accidents are included in this analysis as information concerning terrain was not always provided in the accident reports studied.

AIRCRAFT ALTITUDE AND SPEED AT THE TIME OF THE EMERGENCY

Altitude Distribution. A height distribution of RN helicopter accidents is shown in Fig. 6; this indicates the height above ground, sea or treetop level at the time the emergency first occurred. Three further categories have been included. These are: accidents which occurred in the hover, approach to landing phase and during deck operations. Analysis of this information shows that 17.5% of the accidents occurred during deck operations, 18% occurred in the hover and 14% during the approach to landing phase. Another way to look at this is to observe that 83.3% of all emergencies occur below an altitude of 500ft and that 43.5% of all emergencies (resulting in accidents) take place in the hover, approach to landing or the deck phase of operations.

Speed Distribution. This is displayed graphically in Fig. 7. Analysis reveals that 40.7% of all emergencies resulting in accidents occurred at speeds below 25 knots, and 18% of emergencies affected helicopters whilst in the hover over deck, sea or land.

POST CRASH FIRE

Post crash fire (PCF) has not been a common occurrence in RN helicopter accidents, especially those which can be classified as survivable. During the period 1961-1968, 9 (18%) RN helicopter accidents involved PCFs (Day, 1972). Two of these accidents involved fires due to in-flight engine problems and cannot be correctly called post crash fires. Two of the other accidents were non-survivable and the fatalities were attributed to high impact forces. Only one fatality during that period can be attributed directly to PCF. This occurred in a Whirlwind which sustained a heavy landing and subsequently caught fire causing the death of a passenger. The present series reveals that PCFs occurred in three accidents, and all of these were non-survivable due to high impact forces. Fuel leakage from fractured fuel lines and tanks did occur on three other occasions, but fortunately ignition did not ensue. All PCFs and two of the fuel leakage accidents were the result of land impacts. There were no PCFs subsequent to water impact. Many of the water related accidents are, as already explained, the result of relatively trivial malfunctions and land impacts are likely to be the consequence of a more serious problem.

Comparison with other sources. Data from the Army Air Corps for the period 1971-1982 reveals that PCFs occurred in 25% of all accidents (most of these involved the Sioux, now out of service). Two fatalities were directly attributed to fires following survivable accidents. Royal Air Force data for the period 1971-1983 indicate that fires followed six (13.3%) helicopter accidents and that two major injuries were burns. Two further accidents resulted in rupture of the fuel tanks and only providence prevented ignition.

The NTSB study (National Transportation Safety Board, 1977-1979) indicates that 8.9% of civil helicopter accidents are accompanied by PCFs and 40% of these result in fatalities due to thermal injuries. Prior to the introduction of crashworthy fuel systems to US Army helicopters, almost 60% of all fatalities were due to burns injury or its sequelae (Knapp, 1981). The introduction of Crashworthy Fuel Systems (CWFS) has led to the effective elimination of these fatalities in survivable helicopter accidents (Shanahan, 1984). Interestingly, a recent study of US Navy helicopter accidents from 1972-1981 (Simula, 1985) reveals that burns were the second most common cause of injury, second only to structural failure of seating under impact loads. No PCFs occurred after water impact, but 41.2% of all land impacts resulted in PCF. One type, the H-53, caught fire after 59.3% of land accidents.

DECK ACCIDENTS

There were 19 accidents involving the Wessex (5), Wasp (10) and the Sea King (4) during deck operations. This fact emphasises the desirability of fitting maritime helicopters with an efficient energy absorbing undercarriage, capable of absorbing the vertical velocities likely to be encountered during shipborne operations.

HELICOPTER LOSSES AND FATALITIES DUE TO HOSTILE ACTION

Aircraft losses due to accidents have always outstripped attrition due to enemy action during periods of hostility. It is recorded (Baldes, 1971) that the USA lost over 45,000 aircraft in the training programme alone during WW2 and that this involved the death or injury of 30,000 aircrew. Military helicopter losses appear to follow a similar pattern and during the Vietnam War, over half the total helicopter losses of 4,500 were due to accidents not directly related to combat.

Operation Corporate. Seventeen RN helicopters were totally destroyed during the Falklands Campaign and one suffered Cat 3 damage. Eleven of these aircraft were destroyed on board ship, or on the ground, and were not engaged in flying at the time. They are, therefore, regarded as ground accidents and would not normally figure in an accident analysis. Five of the six flying accidents can be attributed partly or wholly to disorientation subsequent to operations which were undertaken in extreme weather conditions and under very stressful circumstances. These accidents are listed in more detail in Table 10. These five accidents were responsible for all the fatalities and injuries sustained by RN helicopter aircrew and/or passengers during this campaign.

DISORIENTATION ACCIDENTS

As has already been explained, disorientation accidents featured as the sole cause of death or injury to the occupants of RN helicopters during the Falklands war. Interestingly, only two other accidents during the rest of the period under study were directly attributed to disorientation errors. These were responsible for one fatality and one major injury. An extensive review of AAC accidents (Edgington & Box, 1982) concluded that 15% of all Army accidents were due to disorientation and these accounted for 15% of all injuries and 34% of all fatalities.

The importance of disorientation in RN helicopter operations is underlined by a report (Steele-Perkins & Evans, 1978) which reveals that 52% of the RN helicopter pilots surveyed had had at least one episode of severe disorientation; i.e. felt disorientated, mentally stressed and/or there was definite interference with aircraft control. Further data concerning RN helicopter pilots serve to reinforce these original findings. (Evans, personal communication). The advent of a hostile operating environment and the concomitant pressures to 'press on' with the planned mission will obviously increase the likelihood of disorientation incidents. These facts highlight some of the difficulties likely to be encountered by any helicopter operator who intends to employ helicopters, manned by a single pilot, in the demanding maritime environment, especially during wartime conditions. The use of NBC AEA and night vision aids etc will, of course, compound the difficulties experienced.

ANALYSIS OF FATALITIES AND INJURIES

During the period of this study there were 51 fatalities subsequent to accidents in RN helicopters. Details concerning these accidents are summarised in Table 11. When considering the incidence of fatalities and injuries in Naval helicopter accidents, it must be re-emphasised that many of the accidents were caused by relatively trivial malfunctions, which due to maritime conditions became classified as accidents. The authors, after perusing the various accident records, have eliminated 75 accidents which were trivial in nature, or involved such low impact forces that injury of any kind would be most unlikely to occur. However, one such accident did result in a fatality due to drowning. The remaining accidents are considered to have involved impact parameters which could have led to injuries or fatalities. These accidents can be divided into 35 significant severity accidents and 9 non-survivable accidents (see list of definitions). The non-survivable accidents were the cause of 23 fatalities, whilst those accidents of significant severity resulted in 26 major all RN helicopter fatalities occurred subsequent to survivable impacts. The causes of death can be sub-divided as follows:-

a.	Multiple injuries	18 (36%)
b.	Drowning	22 (43%)
c.	Drowning subsequent to minor injury	4 (7.5%)
d.	Head injury	6 (11%)
e.	Chest injury	1 (1.9%)

INJURIES SUSTAINED DURING RN HELICOPTER ACCIDENTS

From a total of 535 passengers and crew, 26 suffered major injury in RN helicopters during the period of this study. (Minor injuries have not been included due to a lack of recorded details). The major injuries are summarised in Fig. 8. As can be seen, spinal injury accounts for the largest proportion (50%). This substantiates evidence from Day (1972) where 34% of all major injuries were listed as being due to spinal compression fractures, Fig. 9. A high incidence of spinal compression fractures is to be expected in the maritime environment, where many of the accidents are due to heavy vertical impacts with the water surface. Under these conditions the undercarriage is unable to absorb the impact energy, which is then transmitted directly by the incompressible medium of water to the occupants via the aircraft fuselage and seating system. The spinal injuries are listed in Table 12, which also includes some data concerning the impact parameters involved.

Discussion of injury and fatality data. Day (1972) listed some of the details of the causes of fatalities in RN accidents covered by his report. These can be summarised as follows: drowning is the overwhelming cause of death (53%) and head injury is the second commonest single cause of death (12%); two cases of drowning were subsequent to an initial head injury and a further case was the direct result of minor leg injuries. There was one death due to burn injuries. The most authorative and well documented evidence concerning spinal injuries and helicopter occupants is contained in research covering United States Navy and Army helicopter operations. This research was directly responsible for the introduction of crashworthy crew seats to a new generation of US Navy and Army helicopters in the last decade. The US Navy is also in the process of retrofitting crashworthy seating to their fleet of SH3 helicopters. The potential benefits of this procedure are likely to be very great and this aspect is discussed in more detail later in this paper.

US Army Data. These data are summarised (Desjardins et al, 1980) for US Army helicopter accidents covering the period 1971-1976 and involve a total of 4550 occupants. Briefly the conclusions were as follows:-

a. The most common major or fatal injury in all types of helicopter accident is head injury (19.7%). This includes data concerning occupants who were not wearing seat belts.

b. Spinal injuries accounted for 16.5% of all major or fatal injuries. The figure varies according to the helicopter type concerned, being high in attack versions (21.5%) and relatively low in cargo helicopters (8.6%). These anomalies are explained by the differing impact parameters of the aircraft under study and the amount of energy absorbing structure present.

These findings are confirmed by an earlier study (Hayley, 1971) which states that 40% of all helicopter fatalities occurred in accidents which were classified as survivable. Head and face injuries were the commonest cause of fatality and injury. Other reports (Mattox 1968, Sand 1978) put the incidence of spinal injuries as 6%, 13% and 10% of all injuries. The range of spinal compression fractures varies from 25%-77% of the total spinal injuries. A further study (Vettes & Delahaye, 1982) of French military helicopter accidents indicates that 14% of all injuries sustained were spinal compression fractures. The present RN study demonstrates a higher frequency of spinal injuries than hitherto reported, spinal compression fractures accounting for 50% of all major injuries to RN helicopter aircrew and passengers. Data extracted from Day's paper also demonstrate a high incidence (34%) of spinal injuries in RN accidents, but he did not include clinical descriptions of the injuries themselves. Major injuries sustained by AAC aircrew in the period 1971-1982 included 18% which were spinal in nature. The high incidence of spinal compression fractures in RN helicopter accidents is due to the operating environment and the type of impact commonly experienced.

DITCHINGS

There were 56 ditchings during the period of study, 51 of these accidents being survivable. Thirtyfive helicopters were lost in the post ditching phase. Three of the latter were lost during the salvage phase of the recovery operation and one was sunk by Naval gunfire. Table 13 compares the sea state at the time of ditching with the survival of the helicopter. (Data from accidents involving fly-ins have been excluded). As can be seen, two helicopters were lost after controlled ditchings onto calm seas. At sea states of 3 or greater, the majority of helicopters were lost no matter how well controlled the ditching may have been. Of the salvaged aircraft, a further 7 inverted and were badly damaged. Many of the ditchings, which resulted in accidents, were the result of relatively minor problems and were lost due to the lack of an adequate flotation system. This, without doubt, is where the most cost effective savings could be made in the design of a future maritime helicopter.

Time required for rescue after ditching. The time required to rescue helicopter crews after ditching is shown below:-

a. <15 mins - 55%

b. 15-50 mins - 40%

c. >45 mins - 4%

The time for rescue ranges from almost immediate to 1hr 10 minutes. Most crews are rescued within 20 minutes, the rapid response rate being due to the presence in the area of other helicopters or ships. This result would seem to indicate that survival in the sea is not a significant problem for modern aircrew, who can usually expect the presence of a well trained rescue organisation in the area. However, it would be complacent to rely on this always being the case as weather conditions or the presence of hostile forces, could all too easily delay or prevent any rescue attempts.

Nevertheless, it is remarkable that, to date, rescue has been accomplished in such a uniformly short time span. This analysis does not include data pertaining to land accidents.

ESCAPE FROM DITCHED HELICOPTERS

As has already been discussed, there is every likelihood that a helicopter when successfully ditched will invert rapidly even in calm conditions. Escape from an inverted helicopter depends on the occupants not being incapacitated by the force of the impact, correct training, and adequate and well marked emergency exits. These points have long been recognised by the RN, who at an early stage in the helicopter's history installed a mock up of the Whirlwind rear cabin for use in underwater escape training at the Royal Naval Survival Equipment School. There is no doubt that many aircrew who have survived helicopter ditchings owe their lives to the training received in underwater escape techniques. Unfortunately, it is also true that passengers unfamiliar with helicopter escape procedures are unlikely to achieve egress from an inverted helicopter in difficult conditions. As discussed, survival after escape is unlikely to be a problem, at least during peacetime: it is the failure to escape rapidly that accounts for the fatalities.

Details concerning fatalities in RN helicopters are covered in Table 11. Thirty one of the 51 fatalities were the result of drowning. All these fatalities occurred in survivable accidents and 27 of the drownings were due to inability to escape from an inverted helicopter or to a minor incapacitating injury. Unfortunately, most of these bodies were never recovered and so the actual cause of their death can only be presumed after a careful consideration of the impact parameters and the evidence of surviving occupants. A further three fatalities were the result of major incapacitating injuries which prevented escape. Of interest is the fact that 23 of the 31 drowning cases were unrestrained or wearing despatchers harnesses at the time of impact. A further case involved incapacitating injury to an observer who was not wearing his shoulder straps, the injuries being the result of head contact with the radar console. All accidents where drowning occurred involved the rapid inversion of the helicopter after ditching.

To summarise, the majority of fatalities due to drowning were the result of minor incapacitation due to lack of restraint or the inability to effect escape in time. A major contributory factor is the poor flotation capability of current helicopters.

Discussion. It is well known that most fatalities associated with helicopter ditchings are the result of drowning. Statistics from the United States Naval Safety Center show that from July 1963 to February 1975, 234 helicopters with a total of 1,093 occupants either crashed or were ditched at sea; 196 persons died in those accidents. 130 were listed as lost - unknown and 29 suffered either a fatal injury or an injury which caused drowning. The remaining 37 victims were not injured, but drowned nonetheless. Of the 897 survivors, 437 (49%) egressed under water. A further study of US Navy helicopter ditchings (Flaig, 1975) covers 78 ditchings over a 4 year period, 40% of all fatalities were due to drowning and the majority of the remaining 60% were lost at sea. As expected, the ability to escape from the helicopter was closely correlated with the flotation capability of the helicopter concerned. Another important factor is the size of the aircraft and the number of passengers carried, it being apparent that the more occupants attempting to escape, then the greater the difficulty of achieving a rapid egress. Fatalities were more likely to be due to drowning in passengers than aircrew, reflecting the lack of training and less favourable escape conditions. Interviews with the survivors of ditched helicopters (Rice & Greear, 1973) reveal that inrushing water was the major cause of difficulty during escape. These findings are included for convenience in Table 14.

Escape from smaller helicopters, such as the Wasp, seems to present no obstacle as there were no recorded instances of difficulty in the Board of Inquiry files relating to the Wasp. The commonest recorded egress problem was inrushing water especially when compounded by too early release of the harness. The second most prevalent difficulty was operation of escape hatches and windows. Also mentioned was the snagging of backpacks and PSPs, difficulty in getting through the exits and buoyancy of the immersion suit. Many survivors commented on the beneficial experience gained by Dunker training, but pointed out that the slow inversion of the original Dunker often bore no relation to the rapid rolling over of a helicopter, particularly if this were initiated by a blade strike. In order to reduce the number of deaths due to drowning in maritime helicopters, then, it is essential to consider the following points:-

a. Delethalisation and energy absorption systems to reduce the possibility of incapacitation of the helicopter occupant on impact.

b. The correct use of adequate restraint systems.

c. The flotation capability of the helicopter.

d. The number and design of emergency escape exits and related emergency lighting systems.

e. Underwater escape training of aircrew and passengers.

f. The use of short term underwater breathing equipment.

g. The ability to survive having achieved escape.

h. The availability of an efficient rescue organisation.

There is insufficient space in a review of this nature to cover all these points in detail although some of them have already been considered in brief. Nevertheless, it is worthwhile to look at the design requirements for producing efficient emergency exits and emergency lighting systems.

EMERGENCY ESCAPE EXITS AND LIGHTING

The standards appertaining to emergency exits in British Military rotorcraft extant at the end of the period of the review were covered by Defence Standard 00-970/vol 2/Chapter 102 /Issue 1 dated 31 Jul 1984. They are intended to ensure that all occupants of a helicopter can quickly and safely leave in the case of emergency. The number and size of exits required are shown in Table 15 and 16. It is obvious that exits must be provided on each side of the fuselage to cater for those occasions when exits are obstructed due to crash damage. Consideration should also be given to the installation of overhead escape hatches (or floor as in the Puma), especially in large helicopters where the width of the fuselage would present a difficult obstacle to escape if the helicopter were lying on its side. The provision of emergency exits has also to be adequate in the case of PCF when the prime consideration will be rapid evacuation. A emergency exits, and the time required for each individual, wearing the maximum amount of clothing and equipment and representing the 99th percentile size range, to effect an escape from the crashed helicopter under conditions of poor illumination and panic. The Crash Survival Design Guide recommends that all exits, which could be used in cases of emergency, should be capable of being operated within 5 secs (ie completely open) and should be at least 22ins square with 6in radius corners, or 22in in diameter. This should allow 95th percentile troops wearing full equipment to evacuate at the rate of 1 per 1.5secs.

A study (Allan & Ward, 1986) at the RAF Institute of Aviation Medicine tackled problems of the minimum sized exit for use in North Sea operations for inter-rig transport. It concluded that civilians wearing normal survival equipment should be able to escape from exits as small as 432mm (17") by 356mm (14"). This study points out that one cannot reduce the size of current exits without first increasing the number of exits available. Also it cannot apply directly to the occupants of military helicopters, as the range of equipment worn by personnel such as troops is extremely varied.

The principle of small, but more numerous exits is nevertheless supported, as experience has shown that escape from large cargo helicopters is often difficult. Frequently, only 4 or 5 occupants succeeded in escaping from the main exits. The correct operation of exits does require thorough training, not only in the emergency operation of exits, but in avoidance of premature release of the harness restraint which helps reduce the problem presented by inrushing water.

The reality of a Naval ditching is that it is likely to be a 'fly in' or heavy vertical impact from a 40' hover. The resulting blade strikes cause immediate inversion of the helicopter. Escape will continue to depend on good training in all survival techniques. Troops and other unrestrained personnel will always fare badly in such situations. Statistics support the observation that adequately illuminated emergency exits might assist aircrew or passengers to egress successfully from a ditched helicopter, but that it is only one factor in the safe execution of a potentially hazardous task. In the early 1960s, the Royal Navy investigated various types of lighting systems for emergency exits, but concluded that the additional weight and engineering complexity of electrical systems was unjustified, and selected the inert beta light system to illuminate the exit hatches and emergency exit release handles of Royal Navy helicopters. Firm reliance was placed on the adherence to drills taught in the underwater escape trainer (Dunker) to ensure a safe escape from a ditched helicopter. The importance of Dunker training in assisting aviators to escape from a ditched helicopter is unquestioned and the drills taught can enable aircrew to escape, in effect 'blindfolded', by pulling themselves through an exit, having maintained their orientation by retaining a firm grip on a known part of the aircraft structure. Nevertheless, observations on the investigation of accidents during operation Corporate by the Royal Navy Aircraft Accident Investigation Unit (RNAAIU) concluded that aviators were not always in a position to complete this drill following impact with the water, and that frequently aircraft cabin occupants were not Dunker trained. The requirement to illuminate escape hatches and exits adequately was, therefore, re-emphasised.

Allan et al (1989) conducted a study to assess the visibility of 3 types of emergency escape exit lights in clear and turbid water. They found that in moderately turbid water, detection of the lights was unreliable over distances greater than one metre. In their report they critically reviewed a number of existing specifications for escape lights and came to the conclusion that in the present form they were difficult to support and that they should be updated. If performance of lighting systems is to be specified in terms of luminance of individual lighting elements, then based on their findings in turbid water, luminance measured over a field of view corresponding to the minimum width of the light source should not be less than 10^4 cd.m^{-2}.

The attenuation coefficient (turbidity) of the water is obviously an important factor and can vary quite considerably from the water found in a river estuary or harbour, to that in mid ocean. A further factor is that the water inside the helicopter cabin, having submerged following a ditching, is very likely to be strongly contaminated with fuel, oil, hydraulic fluid and dust. The turbidity will be further increased by entrained air bubbles. The attenuation of light, scattered by the turbidity of the water is, as might be expected, difficult to compute. The main factor is the amount and size of the particles within the water: peak scattering of the light occurs when the radius of the particle size is approximately the same as that of the wavelength of the light.

In addition to the perceived luminance of an object under water, there is one other factor influencing its detection and identification. Because the refractive indices of water and the fluid within the eye are so similar, the eye loses much of its refractive power. This results in hyperopia or far-sightedness, and blurs the images of objects viewed underwater.

This undesirable phenomenon is largely removed by the wearing of goggles or a face mask, and this has resulted in several authors (Allan & Ward, 1986) commenting on the benefit to a potential underwater escapee from wearing swimming goggles, and thus greatly enhancing his vision underwater. Several different methods have been attempted to produce lighting systems producing sufficient levels of luminance. These include electro-luminescent panels and light-emitting diodes: other methods such as phosphorescent paints have also been investigated, but suffer the disadvantage of having to be primed with a light source for some considerable period if they are to work at anything like their optimum level.

Recent work has attempted to overcome the problem of escape exit lighting by employing a method of escape route indication. This may consist of an illuminated guide bar, or series of guide-bars, which provide both an unambiguous indication of the route to the escape exit and also, by acting as a handrail, provide a means of propulsion through the water in a situation where movement is frequently severely impaired by the buoyancy associated with air trapped in clothing. The success of prototype systems of this sort has resulted in the recommendation that the performance of underwater escape lighting systems should be specified in functional terms rather than absolute levels of luminance.

Another important aspect of any emergency egress lighting system is the method of activation. As with aircraft emergency flotation systems, most agencies agree that there should be at least two systems, one automatic, the other a manual back-up. Concern has been expressed over the inadvertent activation of the system, especially during covert NVG operations. The two options for automatic activation are sea-water or rotor RPM decay. The method chosen should be on the grounds of reliability and maintainability as opposed to cost. The whole lighting system must be sufficiently rugged to operate after having been subjected to high impact forces, and then continue to operate as the aircraft is submerging. Most of the factors influencing the desired brightness or luminance of emergency exit lighting systems also apply when the exits are obscured, not by water, but by smoke.

The ability to effect a successful escape from a submerged helicopter depends not only on finding an escape exit, but also on the escapee being able to remain submerged without breathing for sufficient time. Breath-hold time in cold water is severely reduced (Tipton and Vincent, 1989) possibly, in some circumstances, to times less than those needed to escape. This effect will be compounded by injury, or if escapes are hindered by aircraft wreckage or other escapees. Miniature compressed air breathing devices are now available and are in use with several airforces. There are increasing numbers of reports of successful escapes attributed to the use of these systems.

USE OF CRASHWORTHY SEATS IN RN HELICOPTERS

The high incidence of spinal injuries in RN helicopters has already been discussed, this being due to the nature of water impacts where the normal energy absorbing characteristics of the undercarriage system is bypassed. The incidence of spinal injuries in US Army helicopters not equipped with crashworthy seats is shown in Fig. 10 (Hicks, 1982). As can be seen, there is a highly significant risk of spinal injury at vertical velocity changes greater than 22ft per sec and, of course, the deleterious effects of poor posture should also be taken into account. In contrast, Fig. 10 also shows the incidence of spinal injury as assessed from UH60 accidents where crashworthy seats were employed. These data are not, as yet, complete, but the clear indication is that there will be a dramatic reduction in the incidence of spinal compression fractures. The potential benefit from a crashworthy seating system in the maritime environment should be even greater, and should be immediately apparent even in the comparatively small fleet operated by the RN. Such seating systems could be extended to include passenger and crew members.

RESTRAINT SYSTEMS

These are only mentioned in passing as this subject could rightfully merit a specific study. The most important points to emerge from this review are as follows:-

a. Aircrew members who wear despatchers harnesses are in a very poor situation as they are essentially unrestrained; the harness only serving to prevent ejection from the helicopter at the time of impact.

b. Passengers, and in particular troops, are often seated without restraint of any kind. This dispensation is covered by Para 0109 of JSP 318, which provides specifically for the carriage of troops in operational conditions. The fallacy of this argument has already been shown up by data concerning the loss of helicopters in hostile operating environments.

CONCLUSIONS

The following conclusions and lessons can be derived from the present study:-

1. RN accident and fatality rates have not declined as rapidly as those of the RAF and AAC. The differences are largely due to the maritime nature of most RN helicopter accidents which can easily result in the loss of the helicopter and drowning of the aircrew and passengers.

2. Aircrew error accounts for 51% of all RN helicopter accidents. This compares favourably with other contemporary data, but also implies that accident rates could still be reduced by attention to mechanical and technical causes. Reducing the incidence of aircrew error is a far more difficult problem.

3. The majority of RN helicopter accidents are the result of water impacts and are caused by emergencies which arise below 500' ASL at speeds below 25kts. Most emergencies occur during the hover, approach to landing, or deck phase of operations.

4. Post crash fire during the period of this study only occurred after non-survivable land impacts. There were no occurrences subsequent to water impact, so confirming the findings of previous studies. The studies reported here also indicate that post crash fires occur commonly after land impacts and emphasise the desirability of fitting crashworthy fuel systems to all military helicopters. The technology is both cheap and readily available.

5. Disorientation can be considered to have been the major cause of flying accidents during Operation Corporate. These accidents were responsible for all the deaths and injuries to RN helicopter aircrew and passengers during the course of the campaign. Efforts to reduce disorientation accidents should result in an important reduction in aircraft loss during operational conditions.

6. 55% of RN helicopter fatalities occurred subsequent to survivable accidents and 56% of the total fatalities are as a result of drowning due to inability to escape from a sinking helicopter.

7. The inadequate provision of flotation facilities for current RN helicopters results in their almost inevitable loss when ditchings occur on seas running at state 3 or greater. The potential savings in this area are obvious.

8. Spinal compression fractures account for 50% of all major injuries sustained by RN helicopter aircrew or passengers. The use of crashworthy crew and passenger seating would undoubtedly reduce this high incidence.

9. The majority of RN aircrew and passengers can be expected to be rescued within 15 mins during normal peacetime operations.

10. Escape from an inverted helicopter depends largely on the training received and the correct function of harness and escape systems. Further work on emergency exit design, escape route guidance systems, exit lights and underwater breathing devices, should be carried out.

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FIGURES

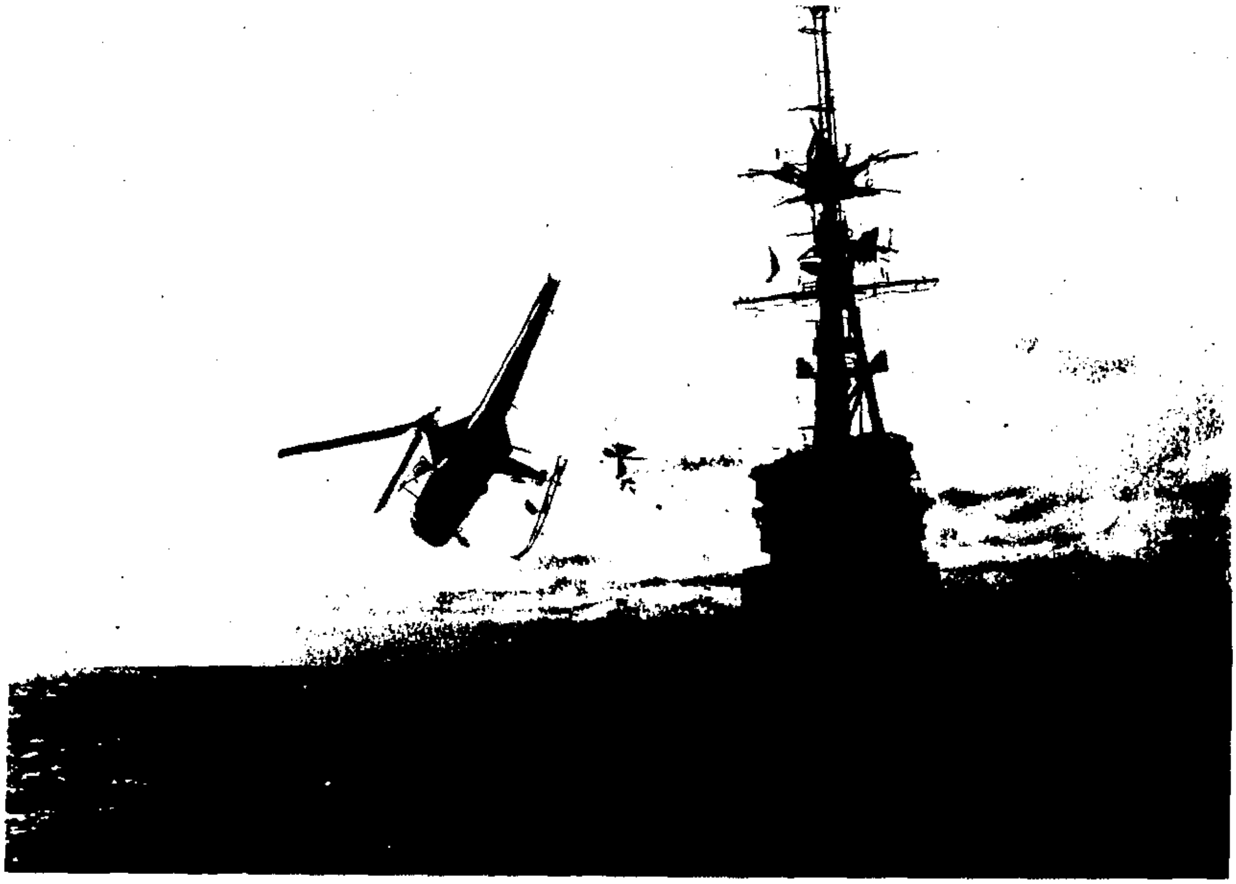
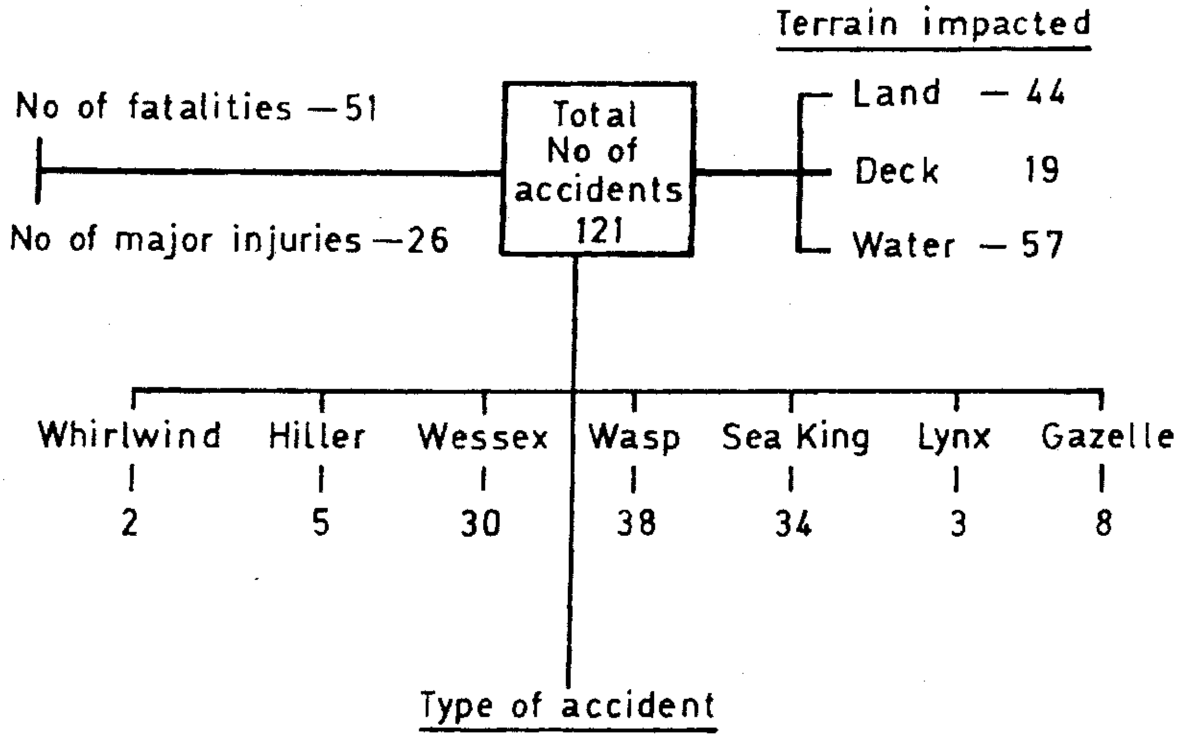


FIG 1 DISASTER AFTER A SNATCH TAKE OFF ABOARD HMS GLORY OFF KOREAN COAST IN 1952. THE PILOT OF THE DRAGONFLY WAS UNFORTUNATELY KILLED



Low severity – 75 accidents resulting in 1 fatality

Significant severity – 35 accidents resulting in 26 major injuries, 26 fatalities

Non survivable – 9 accidents resulting in 24 fatalities

FIG 2 RN HELICOPTER ACCIDENTS 1972–1984

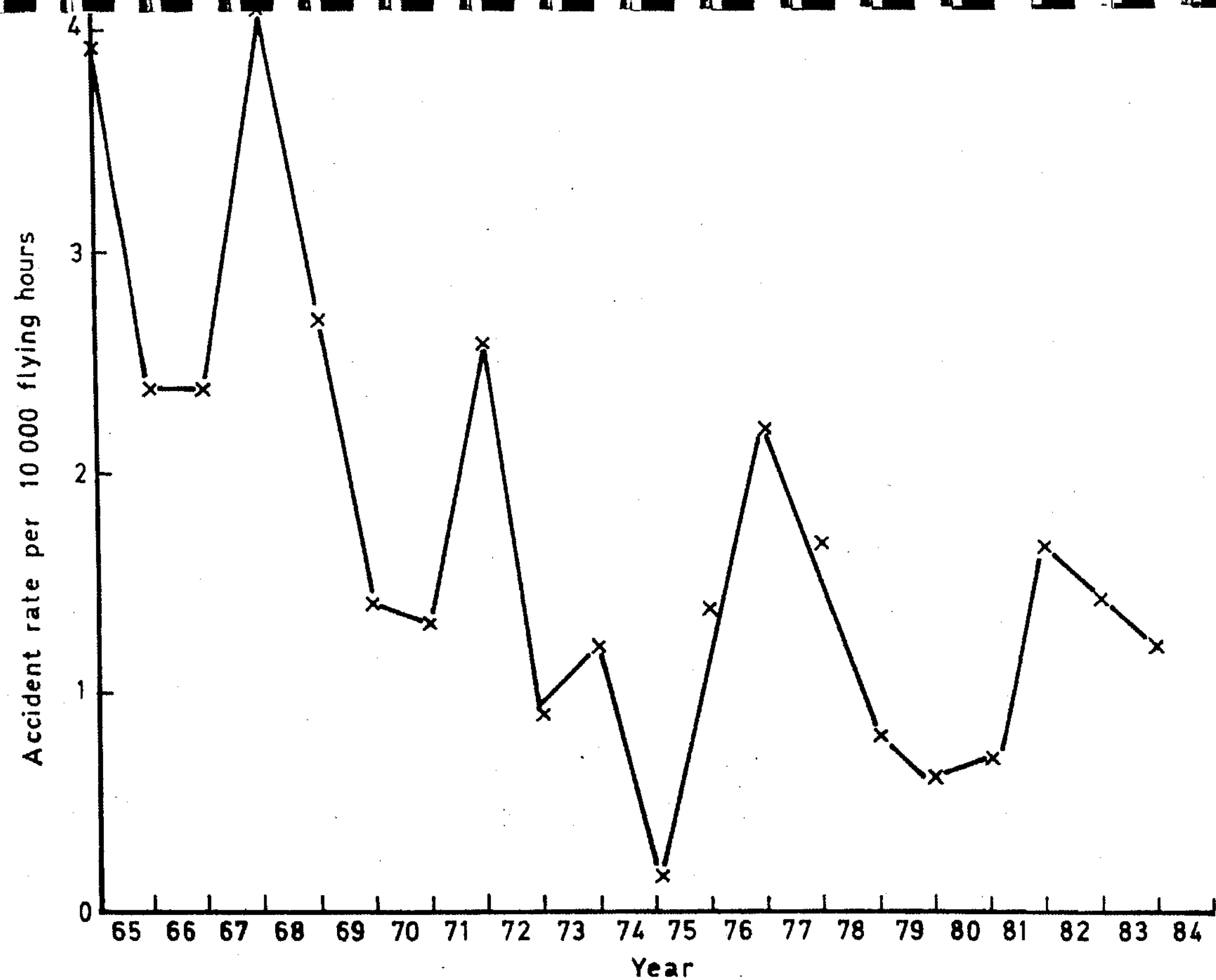


FIG 3 ROYAL NAVY HELICOPTER ACCIDENT RATES 1964 – 1984

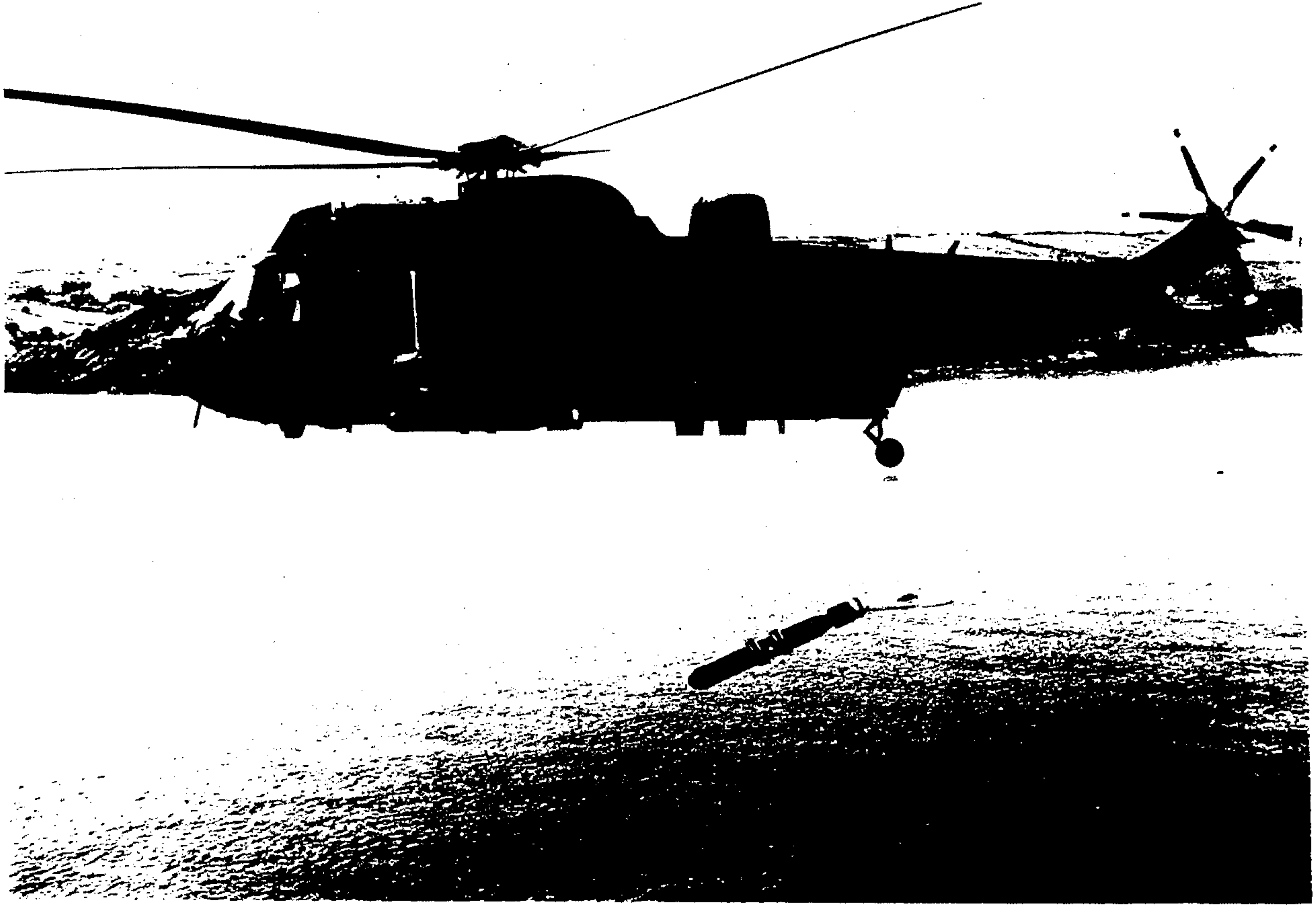


FIG 4 ROYAL NAVAL SEA KING

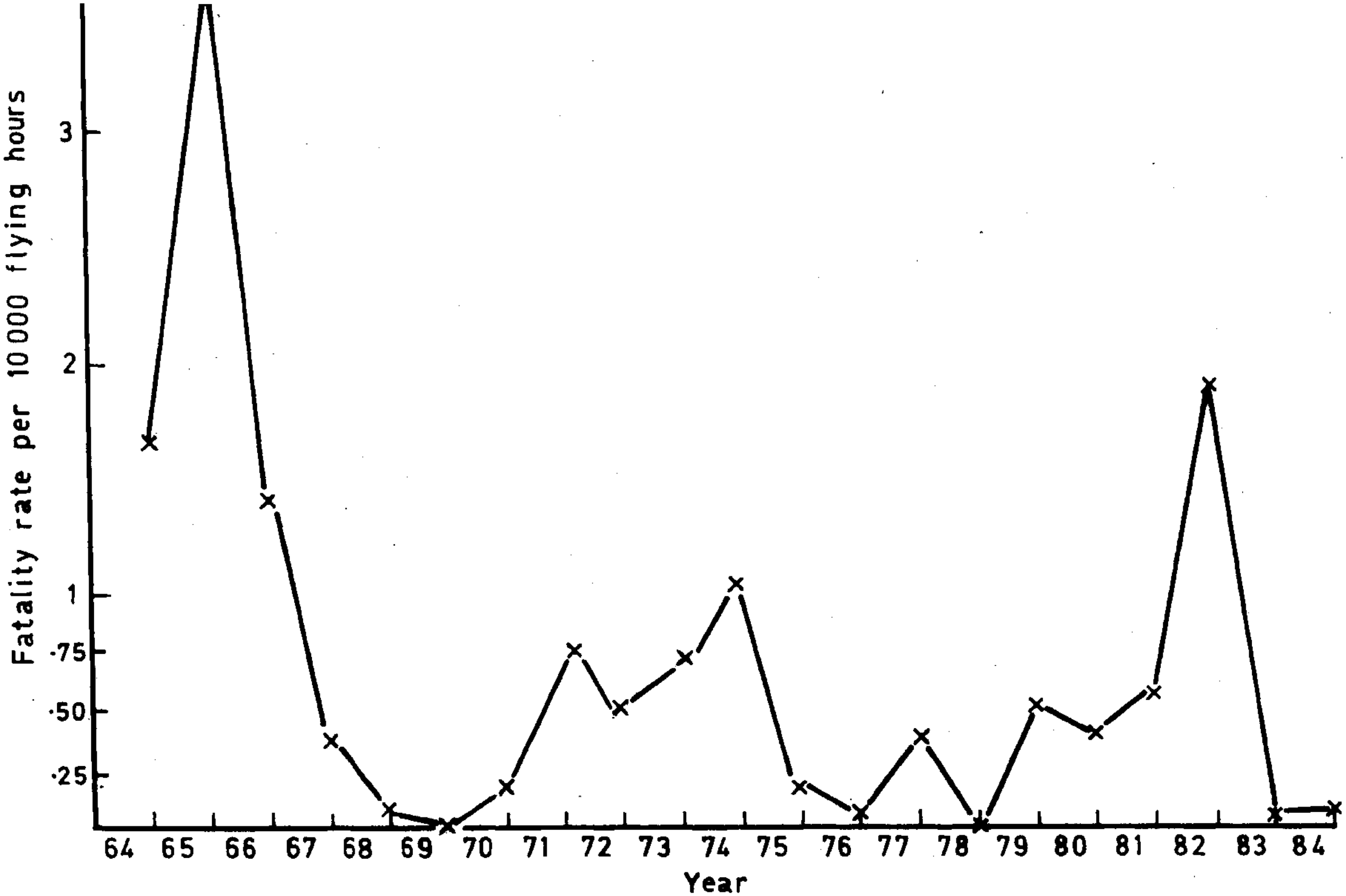


FIG 5 ROYAL NAVY HELICOPTER FATALITY RATES 1964–1984

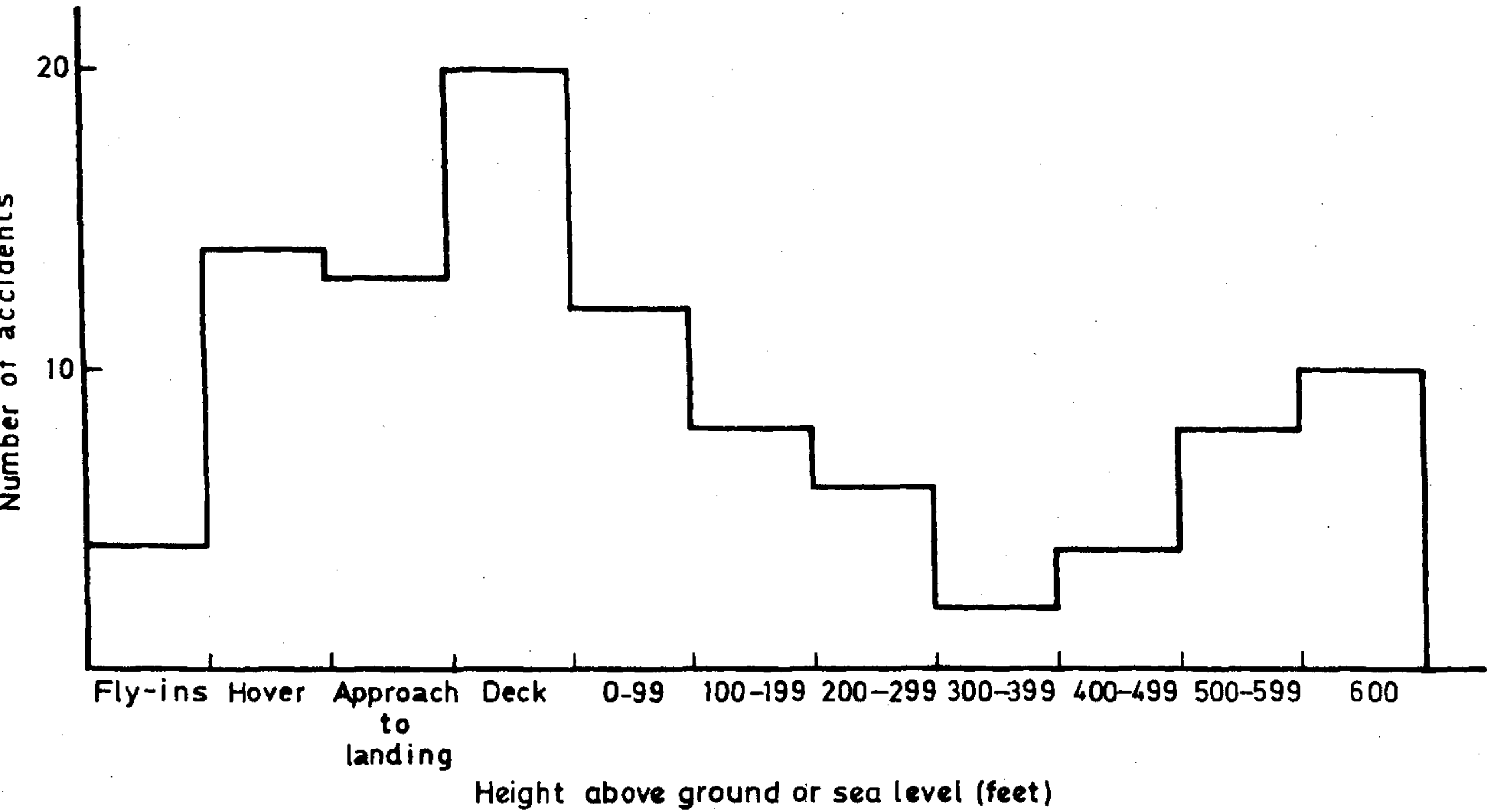


FIG 6 HEIGHT DISTRIBUTION OF ROYAL NAVAL HELICOPTER ACCIDENTS

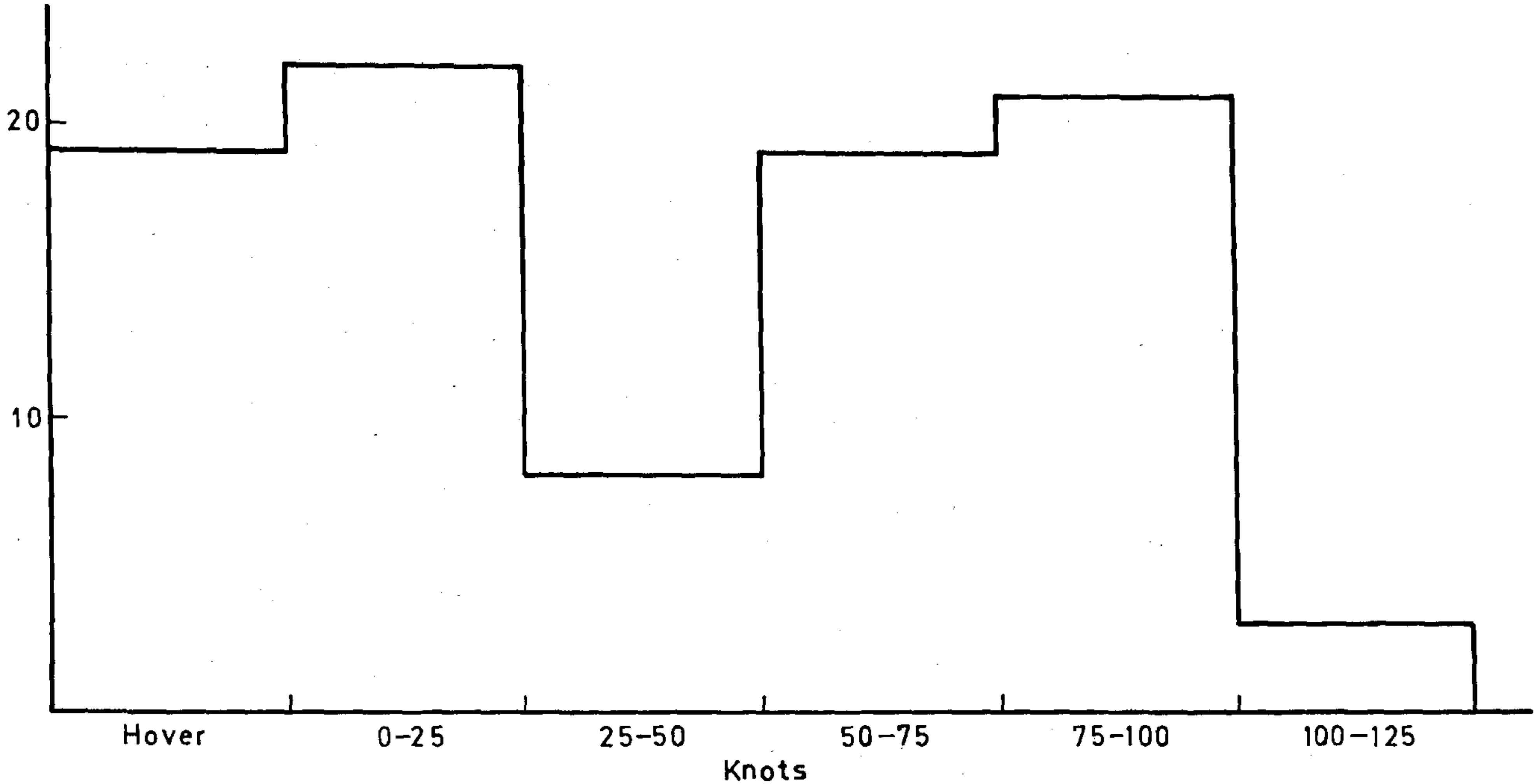


FIG 7 SPEED DISTRIBUTION OF ROYAL NAVAL HELICOPTER ACCIDENTS

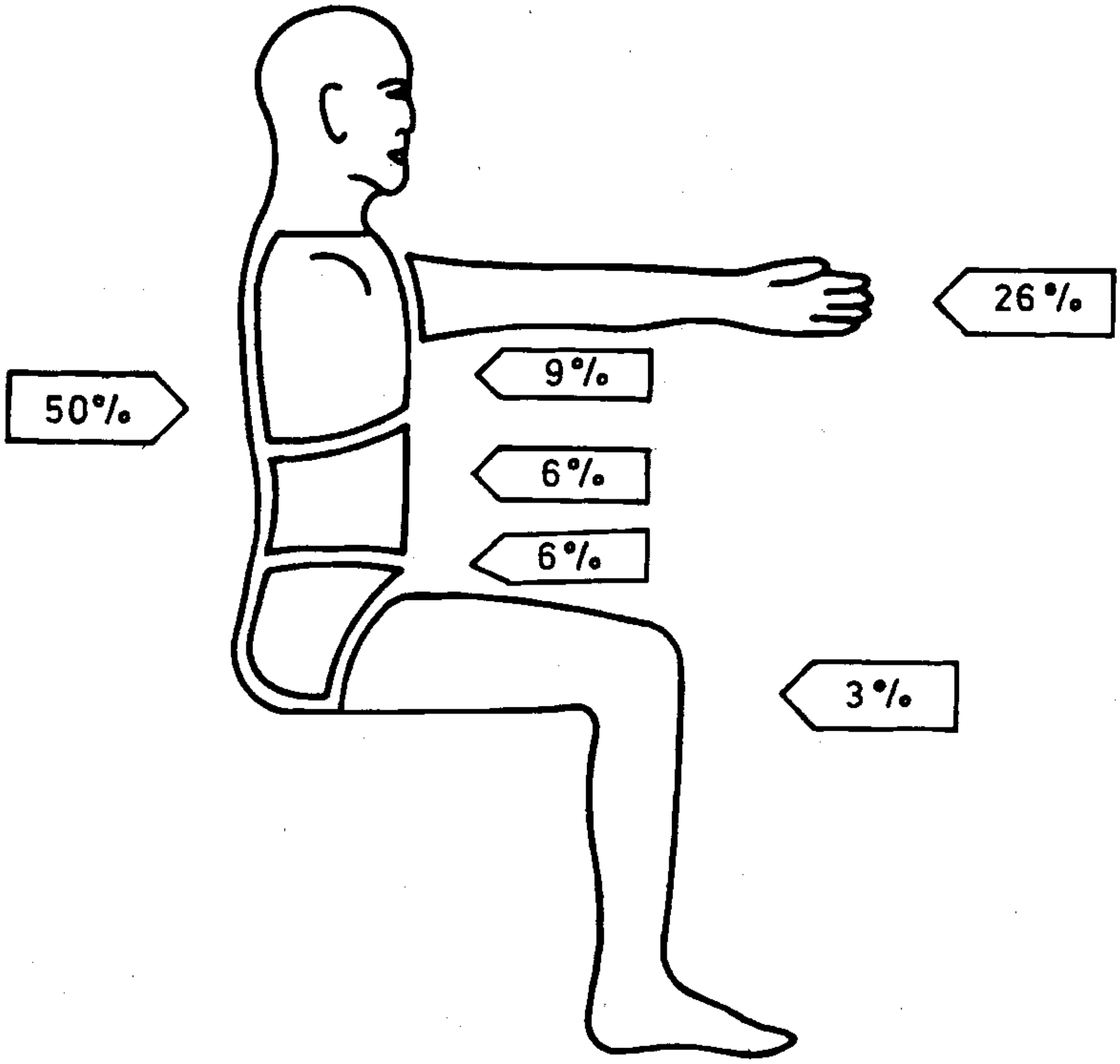


FIG 8 MAJOR INJURIES BY BODY PART (NOT RESULTING IN DEATH
RN HELICOPTER ACCIDENTS 1972-1984

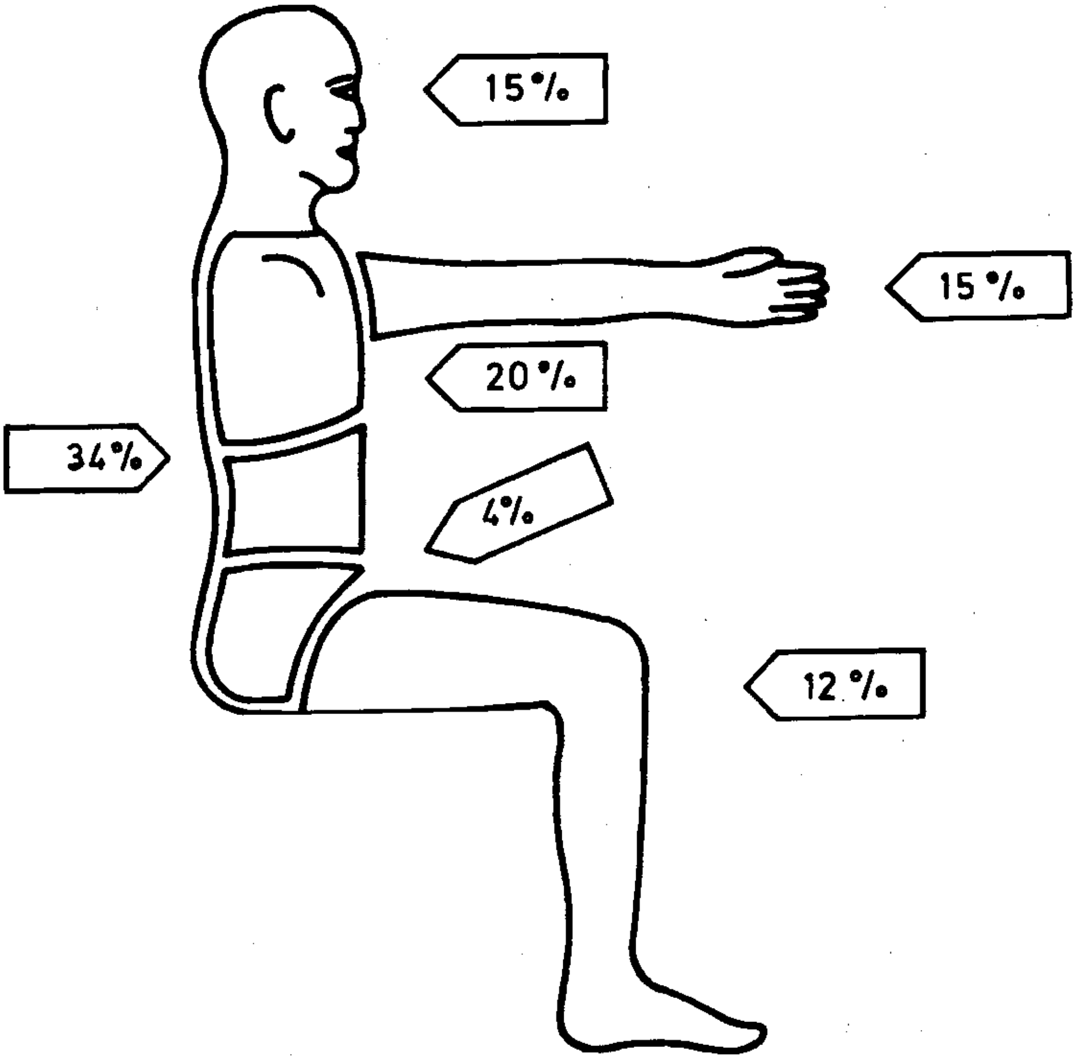


FIG 9 MAJOR INJURIES BY BODY PART (NOT RESULTING IN DEAT
RN HELICOPTER ACCIDENTS 1961-1969

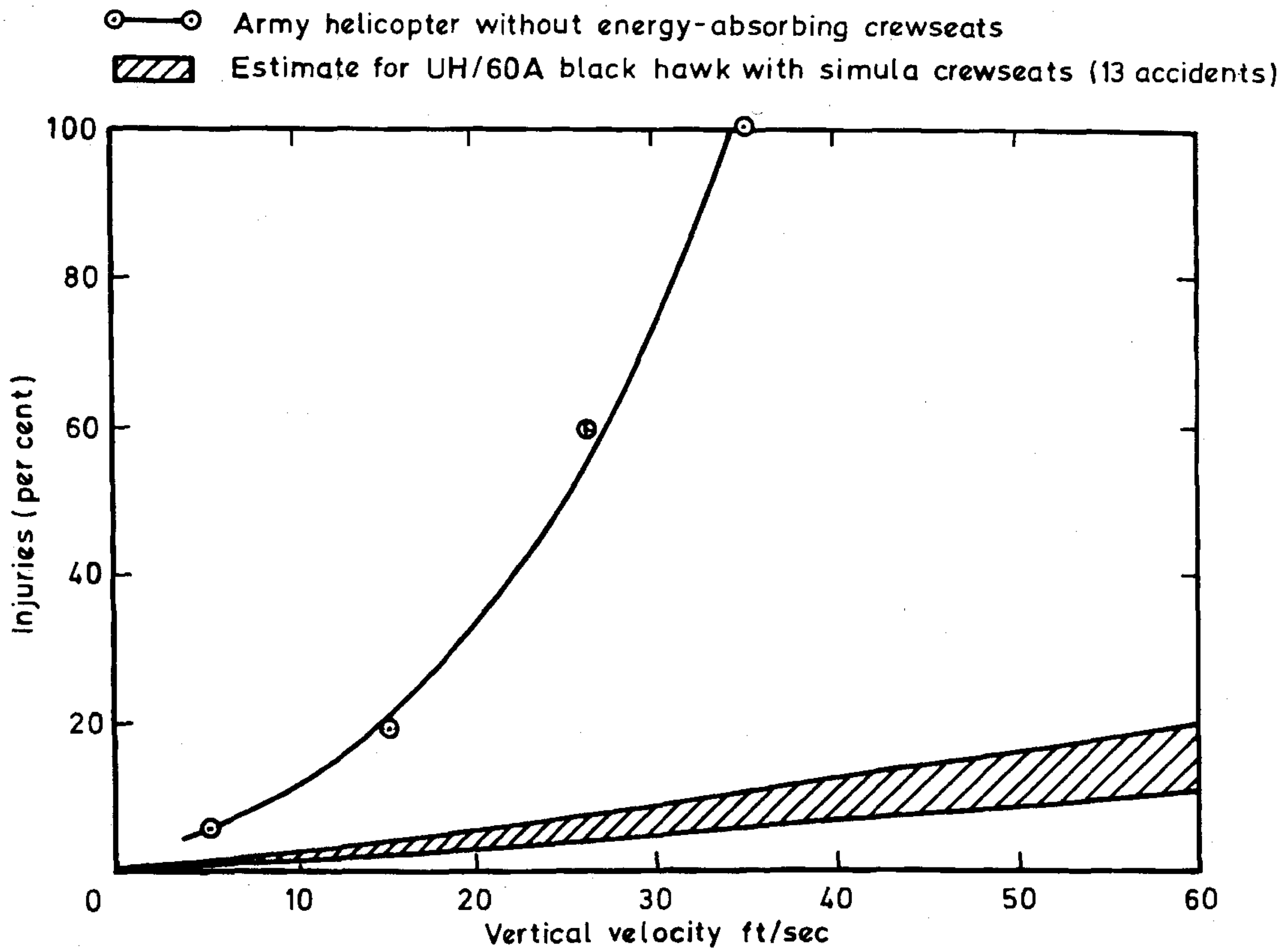


FIG 10 RELATIVE FREQUENCY OF SPINAL INJURIES VERSUS CHANGE IN VERTICAL VELOCITY FOR US ARMY AVIATORS

TABLES

TABLE 1

RN WHIRLWIND ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	l
1	16/4/73	5	1000' ASL at 90 kts in cruise. Engine rundown followed by controlled ditching onto calm sea.	A/c sunk	All escaped easily from inverted posn. Pilot not wearing backpack. Rescued in 3 mins by hovercraft.	Pilot error - engine surge.	Good. Sea state calm.	3	Nil	Nil	Ac rapidly rolled to stbd on impact and sank.
2	21/11/73	5	Directional control lost in hover taxi at 20' AGL and 15 kts. Ac impacted with runway surface.	-	Escape of pilot impeded by hoist assembly which detached during impact.	Failure of teeth of input bevel of tail rotor gearbox.	Good	4	Nil	Nil	Ac rotated several times before turning over. Fuel was spilt from fractured lines. None of the 3 rear crew were strapped in correctly.

TABLE 2

RN HILLER ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	ℓ
3	9/2/72	3	At 1000' AGL at 70 kts. Engine failed in circuit. Crashed into a field.	-	No problems.	Engine seizure due to overheating.	Night good	1	Nil	Nil	Hard nose up landing on sloping ground. Pilot was a student.
4	30/8/72	5	Entered a range autorotation at 1000' AGL and 70 kts. Rotor RPM allowed to drop too low. Crashed into a field.	-	No problems.	Pilot error.	Good	1	Assorted bruising	Nil	Fortunate to escape as a/c disintegrated. Pilot was a student.
5	9/2/73	3	Loss of control at 300' AGL and 50 kts. Crashed into a field.	-	No problems.	Failure of tail rotor flapping hinge ball race.	Good	1	Nil	Nil	Stbd skid dug in. A/c bounced 75' before coming to rest. Cockpit space preserved. Pilot was a student.
6	30/5/74	3	600' AGL at 60 kts. Inability to disengage clutch resulted in a heavy landing on grass airfield.	-	No problems.	Failure of free wheel unit.	Good	2	Nil	Nil	Skids failed on impact.
7	3/9/74	4	Student pilot misjudged autorotation and struck a hedge at 30 kts. A/c rolled over onto rocks.	-	No problems.	Pilot error.	Good	1	-	-	

TABLE 3

RN WESSEX ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	ℓ
8	6/1/72	5	500' ASL and 90 kts. Textbook ditching performed after smoke in cabin and illumination of CWP caption. Sea was calm.	Yes. Success-ful	No problems. Res-cued by boat and helicopter.	Leak from stbd lower exhaust.	Good. Sea calm.	3	Nil	Nil	A/c sank during recovery phase.
9	16/2/72	5	200' and 90 kts. 45° out of wind. Loud rumble heard from engine. Heavy into wind ditching onto 12' swell.	Yes. Floated 10' below surface.	No problems. Res-cued by helicopter.	Engine surge. Cause undetermined.	Good. Heavy swell 12 ft state 4	3	2 major spinal compres-sion fractures	Nil	Rear cabin floor distorted. Possible dynamic overshoot due to loose har-nesses.
11	4/5/72	3	During practice EOL engine surge occurred at 3000' and 90 kts. Successful EOL com-pleted onto a level field.	-	No problems.	Engine surge due to transient lag of inlet guide vane servo.	Good.	2	Nil	Nil	-
12	19/7/72	4	Entry to hover at 40' ASL and <20 kts. Loss of power occurred. A/c ditched onto a calm sea.	Yes. Success-ful	All climbed into adjacent lifeboat.	Transient malfunc-tion of rotor speed governor.	Hazy. Nil wind Sea calm	4	Nil	Nil	-
13	28/8/72	5	Struck wire at 90' AGL and 90 kts and crashed into den-sely wooded copse. Both seat pans distorted by impact and left cyclic broke off and right cyclic bent.	-	No information.	Pilot error though wires were unchar-ted.	Good	2	2 major	-	Pneumothorax to 1st pilot possibly caused by cyclic stick.

TABLE 3 (Contd)

RN WESSEX ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	l
14	19/9/72	5	After deck take off the main rotors struck the rotors of an adjacent helicopter. A well controlled ditching took place.	Yes. But main rotor blades struck water and a/c inverted.	Pass and crew were immersed for 15-20 mins before rescue.	Pilot error.	Good. Calm sea.	12	-	-	-
15	17/1/73	3	During normal deck landing the tail wheel assembly sheared allowing the tail cone and pylon to strike the deck.	-	No problems.	Fatigue failure of tail wheel support bracket.	Good.	4	Nil	Nil	-
16	23/1/74	3	Both engines flamed out after zero speed approach to landing onto powdery snow.	-	No problems.	Disorientation. Pilot error.	Good	-	-	-	-
17	19/2/74	5	A/c was flown under power into a calm sea. A/c was in a descending turn at the time of impact. One side of the fjord was well lit the other unlit. Pilot may have been engaged in changing radio frequencies.	Did not operate. A/c sunk.	Pilot had undone harness but was trapped in cockpit. Observer's body never found.	Computer freeze compounded by disorientation.	Night. Good. Sea calm.	2	-	2	Crash was survivable with no severe impact damage. Pilot was an exchange officer with little type, instrument and night flying experience.
18	15/7/74	5	During climb at 550' and 65 kts loss of power occurred. Auto rotation commenced and a/c ditched on rough sea.	Yes. Successful but a/c sank subsequently.	No problems. Rescued by helicopter.	Foreign body caused compressor and inlet guide vane damage, resulting in engine surge.	Night. Good. Sea state 3.	4	Nil	Nil	Low velocity impact.
19	16/1/76	5	After take off from deck at 70' and 30 kts the a/c rotated 70° nose down, yawed to stbd and crashed into a moderate sea.	Yes. But stbd sep and a/c sank after 2 mins.	Rear crewmember escaped through window as cabin door jammed on impact. Rescued by helicopter.	Probable failure of ASE fore and aft channel.	Good. Sea state 3.	3	All suffered from slight bruising.	Nil	Tail broke off at impact.

TABLE 3 (Contd)

RN WESSEX ACCIDENTS

Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
b	c	d	e	f	g	h	i	j	k	ℓ
3/5/76	4	After a deck landing ground resonance occurred resulting in shearing of the port undercarriage.	-	-	Ground resonance compounded by incorrectly pressurised oleo.	Good.	2	Nil	Nil	
11/10/76	5	At 6000' and 90 kts high frequency vibration plus explosion with warning of engine failure and fire. Autorotation commenced and ditching onto a sea with moderate swell achieved.	Yes. Successful but a/c sank after a few minutes.	No problems. Both entered liferafts and were rescued by helicopter.	Fatigue fracture of planet gear wheels.	Dusk. Vis 4 nms. Sea state 3.	2	Nil	Nil	Pilot suffered from nausea and took anti-emetics.
13/12/76	5	A/c rose from deck into a 4' hover still attached by bonding lashed to rear wheel. Attempt to land resulted in tail rotor strike and a/c spun onto a rough sea with 8'-10' waves. Impact firm vertical and level.	Yes. Successful but a/c inverted and sank after 20 mins.	1st pilot escaped easily. Observer had difficulty due to arm injury. Crewman was swept away due to early release of harness and could not remember how he escaped. Co-pilot was never recovered. Rescue by ship boat.	Ground crew error.	Night. Vis <5 nms. IMC. Sea state 5-6.	4	Nil	1 drowned	Co-pilot possibly suffered incapacitation due to blow from a night vision aid which was only loosely stowed.
20/3/77	4	A/c forced to land due to weather conditions. Loss of external visual clues with high rate of descent. A/c landed heavily in snow drifting to stbd and pitched nose up. Snow was deep powder.	-	No problems. Rescued by helicopter in 90 mins.	Pilot error. Disorientation.	Poor. Vis <300 ms. Low cloud base.	2	Nil	Nil	The landing was attempted downwind in conditions below weather minima.
15/9/77	3	Underslung landrover became detached during transition to the forward flight.	-	-	Ground crew error.	Good.	-	Nil	Nil	

TABLE 3 (Contd)

RN WESSEX ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	l
25	18/5/78	4	After take off at 200' and 60 kts severe vibration felt. A/c returned to airfield and heavy landing resulted in tail damage.	-	No problems.	Failure to insert wrist locking pin. Pilot and maintenance error. 4 independent inspections failed to reveal the fault.	Good	3	Nil	Nil	A/c struck ground in tail down attitude causing collapse of the tail wheel and loss of tail pylon.
26	18/7/78	4	At 40' and 95 knots. A/c struck ship during unauthorised flying display. Controlled ditching onto moderate sea.	Yes. Successful.	No problems. Rescued by ship's boat.	Pilot and supervisory error.	Good. Sea state 3.	3	Nil	Nil	
27	4/8/78	4	In hover at 4' AGL severe undemanded cyclic movement occurred. After firm landing, entered ground resonance and rolled onto side with resultant blade strikes.	-	No problems.	Control unit fault involving roll servo control. Compounded by pilot's failure to check ASE.	Good.	8	Nil	Nil	Pxs carried to make up weight for blade tracking and vibration run.
28	13/9/78	4	At 150' and 60 kts. Metallic grating noise caused pilot to initiate a controlled ditching onto a moderate sea.	Yes. Successful. Sank after 75 mins.	No problems. Rescued by helicopter.	Planet gear failure in reduction gearbox.	Good. Sea state 4.	3	Nil	Nil	
29	20/9/78	4	At 500' and 105 kts. Engine failure occurred. Good ditching achieved onto a moderate sea.	Yes. Stbd bag failed to inflate and a/c immediately inverted but continued to float.	No problem. Escaped from inverted a/c. Rescued by helicopter.	Failure of 7th stage compressor blade.	Good. Sea state 3.	4	Nil	Nil	Textbook ditching with only 5-10 kts ground speed.

TABLE 3 (Contd)

RN WESSEX ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatalities	Comments
a	b	c	d	e	f	g	h	i	j	k	l
30	6/3/79	5	At 80 kts and 200' AGL a/c struck load bearing wire of a funicular railway. Tail cone detached and a/c free fell from 200'.	-	Non survivable in cockpit area. Marginal rear cabin.	Aircrew error. Wire strike.	Good vis but grey horizon.	3	-	3	Both pilots died from multiple injuries. Rear crewman died two hours later from pneumothorax and haemorrhage due to rupture of an emphysematous bulla.
31	22/5/80	5	At 100' AGL and 60 kts warning of zero transmission oil pressure. A low hover was established and all except pilot vacated a/c which was then ditched.	Yes, but a/c later inverted.	No problems. Rescued by boat.	Technical error. Probable ingress of moisture caused double failure warning.	Good. Sea state 3.	5	-	-	
32	27/6/80	5	At 700' AGL and 60 kts engine failure occurred. A/c descended 20° nose down and at 100 kts and broke up on impact. A/c was not flared prior to impact.	Broke off.	Non survivable.	Fatigue failure of 7th stage compressor blades. Compounded by slow reaction from pilot.	Good. Sea state 2.	3	-	3	Two suffered massive injuries. One body not recovered.
33	22/4/82	5	A/c crashed in appalling weather conditions. Struck tail first and rolled to port. A/c had been flared 15-20° nose up.	-	Some difficulty in releasing dinghy packs. Rescued by helicopter.	Disorientation due to sudden onset of total whiteout conditions.	Vis nil. Whiteout wind 35 kts.	7	1 slight.	-	Operational conditions.
34	22/4/82	5	A/c lost visual references and reduced speed to zero before attempting to land. The a/c slid to stbd for several yards before rolling over.	-	No problems. Rescued by helicopter.	As above.	As above.	13	1 slight.	-	As above.

TABLE 3 (Contd)

RN WESSEX ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	ℓ
35	12/10/83	3	Downwind heavy landing caused failure of stbd oleo and main rotors struck ground.	-	No problems	Aircrew error.	Good	9	1 maj	-	1 pass suffered a fractured wrist, Loadmaster who was in despatchers harness had to be hauled back into a/c by passengers.
36	7/12/83	5	At 300' AGL and 110 kts a/c pitched nose down into a spiral dive and impacted onto a snow covered field. A/c struck in a nose down, left banked attitude and slid for 30 yds in the snow.	-	Pax in left front seat was thrown clear due to seat failure. Loadmaster had to be cut free from despatcher's harness.	Aircrew error. Compounded by unclear instructions in aircrew manual.	Good	9	2 maj 7 min	-	Pilot's seat pan failed. None of the pax were strapped in.
37	-	3	Large plastic bag entered rotor disk. Ground resonance encountered. Tail cone was fractured.	-	-	FOD	-	-	-	-	
38	3/12/84	5	A/c crashed out of control into a breakwater. Pilot indicated there was a control malfunction.	-	Non survivable due to impact forces.	Unspecified. Control malfunction.	Good	1	-	1	Death due to massive injuries. Also severe PCF.

TABLE 4

RN WASP ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	l
39	20/1/72	5	At 400' and 80 kts on approach to base. Unusual vibration was followed by loss of yaw control. A/c crashed into a jungle clearing. Impact was heavy, vertical and a/c was spinning.	-	No problems.	Fatigue failure of coupling ring of transmission input to the tail rotor gearbox.	Good	2	2 maj	Nil	Pilot had fractured ribs and haemo-thorax. Px had crush fractures of L2 and L3.
40	9/1/72	5	Just after takeoff from ship at 50' and 40 kts engine failure occurred. Good ditching achieved on sea with slight swell.	Yes. R bag did not inflate. A/c sunk after 2 mins.	No problems. Rescued by boat.	Engine failure due to unknown cause.	Good. Sea state 2.	3	Nil	Nil	
41	20/3/72	4	Engine failed after takeoff at 500' AGL and 95 kts. Autorotative landing achieved onto a ploughed field.	-	No problems.	Failure of tooth on output spur gear in accessory drive unit.	Vis 5 nms.	2	Nil	Nil	Landed on sloping ground. A/c dug in and turned over to port.
42	15/5/72	4	At 10,500' and 80 kts engine speed fluctuated. Textbook ditching performed onto calm sea.	Yes. Successful. Blade strikes caused roll to port.	No problems. Rescued by boat.	Failure of acessory drive unit.	Good. Sea state 2.	2	Nil	Nil	
43	17/5/72	4	Engine failure whilst in high hover alongside training deck. A/c landed heavily in 3' of water alongside dummy deck. Aft undercarriage collapsed.	-	No problems.	Failure of splines at inner end of quill shaft.	Good.	1	1 maj	Nil	Compression wedge fracture of 7th thoracic vertebrae. Injury probably caused by posture as seat pan undistorted. Was wearing a backpack.

TABLE 4 (Contd)

RN WASP ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	ℓ
44	22/1/72	3	Heavy landing after engine-off approach.	-	No problems.	Pilot error.	Good.	2	Nil	Nil	
45	3/12/72	4	Lost power just after take-off from deck. Controlled ditching achieved. A/c rolled over due to blade strike.	Yes. Successful.	No problems. Rescued immediately.	Throttle linkage restriction.	Good. Sea calm.	2	Nil	Nil	
46	5/6/73	4	After deck take off at 100' and 60 kts loss of power occurred. Controlled ditching onto calm sea.	Yes. Successful.	No problems. Rescued by boat.	Failure of 2nd stage axial compressor blades.	Night. Good. Sea calm.	2	Nil	Nil	
47	12/12/73	5	At 500' and 60' in circuit a/c crashed out of control into an earth covered stone wall. The a/c burnt after impact.	-	Not possible except if assisted escape system fitted.	Loss of tail rotor drive due to unknown cause.	Good.	4	Nil	4	Non survivable impact in excess of 30Gs. All fatalities due to multiple injuries.
48	28/3/74	4	Approach to ship at night in poor conditions. Impacted slight sea at 60 kts.	Yes. Successful.	No problems. Rescued by boat.	Faulty glide path indicator. Non compliance with operating instructions. Pilot error in choosing such an approach in poor weather conditions.	Night. Vis 1-2 nms. No horizon. Sea state 2.	2	Nil	Nil	
49	25/7/74	4	Directional control lost at 5' AGL. Heavy landing with sideways compact resulted in port undercarriage failing and main rotor blades struck the ground.	-	No problems.	Fatigue failure of tail rotor hub.	Good.	3	-	-	Bystander suffered compound fracture of tib and fib from rotor blade fragment.
50	19/11/74	-	Man fell overboard and drowned after ground handling error with torpedoes.	-	-	-	-	-	-	-	-

TABLE 4 (Contd)

RN WASP ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatalities	Comments
a	b	c	d	e	f	g	h	i	j	k	l
51	3/4/75	4	Heavy landing during practice engine off approach.	-	No problems.	Pilot error	Good.	2	-	-	Stbd front oleo penetrated the cabin floor.
52	4/6/75	4	Loss of directional control at 50 kts and 20' AGL. A/c struck sea in flat attitude rotating to starboard. Vert decel estimated to be >18G.	Yes	No problems. Rescued by sea boat.	Probable pilot error.	Good. Calm sea.	3	-	-	No spinal injury despite 18G decel.
53	11/7/75	4	In cruise at 2000' AGL and 100 kts loud bang heard due to overhead escape hatch detaching and striking the main rotors. Emergency landing was very heavy due to misting up of canopy in final stages of approach.	-	No problems.	Failure of overhead escape hatch.	Good.	2	-	-	
54	26/8/76	5	During flying display a/c entered a wing over manoeuvre from which it did not recover. Struck the sea in a level attitude and somersaulted to an inverted position. Initial impact was flat with little vertical velocity.	Sank. Flot equipment did not operate due to inverted position.	Both crew escaped easily from inverted helicopter. Rescued by helicopter immediately.	Pilot error.	Good. Sea calm.	2	1 maj	Nil	Crewman was in rear wearing the despatcher's harness. At impact he was crouching between the two seats. Suffered from fractured left ulna and bruising.
55	7/12/76	3	Mayday declared due to oil pressure problem. Resultant heavy deck landing resulted in failure of stbd forward undercarriage.	-	No problems.	Pilot error in difficult situation.	Good.	2	Nil	Nil.	

TABLE 4 (Contd)

RN WASP ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	l
56	21/1/77	3	Heavy deck landing resulting in failure of stbd forward oleo attachment.	-	-	Pilot error.	Good.	2	Nil	Nil	
57	29/3/77	4	At 70' AGL a/c yawed to stbd out of control. Crashed into sea in nose down attitude and inverted.	Failed to operate due to attitude and incorrect connection of actuators.	Both escaped easily from inverted helicopter. Rescued immediately.	Pilot error.	Good.	2	Nil	Nil	
58	5/4/77	5	A/c in transit at 1500' suddenly developed a nose down attitude. Regained level attitude but struck sea with high vertical velocity but little forward motion. Banked to port.	Port bag failed to inflate. A/c sank after 1 hr 40 mins.	Pilot escaped from inverted a/c by top escape hatch. Rescued by helicopter.	Probable pilot error but may have been inappropriate feed from Al to autopilot.	Good. Sea state 2.	1	1 min	Nil	Minor abrasions and whiplash injury. Pilots seat pan was badly distorted. Heavy impact damage on port side.
59	21/6/77	4	A/c damaged in ship's lift.	-	-	-	-	-	-	-	Ground accident.
60	27/7/77	3	Practice engine failure in hover resulted in collapse of port forward oleo and rotor blades struck the a/c tail.	-	No problems.	Pilot error.	Good.	2	Nil	Nil	Wheel locks left in. Also practice engine failure initiated with forward motion contrary to regulations.
61	29/9/77	4	Heavy deck landing resulted in failure of both port oleos. Rotor strikes on deck.	-	-	Pilot error. Command error - deck officer indicating landing was safe to carry out.	Good.	3	Nil	Nil	Accident cased by combination of pitching deck and turbulence from a/c hangar.

TABLE 4 (Contd)

RN WASP ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatalities	Comments
a	b	c	d	e	f	g	h	i	j	k	l
62	22/10/77	3	Port undercarriage failed after heavy deck landing.	-	-	Pilot error. Command error.	Good.	4	Nil	Nil	
63	15/11/77	3	20' AGL and 20 kts engine failure occurred in approach to a high hover. Pilot managed to effect landing on uneven ground.	-	No problems.	Suspected failure of 2nd stage nozzle guide vanes.	Good.	2	1 minor	Nil	Crewman restrained by despatcher's harness.
64	3/2/79	4	At 400' AGL and 90 kts smell of burning noticed. Controlled ditching achieved.	Yes. A/c immediately rolled to port.	No problems. Rescued by boat.	Incorrect diagnosis of engine fire.	Night. Good. Sea state 2.	2	-	-	Poor flotation properties.
65	12/12/81	5	During steep approach to land full power could not prevent a heavy landing.	-	No problems.	Aircrew error. Downwind approach.	Good. Turbulent.	4	-	-	A/c rolled over onto port side after impact with ground.
66	20/1/82	3	During hydraulics off deck landing a/c struck deck heavily.	-	No problems.	Aircrew error.	Good.	2	-	-	Damage to top hat section.
67	26/6/82	3	Heavy landing during practice engine off.	-	No problems.	Aircrew error.	Good.	2	-	-	Damage to forward oleo.
68	28/10/82	4	After deck take off at 40' AGL and 40 kts loss of power occurred. A/c ditched alongside ship.	Yes. Successful.	No problems. Rescued by ship's boat.	Technical error maintenance. Misalignment of seal in air motor housing.	Good. Sea state 1.	3	-	-	
69	27/5/83	4	At 100' AGL and 80 kts engine surged. Well controlled ditching took place.	Yes. Successful.	No problems though aircrewman did not have his backpack on. Rescued by sea boat.	Failure of No 1 oil pump due to foreign body.	Good. Sea state 2.	2	-	-	

TABLE 4 (Contd)

RN WASP ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	ℓ
70	6/6/83	4	Heavy deck landing at night.	-	No problems.	Aircrew error.	Good. Night. Sea state 5.	2	-	-	Failure of port top hat section.
71	6/7/83	4	Heavy deck landing on rolling deck. Tail rotor struck obstruction and the droop stops failed causing the main rotor to sever the tail rotor pylon.	-	No problems.	Aircrew error.	Good. Sea state 4.	4	-	-	
72	6/9/83	4	Loss of power during approach to deck landing caused pilot to ditch a/c.	Yes. Successful.	No problems. Rescued by boat.	Aircrew error.	Good. Sea state 3.	1	-	-	Main and tail rotors damaged by water impact.
73	24/10/83	3	Heavy deck landing at night. Ship was out of wind limits.	-	No problems.	Aircrew error.	Night. Good.	4	-	-	Failure of stbd top hat section.
74	13/4/84	5	After deck take-off at 30' AGL. Max power was limited. A/c ditched in a level attitude.	Yes. Only port bag inflated. A/c immed rolled to stbd.	Pilot escaped from inverted a/c. Crewman via rear door. Rescued by ship's boat.	Probable engine failure. A/c sank.	Good. Sea state 2.	2	-	-	
75	5/6/84	3	Heavy engine off landing.	-	No problems.	Aircrew error.	Good.	2	-	-	
76	26/9/84	3	Heavy deck landing.	-	No problems.	Aircrew error	Good. Sea state 6.	4	-	-	Top hat section damaged.
77	29/10/84	3	Heavy deck landing.	-	No problems.	Aircrew error.	Good. Sea state 3. Heavy swell.	2	-	-	

TABLE 5

RN SEA KING ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	l
78	13/1/72	5	In hover at 40' ASL large torque split occurred which was misdiagnosed. Resulted in heavy vertical ditching onto rough sea with 7' waves with blade strikes.	Yes, but a/c rapidly filled and inverted. Floated for 45 mins.	No problems. All rescued by boat and helicopter.	Computer failure plus pilot error.	Good. Sea state 5-6.	6	1 major	Nil	Compression fracture of 5th thoracic vertebrae due to failure of seat pan of 1st pilot. 2nd pilot's seat pan also distorted.
79	10/4/72	5	In hover at 40' violent vibration occurred. Gentle water landing was achieved.	No, not used. A/c inverted immediately and sank.	2nd pilot failed to jettison window and escaped through open portion. Observer escaped without his back pack. Px unstrapped too early and escape was difficult. Rescued by helicopter.	Probable main rotor tip failure.	Good. Sea state 5-6.	4	Nil	Nil	Lucky to escape without loss of life.
80	21/3/74	5	At 100 kts and 200' ASL a/c flew into a rock face. Fuselage broken in two and a fierce post crash fire ensued.	-	Not possible.	Observer's navigational error. Observer of below average capability.	Night. Good.	4	Nil	4	All fatalities due to multiple injuries. Pilot was exchange officer with limited night and IF experience.
81	22/7/74	4	In hover at 40' ASL. No 2 engine flamed out. A/c landed in level attitude Successful take-off achieved after No 2 restarted.	Yes. Successful.	Not applicable.	Malfunction of overspeed trip governor.	Good.	6	Nil	Nil	No 2 subsequently flamed out again but safe single engine speed had then been achieved.
82	19/11/74	3-4	Loss of directional control in hover at 40'. A/c impacted with sea in flat attitude rotating clockwise. A/c immediately toppled to port and inverted.	Not known.	Observer was snagged twice on escape attempt. Rescue rapid.	Control failure.	Good.	4	-	-	

TABLE 5 (Contd)

RN SEA KING ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	l
83	12/12/74	5	Some vibration occurred during downwind transit. A/c was ditched in a controlled manner. A/c inverted after 1 hour and sank.	Yes.	No problems.	Failure of one main rotor blade.	Good. Sea state 5-6.	5	-	-	
84	19/3/75	5	Emergency ditching from 40'. A/c sank after 3¼ hours.	Yes.	No problems.	Fire in No 2 engine.	Night. Good.	4	-	-	
85	17/11/75	5	In 40' hover with sonar out when loud bang heard from engines. Large quantities of oil entered the cabin and a ditching was carried out from 15' ASL.	Yes. A/c immediately inverted and sank later.	No problems from inverted helicopter. Rescued in 40 mins by boat and helicopter.	Probable failure of drive between No 2 free power turbine and input bevel in gearbox.	Day Good. Moderate sea.	4	-	-	
86	31/3/76	5	In hover at 40' ASL. Severe vibration and random motion experienced. A/c ditched but blade strikes caused it to roll, inverted immediately. There was a 4-8' swell.	A/c inverted and sank immediately.	1 P had not secured his back pack to his life jacket. 2 P kicked out window but was disorientated. Observer released harness too early and was thrown around. Beta lights were not visible. Rescued by helicopter.	Probable loss of part of main rotor blade.	Good. Sea state 5.	4	2 slight.	Nil	Very lucky for all to escape, as drills not carried out correctly.
87	23/10/77	3	At 4000' and 70 kts. Tail pylon unlocked. Light illuminated. A heavy landing onto an RFA resulted in extensive fuselage damage.	-	No problems.	Fatigue fracture of port upper pylon lug, compounded by heavy landing due to pilot error.	Good.	4	Nil	Nil	

TABLE 5 (Contd)

RN SEA KING ACCIDENTS

No a	Date b	Cat c	Circumstances of Accident d	Use of Flotation Aids e	Escape and Rescue f	Cause of Accident g	Weather h	Nos i	Injuries j	Fatal-ities k	Comments ℓ
88	5/10/77	5	In hover at 40' ASL, a/c experienced total loss of yaw control. Heavy flat impact onto sea with slight swell.	Yes, but a/c inverted and sank after 2 mins.	2 P unable to jettison window so he escaped through port window. Rear crew undid harness prematurely, increasing difficulty of escape due to inrushing water. All rescued by boat and helicopter.	Loss of tail rotor control due to unknown cause.	Good. Sea state 1-2.	4	3 maj	Nil	All except pilot had spinal compression fractures. ? due to poor posture at impact.
89	30/3/78	4	90 kts and 80' ASL. Transmission oil pressure light illuminated. Controlled ditching onto almost calm sea achieved.	Yes. Successful.	All escaped easily. Rescued by helicopter.	Over-torqueing of nut resulted in major oil leak.	Good. Sea state 1-2.	8	Nil	Nil	Textbook ditching.
90	26/4/78	4	During ground taxying rear oleo burst resulting in failure of the tail wheel.	-	-	Failure of rear oleo.	-	2	-	-	-
91	25/8/78	4	At 2500' at 100 kts transmission oil pressure caption illuminated and oil seen streaming from port side of a/c. Controlled ditching onto calm sea carried out.	Yes. Successful.	No problems. Rescued by helicopter.	Loss of O ring seal on filter housing due to fracture of a threaded insert.	Good. Sea state calm.	7	Nil	Nil	-
92	18/11/78	3	Hover at 40' ASL. Port engine surged and a/c was allowed to settle onto a calm sea with 3' swell. Single engine take off attempted but not successful.	Yes. Successful.	No problems. Rescued direct to ship by boat.	Failure of 6th stage stator blade.	Good. Sea calm.	4	Nil	Nil	Incorrect technique used for single engine take off attempt.
93	3/2/79	3	Damage to underside of a/c caused by sonar buoy.	-	-	Undetermined.	-	-	-	-	-

TABLE 5 (Contd)

RN SEA KING ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	ℓ
94	29/9/79	3	Deck landing. Damage caused by tail wheel being over the after edge of the flight deck.	-	-	Aircrew Error	Dark night.	3	-	-	-
95	9/10/79	4	During 5 kt running landing, a slow yaw developed. A/c rolled onto L side after landing.	-	No problems.	Failure of tail rotor drive shaft discon-nect coupling.	-	2	-	-	-
96	14/1/80	5	Controlled ditching after indications of loss of transmission oil pressure.	Yes. Success-ful.	No problems. Rescued by heli-copter.	Loss of gearbox oil. Cause unknown.	Good. Sea state 2-3.	5	-	-	A/c was lost during recovery procedures.
97	18/2/81	4	Loss of directional control in hover at 50'. Heavy flat impact.	Yes. A/c inverted.	No problems.	Loss of tail rotor control. No mechani-cal defect dis-covered.	Good. Sea state 3-4.	7	3 min	-	-
98	6/3/81	5	Mid-air collision at 200' and 200 kts closing speed. A/c fell out of control to sea below.	Not operated.	-	Aircrew error.	Vis down to 1K in fog.	4	-	4	Non survivable. All fatalities due to drowning due to mul-tiple injuries.
99	6/3/81	5	Mid-air collision as above. A/c was able to make a more or less controlled ditching.	Yes, but stbd sponson broke off.	A/c rapidly inver-ted. All experi enced difficulty in escape due to rapid inversion. All res-cued by helicopter.	Aircrew error.	As above. Sea state 4.	4	2 slight.	1	Observer drowned.
100	10/6/81	3	Heavy deck landing.	-	-	Aircrew error com-pounded by poor illumination of the flight deck.	Night.	4	-	-	

TABLE 5 (Contd)

RN SEA KING ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	ℓ
101	29/10/81	3	During take-off from deck a/c drifted backwards and struck deck netting. Engines also over-torqued.	-	-	Aircrew error.	Good.	4	-	-	
102	23/4/82	5	During circuit to shipborne landing pilot became dis-orientated. A/c impacted sea and sank.	Not known.	Pilot cannot remem-ber how he escaped. Crewman lost. Res-cued by helicopter.	Aircrew error. Dis-orientation under difficult condi-tions.	Night. Sea state 4.	2	-	1	Pilot's life jacket damaged by impact.
103	12/5/82	5	In hover at 60'. Engine failure occurred. A/c was struck by wave during attemp-ted single engine transition.	A/c immedi-ately inverted.	Co-pilot's window failed to jettison. He exited via slid-ing window. Rescued by helicopter.	Unknown. Probable ECU failure or fuel computor/throttle actuator runaway.	Sea state 6.	4	-	-	Observer removed own PSP due to escape difficulties. All complained of cold hands.
104	18/5/82	5	During approach to hover rad alt failed at 50' ASL and 10-15 kts. A/c impacted with sea.	Yes. Success-ful.	No problems. Rescued by heli-copter.	Aircrew error. Disorientation.	Sea state 1. Night, no moon or hor-izon.	4	-	-	-
105	23/5/82	3	Tail rotor struck ground during approach to hover.	-	-	Aircrew error.	-	-	-	-	No details avail-able.
106	11/7/82	5	In hover at 70' ASL. Engine failure. A/c ditched.	Yes, but a/c sank in 10 mins.	No problems except for initial diffi-culty in jettison-ing pilot's window. Rescued by heli-copter.	Engine failure. Probably No 2 ECU.	Good. Sea state 5.	4	-	-	A/c almost undam-aged but inverted and sank.

TABLE 5 (Contd)

RN SEA KING ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	ℓ
107	19/5/82	5	At 200-300 ASL at 60 kts during landing circuit a loud bang was heard. The a/c struck the water and immediately inverted.	Not actuated. A/c inverted and sank.	Co-pilot no problems. Pilot probably kicked a hole in the roof light. Only 7 of 27 Pax escaped. Rescued by boat and helicopter.	Unknown.	Night. Sea state 3.	30	4 major 1 minor	21	Co-pilot's spinal compression fracture not diagnosed for 2 months.
108	3/2/83	5	During recovery from a wing over the tail rotor struck the water. A/c impacted at 50-70 kts in nose up attitude.	Not actuated. A/c sank immediately.	All except pilot escaped. Rescued by helicopter.	Aircrew error.	Good.	4	-	1	Pilot failed to escape due to unknown cause. Possible minor incapacitation.
109	29/2/84	4	Wire strike at 100 kts at 50' AGL. A/c flew ¼ mile to landing site and sustained a heavy landing.	-	No problems.	Aircrew error.	Good.	2	-	-	Tail cone and pylon detached. Main undercarriage casing and shock absorption bolts were fractured.
110	30/8/84	4	During manual throttle approach to hover. A/c moved to stbd and rolled to stbd. A/c came to rest on stbd side.	-	1st pilot had difficulty undoing PSP barrel connectors.	Aircrew error.	Good.	2	-	-	-
111	26/9/84	3	In hover at 30 ASL. No 1 engine failed. A controlled ditching took place.	Yes, a/c inverted during recovery.	No problems. Rescued by helicopter.	Leakage of hot compressor air caused overspeed trip governor to trip.	Good. Sea state 2.	4	-	-	Stbd forward flotation gear failed to inflate, due to faulty inflate button.

TABLE 6

RN GAZELLE ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	l
112	22/5/75	5	120 kts at 50' AGL. Wire strike resulted in a non survivable crash in a densely wooded valley.	-	Not possible.	Pilot error. Wire strike.	Good. 9 ms vis.	2	Nil	2	Fatalities due to multiple injuries. Both crewseats sustained massive damage.
113	4/3/76	5	During limited power approach a/c oscillated before crashing pitched nose up 10½° at <30 kts. Rolled to stbd.	-	No problems.	Pilot error (student pilot).	Good. Hazy.	1	Nil	Nil	Impact mainly absorbed by the tail boom.
114	13/6/77	5	At 250' and 85 kts in left turn. Mid air collision. A/c fell into sea out of control.	-	Not possible. ? assisted escape.	Pilot error.	Good.	2	Nil	2	Nose down high speed water entry caused massive a/c damage. Deaths due to multiple injuries.
	13/6/77	5	As above	-	As above.	"	"	1	Nil	1	
115	12/5/78	5	At 500' AGL. After rolling out of wing over and uncontrollable spin to port developed. A/c crashed into a field. A heavy vertical impact.	-	Student had to be helped out as helmet was trapped between airframe and ground.	Possible inadvertent entry into vortex ring condition due to too low an airspeed. Pilot error.	Good.	2	1 min 1 maj	Nil	1 P cuts & bruises. 2 P cuts & bruises and compound fracture of left middle finger. 12-16g vertical velocity change resulted in stbd skid failure engine broke free and instrument panel detached.
116	18/11/80	5	Control lost demonstrating spot turn in hover. A/c impacted heavily and rolled onto stbd side.	-	No problems.	Loss of control in circumstances beyond experience of pilot.	Good.	2	1 maj	-	Pilot had crush fracture of 1st lumbar vertebrae. Small fire in turbine area due to fuel spillage onto a hot engine.

TABLE 6 (Contd)

RN GAZELLE ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	ℓ
117	12/3/82	5	Loss of control during wing over manoeuvre at 100' AGL and 90 kts. Impact was very heavy with large vertical component. Banked 10-15° to port. The a/c slid for 300' before coming to rest.	-	No problems. Rescued by heli-copter.	Aircrew error.	Good.	2	1 maj 1 min	-	Compression frac-ture of L1. Under-carriage penetrated fuel tank. R stbd seat attachment points failed. Fire extinguisher attach-ment failed.
118	10/8/83	3	Misjudged engine off landing.	-	No problems.	Aircrew error.	Good.	2	-	-	Rotor blade tips struck tail pylon.

TABLE 7

RN LYNX ACCIDENTS

No	Date	Cat	Circumstances of Accident	Use of Flotation Aids	Escape and Rescue	Cause of Accident	Weather	Nos	Injuries	Fatal-ities	Comments
a	b	c	d	e	f	g	h	i	j	k	ℓ
119	30/9/82	5	Hydraulic gauges registered zero in flight. Crew became aware of burning in the alternator control and protection area. A power on ditching was achieved.	Yes, but a/c turned onto port side immediately and sank.	Observer and aircrewman vacated from low hover. Pilot escaped from inverted a/c. MS5 dinghy was blown out of reach. Rescued by helicopter.	Mechanical failure. Hydraulic pipe failure ?	Good. Wind 35 kts. Sea state 6.	3	-	-	Sea anchor on dinghy is not self deploying.
120	4/5/83	5	At 500' ASL and 100 kts progressive loss of yaw control experienced. Emergency water landing attempted. Severe impact with nose down attitude and left yaw.	Yes, but stbd flot gear failed to operate. A/c rolled to stbd and sank.	MS25 dinghy not used due to upwards displacement of floor. Rescued by ship's boat.	Fatigue failure of tail rotor pitch change lever. This allowed a more +ve blade pitch than permitted by design.	Good. Sea state 2.	4	4 maj	-	All fuel tanks were ruptured on impact. All occupants suffered spinal compression fractures. Winchman in despatcher's harness suffered internal injuries. Pax was unsure of the correct method for operating the rear emergency exits.
121	25/11/83	3	Wire strike at 100' AGL and 120 kts. A/c which was in operational conditions continued its flight.	-	-	Aircrew error. Wire strike. Operational conditions.	Good.	2	-	-	-

TABLE 8

	Accident Rate per 10,000 flying hrs	Fatality Rate per 10,000 flying hrs
AAC	0.73	0.266
RAF	0.56	0.200
RN	1.08	0.540
		(0.32 excluding Op Corporate fatalities)

TABLE 9

Terrain Impacted by Aircraft Type

	Whirlwind	Hiller	Wessex	Sea King	Gazelle	Lynx	Wasp	Total
Water	1	0	14	23	2	2	14	56
Flat	0	0	2	1	2	0	5	10
Sloping	0	1	0	0	0	0	1	2
Airfield	1	1	3	3	2	0	4	14
Trees	0	0	1	0	1	0	0	2
Uneven Rocky	0	3	2	2	0	0	3	10
Snow	0	0	5	0	0	0	0	5
Deck	0	0	2	4	0	0	10	16
Total	2	5	29	33	7	2	37	115

TABLE 10

Disorientation Accidents (Operation Corporate)

Aircraft	Circumstances	Injuries/ Fatalities
Wessex	Total whiteout conditions in extremely severe weather conditions	1 minor
Wessex	As above	-
Sea King	Fly in on dark night	21 fatal 3 major 3 minor
Sea King	Fly in on dark night after radalt failure	Nil
Sea King	Fly in on dark night during circuit to deck landing	1 fatal

TABLE 11

Fatalities in RN Helicopters

Helicopter Type	Comments
Wessex	Survivable accident with little impact or seat damage. The pilot's body was seen floating in the cockpit free of his harness. It is, therefore, surmised that he was unable to effect his final escape despite being able to free himself from his harness. The crewman was never found. The aircraft and bodies were lost during the recovery procedure.
Wessex	Survivable accident, three of the four occupants escaped with only minor injuries from an inverted helicopter. The co-pilot did not escape and it is likely that he was prevented from doing so by the inrush of water or by a minor incapacitation from the hand held night vision aid he was carrying in the cockpit.
Wessex	Non survivable accident involving a free fall from 200 ft agl after a wire strike. Fatalities were caused as follows: 1st Pilot. Severe multiple injuries. 2nd Pilot. Severe multiple injuries. Aircrewman. Fractured femur, chest injuries involving a haemo-pneumothorax following rupture of an emphysematous bulla on impact.
Wessex	Marginally survivable accident involving a fly in. Aircraft impacted the sea at 100 kts in a nose down attitude. Pilot. Body never recovered. Sonar operator. Death due to massive injuries received from contact with the radar console. His shoulder straps were not done up on impact. Observer. Massive injuries, but death recorded as being due to drowning.
Wessex	Aircraft crashed out of control onto a breakwater. Pilot. Death due to multiple injuries including a fractured skull.
Wasp	Non survivable accident. Aircraft crashed into a stone wall. Damage to the seats indicates impact parameters in excess of $+30G_z$. Pilot and three passengers died from severe multiple injuries.
Sea King	Non survivable accident. Aircraft impacted with cliff face at 100 kts. All four fatalities were due to ...ltiple injuries

TABLE 11 (Contd)

Helicopter Type	Comments
Sea King*2	Midair collision. 1st aircraft. Free fell to sea from 2000 ft. Pilots. Both died of drowning due to major incapacitating injuries. Observers. Both bodies were never recovered. 2nd aircraft. Controlled ditching, but the helicopter rapidly inverted. Observer. Body never recovered; he may not have been fully strapped in at the moment of impact and he may have been incapacitated by contact with the radar console.
Sea King	Fly in. Aircraft immediately inverted. Both pilots and 7 troops escaped with varying difficulty from the inverted helicopter. Crewman. Died of drowning secondary to a head injury probably received from the GPMG mounted in the rear cabin. 20 troops missing presumed drowned.
Sea King	Fly in. Inverted and sank in a few minutes. Crewman who had been called forward to monitor lookout in difficult conditions did not survive. He was probably incapacitated due to being unrestrained at the time of impact.
Sea King	Survivable accident. Fly in. Aircraft immediately rolled over and sank almost at once. 1st pilot failed to escape due to unknown cause. Probably due to a minor injury causing incapacitation, the major impact being on the port side.
Gazelle*2	Midair collision. Non survivable. Both aircraft free fell from 250 ft asl. All three occupants of both aircraft died as the result of massive injuries.
Gazelle	Wire strike. Non survivable. Both aircrew died as the result of massive injuries.

TABLE 12

Spinal Injuries in RN Helicopters

A/C Type	Injury	Impact parameters
Wasp	Pilot RHFS - Compression fracture T7	Vertical impact into shallow water. Injury sustained due to bad posture as vertical velocity change unlikely to be in excess of 8G.
Wasp	Pax LHFS - Compression fractures L2 and L3	Heavy vertical spinning impact into jungle clearing.
Wessex	Pilot LHFS - Fractured tips of transverse processes L3-L5	Heavy vertical impact into densely wooded valley following a wire strike.
Wessex	Loadmaster - Compression fractures T2-T3, T6-T8	Heavy impact in nose down and left wing low attitude. He was wearing a despatcher's harness. Aircraft came to rest 30 ms from the point of initial impact.
Wessex	Obs - Ant wedge fracture T5 Obs - Compression fractures T2,3 and 5	Heavy vertical impact onto sea with heavy swell. The aircraft probably impacted on the crest of a wave, transmitting all the energy into the rear cabin.
Sea King	Pilot LHFS - Compression fracture T5	Heavy vertical impact from 40 ft hover. Injury a direct result of seat pan failure.
Sea King	Pilot RHFS - Compression fracture C7 Obs - Compression fractures C7 and T7 Obs - Compression fracture T4	Heavy vertical impact from 45 ft asl. Three of the four occupants suffered from spinal injuries probably due to poor posture.
Sea King	Pilot LHFS - Fracture T12	Fly-in with large velocity component. Fracture was not demonstrated for two months.
Gazelle	Pilot RHFS - Compression fracture L1	High speed impact with multi-directional impact parameters. Seat mountings failed.
Lynx	Observer LHFS - Compression fractures L3,L4 Pilot RHFS - Compression fractures T5-T8 with avulsion of T6 and T7. Winchman - Compression fracture L2 Pa[illegible] - Compression fracture	Heavy vertical impact with slight nose down, left wing low and low forward speed.

TABLE 13

Fate of Helicopter After Controlled Ditching
Compared to Sea State at the Time

Sea State	Salvaged	Sunk
Calm	7	2
1	2	0
2	7	5
3	3	5
4	3	4
5	0	4
6	0	4

TABLE 14

Major Causes of Escape Difficulties
from Ditched Helicopters

Egress Problem	No. of survivors
Inrushing water only	43
Inrushing water plus: Reaching hatch	34
Confusion/ disorientation	26
Releasing hatch	16
Darkness	12
Fire/smoke/fuel	11
Releasing restraint	9

TABLE 15

Number of Emergency Exits

Passenger Seating Capacity	Emergency Exits each side of the fuselage			
	Type I	Type II	Type III	Type IV
1-10	-	-	-	1
11-19	-	-	1 or	2
20-39	-	1	-	-
40-59	1	-	-	1
60-79	1	-	1 or	2

TABLE 16

Minimum Sizes

The opening must be larger than a rectangle of the dimensions given below, with corner radii not greater than 1/3 the width, and a flat base not less than 1/3 the width.

	Type I	Type II	Type III	Type IV
Width, mm	610	508	508	483
Height, mm	1220	1118	915	660
Maximum Steps				
Up inside, mm	0	254	508	737
Down outside, mm	-	432	686	915

DEFINITIONS

Period of Operation. The period of operation of an aircraft is from the time the aircrew start their pre-flight checks for the purpose of the flight, to the time when the after flight shut-down checks have been completed. Flying accidents are those which occur during the period of operation.

Aircraft Accident. An occurrence during the period of operation of the aircraft which results in either, or both, of :-

a. A person receiving fatal or major injuries.

b. The aircraft sustaining Category 3, 4 or 5 damage.

Injury Definition

a. Fatal Injury. An injury which results directly in the death of an individual either at the time of the accident or within a calendar year of that time. Missing persons are considered as fatally injured unless evidence of their survival is confirmed.

b. Major Injury. An injury that requires medical treatment involving absence from duty for a period in excess of 21 days. In addition, the following are always classed as major injuries:-

(1) Fractures of bones (except simple fractures of fingers or toes, simple fractures of ribs without respiratory involvement, and fractures of vertebrae without spinal cord involvement).

(2) All second or third degree burns, or any burn involving more than 5% of the body surface.

c. Minor injury. An injury that requires medical treatment involving absence from duty for a period of 7-21 days, and which falls outside the definition of a major injury. In addition, the following are also classified as minor injuries unless they involve absence from duty for a period in excess of 21 days:-

(1) Unconsciousness, caused by a blow or impact, lasting for more than 30 seconds or producing any degree of retrograde amnesia.

(2) Simple fractures of fingers or toes, simple fractures of ribs without respiratory involvement, and fractures of vertebrae without spinal cord involvement.

(3) First degree burns involving more than 1%, but less than 5% of the body surface.

d. Slight Injury. An injury that does not come into the provision of major or minor injuries, but nevertheless requires medical treatment as opposed to medical examination.

ABBREVIATIONS

A/C	Aircraft
AEA	Aircrew Equipment Assembly
AGL	Above ground level
ASE	Automatic stabilisation equipment
ASL	Above sea level
Cat	Aircraft damage category
Comp	Compression
CWP	Central warning panel
CWFS	Crashworthy Fuel System
ECU	Engine condition unit
EOL	Engine off landing
FLOT	Flotation
FOD	Foreign object damage
GPMG	General purpose machine gun
LED	Light emitting diode
LHFS	Left hand front seat
NBC	Nuclear, Biological and Chemical
Pax	Passenger
PCF	Post crash fire
PSP	Personal survival pack
RADALT	Radar altimeter
RHFS	Right hand front seat
RFA	Royal Fleet Auxiliary
Sep	Separated
Stbd	Starboard
VIS	Visibility

AIRCRAFT DAMAGE CATEGORIES.

Damage to aircraft is classified as follows:-

Cat 1: The aircraft has suffered no damage or has suffered slight damage which is repairable within unit capacity.

Cat 2: The aircraft damage is repairable within the servicing capacity of the parent unit.

Cat 3: The aircraft damage is considered to be beyond unit resources, but may be repairable on site by a Service working party or by a contractors working party.

Cat 4: The aircraft damage is considered to need special facilities or equipment for repair which are not available on site.

Cat 5: The aircraft is considered to be damaged beyond economical repair.

CLASSIFICATION OF ACCIDENT SEVERITY

Low-severity accident. An accident resulting in structural damage, but not involving impact forces sufficient to cause injury to the aircraft occupants.

Significant-severity accident. An accident resulting in substantial structural damage, or impact forces likely to cause injury to the aircraft occupants.

Non-survivable accident. The impact accelerations exceeded the limits of human tolerance, and/or the occupied volume was compromised. Post crash fire alone is not considered a justifiable cause to classify an accident as non-survivable.

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