Department of Transport and Communications

Bureau of Air Safety Investigation

# Australian Helicopter Accidents 1969 - 1988

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AGL | Above Ground Level |
| BASI | Bureau of Air Safety Investigation |
| CAA | Civil Aviation Authority |
| FAC | Federal Airports Corporation |
| IFR | Instrument Flight Rules |
| IMC | Instrument Meteorological Conditions |
| LAME | Licenced Aircraft Maintenance Engineer |
| NVMC | Night Visual Meteorological conditions |
| RPM | Revolutions Per Minute |
| VFR | Visual Flight Rules |
| VMC | Visual Meteorological Conditions |

*'Helicopter - An object in which experimenters have as yet failed, and by which it seems unlikely that any useful purpose will be served if they ever succeed.'*

Jane's *All the Worlds Aircraft* 1917

# MAIN FINDINGS

* The overall yearly number of accidents increased greatly during the late 1970s, reflecting a surge in helicopter activity.
* The helicopter accident rate has been relatively steady since 1981. In 1987 the rate was 20.9 accidents per 100 000 flying hours.
* Aerial mustering accounted for the largest single group of accidents.
* An unexpectedly large number of accidents occurred on ferry flights.
* Private flyers are accounting for an increasing proportion of all accidents. The accident rate for private/business helicopter flying is now greater than it was in the 1970s.
* The proportion of accidents on mapping/photo/survey flights is decreasing, reflecting a decrease in mapping and survey activity.
* Engine failure or malfunction has been the most common type of occurrence leading to an accident.
* The majority of accidents were attributable to pilot factors.
* Failure of the main or tail rotor drive train was a major accident factor.
* Inadequate maintenance was a factor in one in ten accidents.
* Maintenance problems occurred mainly in northern Australia.
* Most accidents occurred during flight rather than taxi, take-off or landing.
* A number of accidents resulted from loss of tail rotor effectiveness, however, some of the other 'textbook' hazards of helicopter operations, such as Vortex Ring State and Retreating Blade Stall have very rarely featured in Australian accidents.

# INTRODUCTION

**What is BASI**

The Bureau of Air Safety Investigation (BASI) is the aviation investigative arm of the Department of Transport and Communications. BASI investigates aircraft accidents and incidents in order to establish why they occurred. By publicising the results of its investigations, conducting research and making recommendations to the regulatory bodies and the industry, BASI attempts to prevent similar accidents and incidents from occurring in the future.

BASI is completely separate from the CAA and the FAC and has no power or authority to change regulations or take action against any licence. BASI does not investigate accidents in order to attribute blame.

**History of helicopters in Australia**

The history of helicopters in Australia did not begin until after World War II. Although in 1943 the Army planned to use helicopters for reconnaissance work in New Guinea, it was not until 1948 that the RAAF received its first helicopters, Sikorsky S51s. Civil helicopters followed in 1956, with the import of a Bristol Sycamore for ANA and a Hiller 12c for TAA early in that year. In May 1956 ANA's helicopter began operating in Tasmania.

What seems to have been the first civil helicopter accident in Australia was reported in the *Aviation Safety Digest* of December 1957:

> A Bristol Sycamore helicopter, working under charter to a mining company in Western Tasmania, left Queenstown one morning last January to carry out a camp shift in a survey area 40 miles to the south. It had been refuelled to full tanks before departure and when the task was completed, late in the same morning, the aircraft set course back to Queenstown with the pilot and one passenger aboard. About halfway along the route and at a height of 2000 feet, the pilot decided to transfer fuel from the auxiliary to the main tank preparatory to landing. Soon after the transfer pump was switched on, the main engine power failed and the pilot had to carry out an autorotation landing in rugged mountainous country. He did this very successfully, but unfortunately, the front wheel sank into marshy ground soon after touchdown and the helicopter slowly tilted onto its port side, damaging the rotors and the rotor head.

The pilot and passenger escaped injury and were eventually reached by a ground party 29 hours later. After the helicopter had been lifted back onto its undercarriage, two litres of water were drained from the fuel tank. A thorough fuel check had been carried out by an engineer prior to the flight, who saw no line of demarcation when he carried out a fuel drain and so believed that the fuel was uncontaminated with water. In fact, he probably drained a full container of water from the tank. The contamination was subsequently tracked down to a fuel drum which was found to contain a substantial quantity of water.

**Why study helicopter accidents?**

It is worth taking a close look at the sort of accidents which happen to helicopters. The number of helicopters and helicopter pilots has been steadily increasing in this country and without doubt the helicopter will take on increased roles in the future. Whereas in 1976 there were 111 civil helicopters in Australia, ten years later 367 helicopters were on the civil register. At the start of 1988 there were just over 2000 helicopter pilot licence holders, including holders of student licences. However, ten years before there had been only 650 licence holders.

Just as helicopter activity continues to grow, so does the yearly number of accidents. Forty-four helicopter accidents occurred in 1988, more than in any previous year.

Helicopter operations are in general, very different to fixed wing flying and warrant separate attention. Some major differences are:

1. The great majority of helicopter pilots are professionals, in contrast to fixed wing flying, where many more pilots hold private licences.

2. Helicopters serve very different purposes to fixed wing aircraft. Whereas the ultimate purpose of most fixed wing flying is transportation of people or goods, helicopters perform a much wider variety of tasks, frequently at low level. Aerial mustering, photographic, survey and sling cargo operations are examples of the jobs helicopters perform.

3. The flying task itself is different and calls for more intense concentration. Unlike fixed wing aircraft, most helicopters cannot be trimmed for straight and level flight but require continuous control input from the pilot.

**Purpose of this report**

It is rarely possible to identify a single cause of an accident. Rather, accidents can be seen as the outcome of a chain of events. Eliminating any of the links of the chain will change the outcome and the accident may not occur. The accident chain may stretch over a long period of time, and some of the conditions for the accident (or links) may have been put in place years before the accident occurred, perhaps during pilot training or even earlier. The chain is made of links called 'factors' which can relate to the aircraft itself (for example, sticking valves in a reciprocating engine), the pilot (e.g. decisions made before or during the flight), weather, maintenance personnel, procedures and numerous other sources.

The split second in which the aircraft first sustains damage may be the culmination of a chain of events which may have been falling into place unnoticed over hours, months or even years.

The key to preventing accidents is to identify the factors which may become links in future accident chains and then reduce the chance of each individual link joining others to create a chain.

In line with this framework of how accidents happen, this report aims to achieve the following four objectives.

1. Describe the general pattern of helicopter accidents.

2. Identify the factors which have led to helicopter accidents.

3. Identify areas of helicopter operations where accident prevention measures may be targeted most profitably.

4. Stimulate discussion about helicopter safety.

**Scope of the report**

BASI records information on all accidents and incidents occurring to non-military aircraft in Australia or to Australian registered aircraft overseas. The Bureau defines an accident as an event associated with the operation of an aircraft which takes place between the time of boarding and disembarkation and which involves fatal or serious injuries to people and/or substantial damage to or destruction of the aircraft. In contrast to an accident, an air safety incident does not involve injury or significant damage, and may include occurrences such as breakdowns in air traffic separation, instrument malfunctions and engine failures. This report is based on accidents only.

A search was made for all records on BASI's files of helicopter accidents from 1969, when computer records were first kept, until late 1988. This report is concerned with the 459 helicopter accidents which occurred in this period.

# HELICOPTER ACCIDENT TRENDS 1969-88

Figure 1 illustrates the accident pattern from 1969 to 1988 and helicopter flying activity up to 1987. The graph indicates that there was a substantial increase in accidents between 1976 and 1980, reflecting a large jump in helicopter activity over the same period.

**Figure 1. Helicopter accidents 1969-88 and flying activity 1969-87**

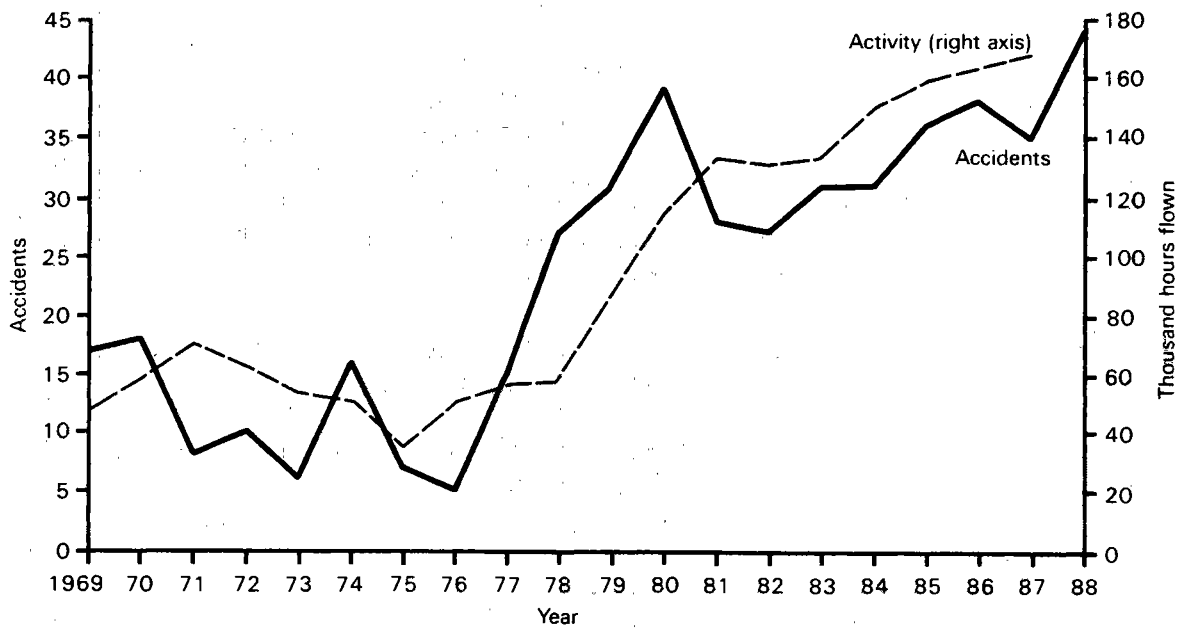
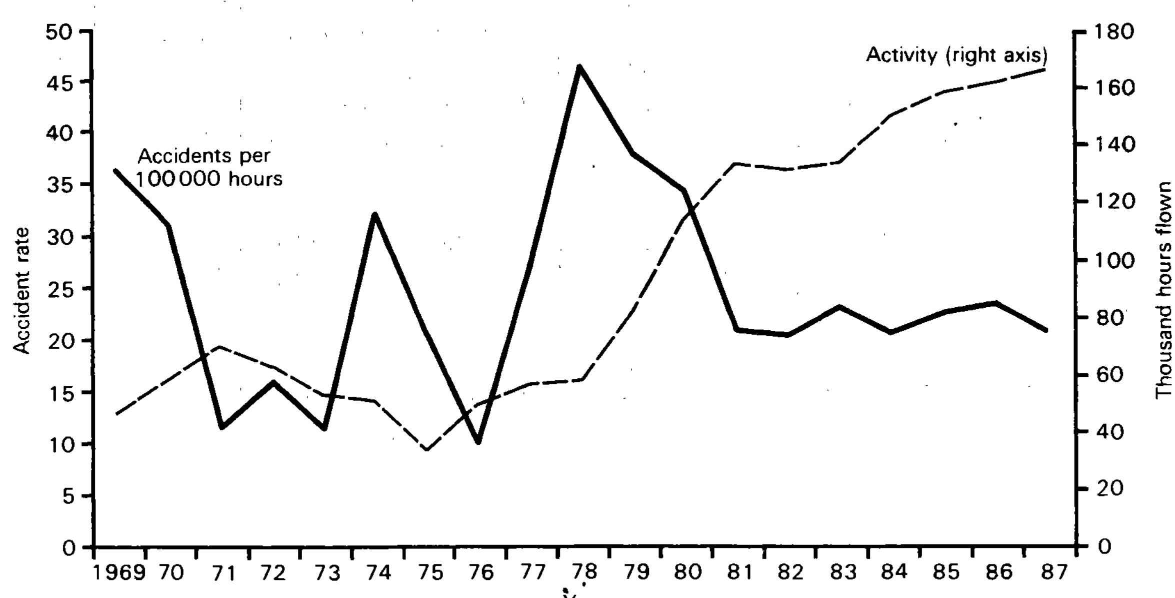



Figure 2 presents the helicopter accident rate alongside flying activity. As can be seen, the accident rate varied greatly from year to year in the 1970s but now seems to have stabilised. Of interest is the very large increase in the accident rate which accompanied the boom in helicopter activity after 1976. The accident rate peaked in 1978 and had stabilised by 1981, implying that some areas of the industry could not maintain safety standards during the early stages of the helicopter boom. In 1987 the rate was 20.9 accidents per 100 000 flight hours.

**Figure 2. Helicopter activity and accident rate 1969-87**



# FIRST OCCURRENCE

The first occurrence is the first event leading to an accident. In some cases the first occurrence only results in an accident in particular situations. For example, in the period of this study there were approximately 400 engine failures and malfunctions yet only 95 of these resulted in damage or injury. This report however, only covers occurrences which led to accidents.

**Table 1 - First type of occurrence**

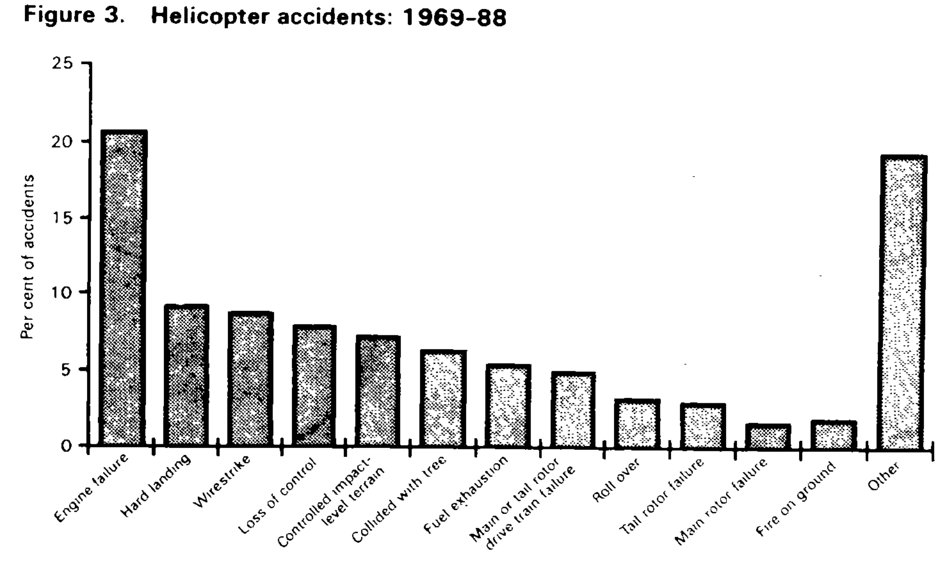
| | *Cases* | *%* |
|---|---|---|
| Engine failure or malfunction | 95 | 21 |
| Hard landing | 42 | 9 |
| Wirestrike | 40 | 9 |
| Loss of control | 36 | 8 |
| Controlled impact-level terrain | 33 | 7 |
| Collided with trees/shrubs/bushes | 29 | 6 |
| Fuel exhaustion | 25 | 5 |
| Main or tail rotor drive train failure | 23 | 5 |
| Roll over | 15 | 3 |
| Tail rotor failure | 14 | 3 |
| Fire on ground | 9 | 2 |
| Main rotor failure | 8 | 2 |
| Other | 90 | 20 |
| **Total** | **459** | **100** |

Table 1 indicates that engine failures or malfunctions have clearly been the most common type of helicopter accident. These figures are illustrated in figure 3.

Engine failure or malfunction and hard landing have also been the two most common occurrences for fixed wing aircraft. Loss of control accidents have been much more common among helicopters than among fixed wing aircraft, reflecting the extra demands of helicopter operations.

All the fires on the ground were caused by hot exhausts igniting dry grass. Eight of these accidents occurred to the Hughes 300. In all but one case the fire completely destroyed the helicopter.

Figure 3. Helicopter accidents: 1969-88



## Stage of flight

### Table 2 - Stage of flight

| | Cases | % |
|---|---|---|
| Ground | 25 | 6 |
| Taxi-ing | 15 | 3 |
| Take-off | 57 | 13 |
| Flight | 269 | 59 |
| Landing | 88 | 19 |
| **Total** | **454*** | **100** |

* This number does not equal the number of occurrences as stage of flight information was not available for all accidents.

Table 2 indicates that contrary to the pattern among fixed wing flying, most helicopter accidents have occurred during flight. These figures are illustrated in figure 4. Time trends were considered by dividing the accidents into two groups, those before and those after December 1980. As shown in figure 5 there is evidence that since 1980, flight and taxi have been associated with a greater proportion of accidents. By comparison, take-off seems to be somewhat safer now than it was before 1981. However these effects are not large.

**Figure 4. Stage of flight of helicopter accidents**

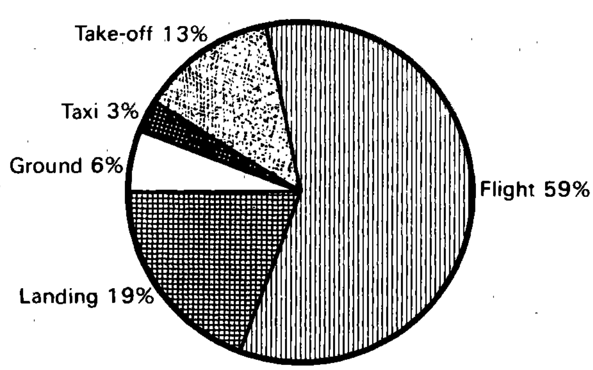
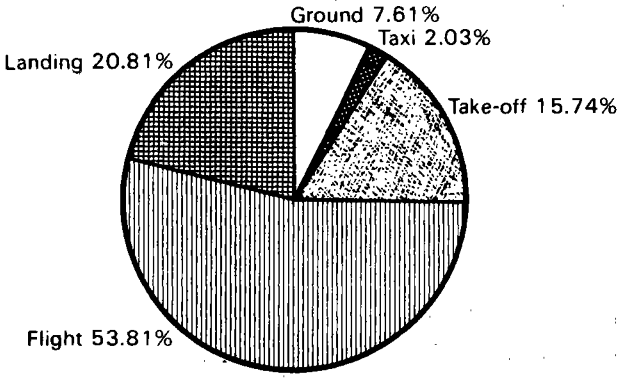
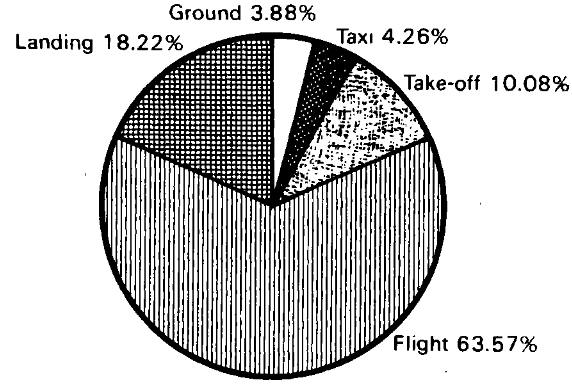



**Figure 5. Stage of flight of helicopter accidents**




**1969-80**




**1981-88**

# DETAILED EXAMINATION OF MAJOR TYPES OF OCCURRENCES

**Engine failure/malfunction**
Table 3 provides detail on 89 engine failures and malfunctions which led to accidents. The table gives the most immediate cause of the failure or malfunction, although it must be remembered that other factors were nearly always present. A number of accidents were excluded as they were still under investigation.

**Table 3 - Engine failures and malfunctions**

| | | |
|---|---|---|
| Undetermined cause | | 25 |
| Material failure | | 34 |
| *Material failure of reciprocating engines:* | | |
| Power | 10 | |
| Cylinders | 4 | |
| Fuel system | 5 | |
| Lubrication system | 1 | |
| Other | 3 | |
| *Material failure of turbine engines:* | | |
| Compressor assembly | 6 | |
| Fuel system | 1 | |
| Combustion assembly | 0 | |
| Turbine assembly | 2 | |
| Other | 2 | |
| Inadequate maintenance | | 9 |
| Engine malfunction | | 7 |
| Throttle disconnected | | 4 |
| Fuel starvation | | 3 |
| Improper operation of powerplant controls | | 2 |
| Inadequate lubrication | | 1 |
| Did not detect malfunction in instrument | | 1 |
| Foreign object ingested | | 1 |
| Fuel contamination | | 1 |
| Left oil cap off | | 1 |
| **Total** | | **89** |

Examples of 'Power' failures are failures of conrods and bearings. 'Fuel system' failures included problems with fuel pumps and mixture controls. There were three cases of fuel pump failure, all on Hughes 300 machines. Examples of 'Engine malfunction' are sticking valves and malfunctioning spark plugs. 'Inadequate maintenance' included insufficiently torqued bolts and incorrectly installed parts.

'Fuel starvation' occurs when usable fuel on board the aircraft is unable to reach the engine. Cases of fuel starvation included broken fuel lines and a blocked fuel vent.

**Hard landing**
The majority of hard landings (60 per cent) occurred during autorotations. There were three cases where the tail rotor hit the ground during a power-on landing and a further two cases in which the aircraft was overweight. Unfavourable winds were a factor in two accidents. About half the hard landings (53 per cent) occurred on training flights and 8 (or 19 per cent) occurred on check flights

**Wirestrike**
Helicopter wirestrikes typically occurred under different circumstances to fixed wing wirestrikes, as, less than a third of the helicopter wirestrikes involved agricultural flying. Eleven wirestrikes occurred during takeoff and landing and four occurred during low level movie filming. As with fixed wing flying, tracking low along creeks, roads or rail lines was particularly hazardous.

**Controlled flight into level terrain**
These accidents were particularly common during mustering. The typical accident involved the tail rotor striking the ground as the helicopter was being manoeuvred at very low altitude. Poor visibility was a factor on two occasions.

**Loss of control**
Of these accidents, ten were related to wind or turbulence. There were eight cases where the pilot failed to maintain lift, in most cases due to overpitching/losing rotor RPM. 'Loss of tail rotor effectiveness' occurred in at least four accidents. Nine of the loss of control accidents were unexplained and the remainder occurred for unique reasons. It has been suggested that flicker vertigo may have been involved in some of the unexplained accidents. Although it is very hard to find supporting evidence for flicker vertigo, the possibility cannot be discounted. Only three loss of control accidents occurred during training.

**Collided with trees, shrubs or bushes**
In eight cases the pilot did not see the tree. In four cases the pilot overpitched on takeoff and descended into the tree. A further three accident occurrences involved loss of lift in gusty conditions. The remaining occurrences were unique accidents.

**Fuel exhaustion**
It is important to distinguish between 'fuel starvation' and 'fuel exhaustion'. 'Fuel starvation' occurs when usable fuel on board the aircraft is unable to reach the engine. 'Fuel exhaustion' however means that the tanks are 'dry'. The 25 fuel exhaustion accidents occurred for the following reasons:

| | |
|---|---|
| Pilot continued operations knowing fuel was low | 7 |
| Pilot miscalculated fuel consumption | 7 |
| Tank was checked when machine was on a slope | 3 |
| Undetected fuel leak | 3 |
| Inattention to fuel state | 3 |
| Other reasons | 2 |
| **Total** | **25** |

**Main or tail rotor drive train failure**
The following failures occurred:

| | |
|---|---|
| Engine output drive shaft | 4 |
| Tail rotor drive shaft and couplings | 4 |
| Free wheel unit | 3 |
| Clutch | 2 |
| Drive belts | 2 |
| Sheaves | 2 |
| Main rotor gearbox | 2 |
| Tail rotor gearbox | 1 |
| Torsion coupling | 1 |
| Main rotor gearbox mount bolt | 1 |
| Main rotor drive flange bolts | 1 |
| **Total** | **23** |

The major sources of failures were tail rotor drive shafts (particularly couplings), free wheel units, torsion couplings, clutches, drive belts and sheaves.

Two of the engine output drive shaft failures were caused by a lack of lubrication on helicopters used for mustering. It is interesting to note that there were only two failures of the main rotor gearbox and none of the main rotor drive shaft.

It should also be noted that some components which had a history of failures have now been upgraded or replaced. Examples are more wear resistant sheaves on R22 helicopters and heavier duty torsion couplings on the Hiller UH12E.

**Main rotor failure**
The main rotor failures were as follows:

| | |
|---|---|
| Blade or grip failure | 4 |
| Control failure | 3 |
| Debond of abrasion strip | 1 |
| **Total** | **8** |

Fortunately there have been few accidents as a result of main rotor failure. This may reflect the close attention that rotors receive.

**Roll-over**
There was no typical roll-over accident, as most accidents in this class occurred for unique reasons. The most common single factor in the accidents was landing on soft ground (three accidents) and uneven ground (two accidents). Two accidents involved student pilots.

**Tail rotor failure**
A breakdown of the problem areas is as follows:

| | |
|---|---|
| Blade or grip failure | 7 |
| Failure of pitch control system | 5 |
| Debond of abrasion strips | 1 |
| Failure of bogus part | 1 |
| **Total** | **14** |

The failure of the pitch control system occurred almost exclusively in Bell 47s, the exception being one case in a Hiller UH12E. The failure was usually due to excessive wear.

# PILOT FACTORS IN HELICOPTER ACCIDENTS

The majority of accidents (67 per cent) were due totally or in part to pilot factors. The proportion of accidents related to pilot factors is similar in the US, where in the period 1982-85 63.5 per cent of helicopter accidents involved pilot factors.[1] In common with fixed wing aviation, the pilot has emerged as the element of the system most likely to contribute to an accident. Pilot factors can be divided into four basic types:

**Perception**
**Information processing**
**Execution**
**Procedural**

**Perception**
Perception relates to the sensory information the pilot gathers about the immediate state of self, aircraft and environment. The pilot must monitor sound, such as that of the engine and the rotors; vision, instrument readings, height (AGL), met conditions, the presence of obstructions and relative movement. Smell may also have some importance to the pilot as a warning of fuel leaks or smoke. The sense of touch enables the pilot to discriminate between switches.

A number of effects can interfere with the pilot's perception of the environment. Perceptual illusions for example, are usually only a problem during training, but may play a role in some night accidents. One visual illusion, the 'black hole effect' is discussed in a later section.

In addition to sensing the environment, pilots must sense things about themselves. The vestibular system is one of the most important sense organs of this type. It is located in the inner ear and provides information on angular and linear acceleration and position in relation to the vertical. However, the vestibular system cannot detect constant-speed movement and may misinterpret changes in acceleration.

In ordinary (VMC) conditions, vision is the dominant sense, and if a contradiction exists between, for example, what is felt in the vestibular system and what is seen, then the person will invariably trust their eyes. 'Seeing is believing'. However, in some situations such as (IMC) or night flying the visual information is degraded and the limitations of the vestibular system become apparent. In such conditions, a pilot may become disoriented. Although helicopter pilots usually operate in sight of the ground, the unreliability of the body's movement detection system can still be a factor in accidents, particularly when landing on featureless terrain, where constant-speed sideways movement may go unnoticed.

**Information processing**
In between perceiving a situation and producing a response, the pilot must interpret what is perceived and decide on a course of action.

In flight, a pilot must pay attention to many flight parameters, including rotor and engine or turbine RPM, altitude, groundspeed, torque or manifold pressure and the attitude of the machine. Although it may seem that the pilot can deal with all of this information simultaneously, this is not the case. The human mind is a single channel processor, which means that only one piece of information can be dealt with at a time. The impression the pilot may have that all of this information is being processed simultaneously comes from the ability to rapidly switch attention from one problem to the next. The pilot is in effect dealing with the flight tasks one after another. One estimate is that the mind can make 11 decisions a second, although this will vary from person to person and will be affected by factors such as age and stress.

***Workload***
Not only is the helicopter pilot's manipulative workload higher than in fixed wing aircraft but reciprocating-engine helicopters impose a further task, that of manual throttle control. However, most of the demands on the pilot are visual rather than manual.

The visual demands on the helicopter pilot increase as altitude decreases. A U.S. study showed that when flying very low altitude 'hedge-hopping' missions, military pilots could only give 10 per cent of their time to an extra visual task in the cabin.[2] In comparison, when in the hover in ground effect, the pilots could devote 60 per cent of their time to the extra task. The extra demands on the pilot's attention during low flying are important considerations in wirestrike accidents.

***Tunnel vision***

In most situations of course, the information processing system is more than adequate for the task; however there are times when numerous problems are calling for the pilot's attention and the system becomes overloaded. Here, the pilot must deal with the most pressing problems and ignore others. At times like this a condition sometimes called 'tunnel vision' may develop, in which the pilot devotes too much attention to one aspect of the flying task. For example, when landing in a confined area the pilot's concentration may be taxed to the limit, and while most attention is diverted to avoiding the trees a decrease in RPM may go unnoticed. The high workload of the helicopter pilot makes tunnel vision all the more likely.

***False hypothesis***

A second information processing problem commonly faced by pilots is referred to as 'false hypothesis'. False hypothesis is quite simply, where pilots get wrong ideas into their heads. Common examples are wrongly believing that an air traffic clearance has been received, that there is sufficient fuel on board for the mission or that the flight is being conducted over region X when in fact the helicopter is over a completely different area. A pilot can become 'locked in' to a false hypothesis, and may disregard new information which would contradict the idea. False hypotheses can form for a number of reasons.

Expectation: Out of long experience or habit, the pilot may climb into the cockpit with a number of expectations. For example the pilot may believe that there is a full load of fuel because 'Bloggs always fills the tank after the last flight each day'.

Wishful thinking: Or the 'she'll be right' attitude is the tendency when making a decision to prefer a desirable but perhaps unlikely outcome to a more likely but undesirable one. A pilot faced with an unexpectedly low fuel gauge may be inclined to believe that the gauge is wrong rather than consider alternative possibilities, such as an unusually high rate of fuel burn.

Diverted attention: False hypotheses are particularly likely to form if much of the pilot's attention is devoted to a single aspect of the flight. For example, an agricultural pilot concentrating on a fault with the spray equipment may be more likely to believe that the flight path is clear of obstructions.

Motor memory: A pilot who accidentally substitutes a wrong action for the correct action, such as operating the wrong switch, is very likely to believe that the correct action has been made. This belief can be very resistant to contradiction, particularly if the action is one which has been performed so many times that it is largely outside of conscious control.

The quality of decisions made in the cockpit is influenced by many other factors including personality, aptitude, stress, fatigue and emotion.

***Stress and emotion***

Pilots who are hot, cold, hungry, angry or anxious are likely to make poor decisions. In particular, they may make decisions before they have gathered all the relevant information or may ignore new information and persist with a false hypothesis. Too little stress however, can also be a problem as pilots do not perform at their best when they are are overly relaxed or bored.

***Fatigue***

It has been shown that a fatigued person takes longer than normal to make decisions. Fatigue can also affect performance by reducing visual acuity.[3]

### Execution

Execution relates to the physical actions which occur once the situation has been perceived and the pilot has decided upon the action to take. Mis-operation of controls and in some cases overpitching are two common examples of execution problems.

The execution of a well learned skill can usually be performed without conscious effort. However whilst the skill is being acquired, the actions will require a high level of attention, and will consequently occupy some of the central processing capacity. This may lead to problems in information processing as discussed above.

A central part of acquiring any skill is self-monitoring of performance. Monitoring or 'quality control' tends to be thorough during training, but may diminish once the skill has been acquired. So although errors of execution tend to be most common during training, monitoring errors (where a mistake slips through) are largely a problem among more experienced pilots.

Pilots who have recently changed aircraft types are particularly likely to encounter problems of execution, and even long after the transfer to the new type, in an emergency or other highly stressful situation the pilot may attempt to operate the helicopter as though it was the old type. This tendency to apply a well-learned and familiar action in the wrong situation is known as 'regression'. It can occur whenever people operate complex equipment, whether it be driving a car, using a computer or flying a helicopter.

**Procedural**

Procedural factors do not fit easily into the usual concept of "pilot error". Procedural factors are often referred to as problems of 'judgment' or 'airmanship, they relate to what the pilot routinely does, the procedures the pilot carries out or chooses to overlook. Because they are frequently intentional, these factors are perhaps the most difficult to eliminate. Two examples of procedural factors are routinely flying low on ferry flights and neglecting visual fuel checks. The procedures a pilot follows may be influenced by a number of factors, including risk assessment, company pressures and group expectations.

***Risk assessment***

Choosing a course of action is likely to involve some weighing-up of risk. In many situations, the pilot must choose between one action which involves high risk and a high payoff and an alternative which involves low risk and a penalty or low payoff. For example, whilst operating in a remote area a pilot notices intermittent vibrations. The pilot has the choice of flying the 60km back to base where a LAME can check out the machine, or landing and making a radio call for a vehicle to come out to the site. The first course of action will, if it succeeds, save a lot of time and inconvenience. But if it fails and the vibrations become more severe on the way back to base, the machine may be out of service for a lot longer.

People assess risk in different ways, and have different standards of 'acceptable risk'. Standards of acceptable risk also differ between operations. The amount of risk which is considered acceptable to a mustering operation would be unacceptable on a passenger charter flight. Personal judgments about risk are likely to be related to the pilot's flying history or knowledge of other pilots' accidents, with the result that pilots who have not recently heard of an accident in their field of operations are likely to underestimate risk.

***Company pressures***

Most helicopter pilots fly for commercial organisations where time on the ground because of maintenance or bad weather is money lost. Pilots are usually under pressure to get a job done in the shortest possible time and this may influence the decisions they make. While some pressure is not necessarily a bad thing, pilots may overestimate the urgency of a task and impose more pressure on themselves than is really necessary.

***Group expectations***

Every group of pilots has standards of acceptable conduct which are not laid down and very often go unsaid. A flying practice which is accepted in one group may be frowned upon in another. The flying decisions a pilot makes will to some extent reflect the expectations of the group.

**Notes**

[1]Roy E. Fox, Helicopter Accidents Trends, paper presented at AMS-FAA-HAI national specialist meeting, Vertical Flight Training Needs and Solutions, Arlington, Texas, 17-18 September 1987.

[2]D. D. Strother, Visual and Manual Workload of the Helicopter Pilot, paper presented at the 30th National Forum of the American helicopter Society, Washington DC, May 1984.

[3]A. T. Welford, Skilled Performance: Perceptual and Motor Skills, Scott, Foresman and Company, 1976.

# PILOT FACTORS IN HELICOPTER ACCIDENTS 1969-88

All of the four types of pilot factors listed on page 10 have been involved in helicopter accidents. Table 4 indicates that procedural factors such as inadequate planning and poor decision making have been the most widespread of the four types of broad factors.

In common with the pilots of fixed wing aircraft, helicopter pilots have frequently set the conditions for an accident by failing to prepare adequately for flight. Examples of inadequate preflight preparation include not checking for fuel contamination and overloading the aircraft. An example of improper in-flight decision or planning is continuing a flight when fuel is known to be low.

Considering that most helicopter pilots are professionals, problems with basic flying skills such as "Mis-operation of primary flight controls" have occurred surprisingly frequently. A more detailed analysis of the major pilot factors follows.

**Table 4 - Major pilot factors***

| | *Cases* |
|---|---|
| Inadequate preflight preparation/planning | 58 |
| Improper inflight decision or planning | 57 |
| Did not see or avoid objects or obstructions | 53 |
| Misoperation of primary flight controls | 43 |
| Allowed rotor RPM to decay | 39 |
| Diverted attention from operation of aircraft | 34 |
| Improper landing flare | 31 |
| Attempted operation beyond experience/ability | 29 |
| Misjudged altitude | 27 |
| Selected unsuitable area for take-off or landing | 25 |
| Lack of familiarity with aircraft | 23 |
| Operated carelessly | 21 |
| Inadequate supervision of flight | 20 |
| Exercised poor judgment | 15 |
| Improper operation of powerplant controls | 14 |
| Misjudged horizontal/vertical clearance | 12 |
| Did not obtain/maintain flying speed | 11 |

* Note that each accident may involve more than one pilot factor, therefore the sum of the pilot factors may be greater than the total number of accidents.

# FURTHER DETAIL ON MAJOR PILOT FACTORS

The following section provides further detail on the major pilot factors which contributed to accidents.

**'Inadequate preflight preparation and planning'**

| | |
|---|---|
| Flying with inadequate fuel | 13 |
| Not detecting wires before low level flying | 9 |
| Inadequate preflight inspection of aircraft | 5 |
| Poorly planned sling operations | 4 |
| Unsuccessfully attempting to takeoff over obstructions* | 4 |
| Unsecured door | 2 |
| Not surveying landing area | 2 |
| Overweight on takeoff | 2 |
| Other | 17 |
| **Total** | **58** |

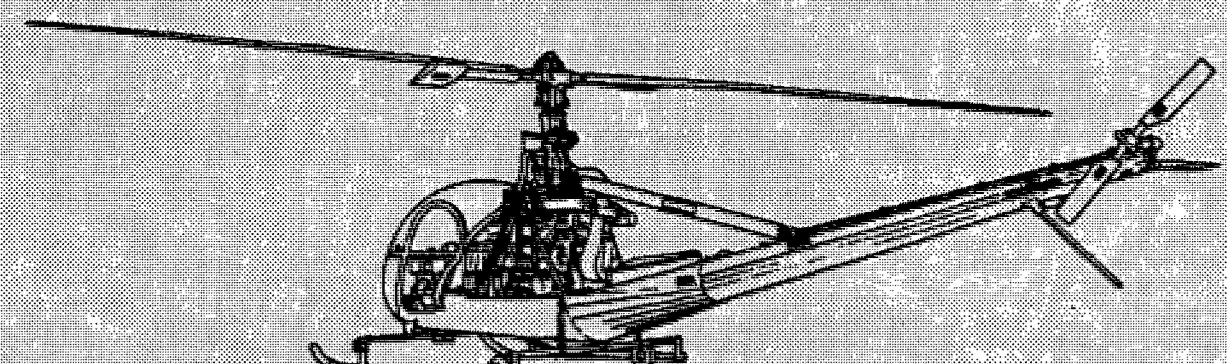
* In two cases the obstruction was a fuel drum. These cases could equally have been included among the 'overweight on takeoff' group.

Nearly all these accidents have resulted from procedural errors rather than from any difficulties in perception, information processing or execution.

*Case study 1*

A Hiller UH 12-E was being used on crop spraying operations. Shortly before last light the pilot commenced the flight back to base. He was concerned with the fuel state and made an en-route landing to allow one of the passengers to dip the tank. Believing that adequate fuel remained, the pilot took off again, but shortly afterwards the engine lost all power. During the subsequent autorotation, manoeuvering was necessary to avoid power lines. The landing was heavy and the main rotor blades struck and severed the tailboom.

The pilot had not kept an accurate record of fuel usage, and it was likely that his decision-making had been impaired by fatigue. In fact the engine operated 7 minutes longer than the expected total endurance. The helicopter had probably been resting on sloping ground when the tank was dipped.



**'Improper in-flight decisions or planning'**

| | |
|---|---|
| Poorly planned approach * | 8 |
| Misjudged or poorly planned autorotations | 5 |
| Continued flight when low on fuel | 4 |
| Unwarranted low flying | 4 |
| Continuing a flight after a serious problem had developed | 3 |
| Selected unsuitable landing area | 2 |
| Other | 31 |
| **Total** | **57** |

* In three cases of poorly planned approach the pilot failed to take winds into account.

These factors are a mix of 'Procedural' and 'Information processing' problems. In a number of cases such as that of 'continuing flight when low on fuel' and 'unwarranted low flying' the pilot factor is a procedural one and probably followed an underestimation of risk by the pilot. In other cases, such as difficulties with autorotations and approaches, information processing was a problem. For example, a pilot may have chosen a poor approach path to a landing site as a result of poor judgements of wind conditions or obstructions.

Sometimes, the nature of the approach may set the conditions for visual illusions to occur. One illusion relevant to night landings is the 'black hole effect' where the pilot, approaching an illuminated landing area over dark featureless terrain, misjudges the approach path and flies into the ground short of the landing area. This effect was first observed in the late 1960s in early jet transport accidents. Investigations into these accidents revealed that even the most experienced pilots tend to overestimate their altitude during night approaches over dark terrain or water.[1]

*Case study 2*

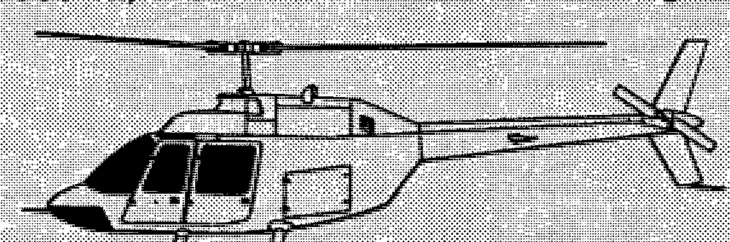
**At about 1700 hours the pilot received a phone call from a seismic survey company to say that a crewmember on board a survey ship was showing signs of hepatitis and needed to be brought ashore. The pilot agreed to conduct the flight that night, but would need to land the Bell 206B at a town enroute to refuel.**

**The pilot had extensive helicopter experience. He had made many ship landings and had logged approximately 13 000 hours, with about 7000 hours on rotary wing aircraft.**

**The night was dark and overcast, and the flight to the refuelling point was marginally NVMC. The pilot said later that if it had been an ordinary flight he probably would have turned back.**

**After flying over the landing area, which was illuminated by the headlights of two police cars, the helicopter did a descending turn to the right over high sand dunes, using the lights of the town to maintain attitude. At about 650 feet the pilot lined up on finals and transitioned to complete visual flying. At this point he asked the passenger in the left-hand seat to assist by calling out the altitudes as he descended, the last reading was 300 feet.**

**Without warning the helicopter struck the ground heavily and rolled over to the right. The pilot remembered sand shooting up through the perspex and the 'engine out' light flashing on. The pilot and passenger evacuated safely. The investigators concluded that the pilot had experienced a visual illusion (the black hole effect) which had led him to overestimate his height AGL.**



**'Misoperation of primary flight controls'**

Common problems were overpitching, losing rotor RPM during autorotations and difficulties with the flare on autorotations. Twelve of the accidents occurred during check or training, seven on mapping/photo/survey flights and six each on passenger charter and mustering flights. The flying experience of pilots who misoperated controls was not significantly less than that of other pilots who were involved in accidents.

It is likely that most cases involved a combination of the four major types of factors. Overpitching, for example can be related to attempting to takeoff with an aircraft overloaded for the conditions (a procedural factor) but may also involve information processing aspects such as tunnel vision or diverted attention. Other cases of overcontrolling cyclic, usually by students, are examples of errors of execution.

**'Diverted attention from operation of aircraft'**

Pilot was distracted by:

| | |
|---|---|
| Cattle | 9 |
| Sling load | 3 |
| Passengers | 3 |
| Radio problem | 2 |
| Spray equipment | 2 |
| Other | 15 |
| **Total** | **34** |

In most cases the pilot was distracted by something to do with the job. Problems of distraction fit neatly into the category of 'Information processing' errors. As has been mentioned, the pilot, as a 'single channel information processor', can only deal with one problem at a time. When two tasks are demanding attention simultaneously, one must be put on hold. Accidents happen when an essential flying task is unconsciously set aside to enable attention to be diverted to something else. Distractions can be particularly dangerous for pilots who have not flown for some time, or who are unfamiliar with the aircraft type as they must devote more attention to the job of flying the aircraft, and will have less time available for other tasks.

Wirestrikes or collisions with other objects were the most common distraction-related accidents, although other accident types such as controlled impact with level terrain or hard landings also occurred.

***Case study 3***

**The pilot of a Hiller UH12-E was driving an animal towards the main mob when another broke from the herd and ran towards the helicopter. He attempted to block the animal by coming to a low hover in its path, but it still attempted to move towards the tail of the helicopter. The pilot commenced rearwards flight, and then looked to see what the cow was doing.**

**Looking back to check his tail position he noticed it was very close to the ground. The pilot pulled on the collective and applied forward cyclic but was unable to prevent the tail rotor from striking the ground. The helicopter then spun through 270 degrees before landing heavily. The right skid collapsed, the helicopter lurched sideways and the main rotor blades struck the ground.**

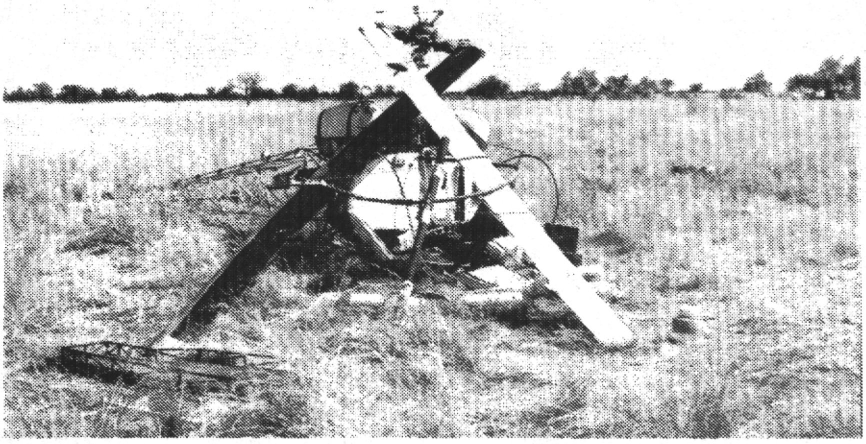
**The pilot's first flight in 10 months had been two days before the accident when he renewed his mustering endorsement. However, the pilot had over 1200 hours on type. It is likely that the pilot's lack of recent experience made it difficult for him to give sufficient attention to all aspects of a demanding job.**

**'Allowed rotor RPM to decay'**

| | |
|---|---|
| During autorotation | 19 |
| In flight | 8 |
| In hover | 6 |
| Power on landing | 3 |
| Take off | 3 |
| **Total** | **39** |

Thirteen of the autorotations were during practice or training. High density altitude was a factor in a number of accidents. In a few cases, problems in maintaining rotor RPM were simple problems of execution, relating to the physical actions of the pilot. However, misjudgments or procedural errors are likely to have been major underlying factors in many of the accidents. For example, in some accidents the loss of rotor RPM resulted from taking off over obstructions with a high all up weight.

In some cases information processing problems may have been involved, such as where the pilot's attention was diverted from monitoring rotor RPM, and in fact all but seven of the accidents occurred in reciprocating engined helicopters, where the pilot must pay more attention to throttle control.



*Bell-47 - rotor rpm decayed while in the hover. Pilot subsequently overpitched while trying to regain control*

**Notes**

[1]Kraft, 'A Psychophysical Contribution to Air Safety: Simulator Studies of Visual Illusions in Night Visual Approaches', in Psychology: From Research to Practice, ed. H. A. Pick, Plemun, New York, 1987.

# FIVE COMMON ACCIDENT TYPES AND THE PILOT FACTORS WHICH LED TO THEM

Note: An accident may involve multiple pilot factors. Therefore the total number of pilot factors may be greater than the number of accidents

### Hard landing

The most common pilot factors in hard landings were:

| | |
|---|---|
| Inadequate supervision of flight | 13 |
| Improper landing flare | 11 |
| Misjudged altitude | 9 |
| Allowed rotor RPM to decay | 9 |
| Improper operation of primary flight controls | 8 |
| Lack of familiarity with aircraft | 7 |
| Improper in-flight decisions or planning | 5 |

Inadequate supervision generally relates to training accidents. Many in the industry believe that some helicopters typically used for training are the most unforgiving of errors.

*Case study 4*

**A student pilot was undergoing a licence test in a Robinson R22A. As the final sequence of the test flight the examiner requested the student to carry out a normal autorotative landing from circuit height. After a slightly high flare, the aircraft recovered but then landed on the rear of the skids. It then bounced forward and the tail boom was severed by the main rotor. The examiner had little recent experience on the type and did not recognise that the tail was low prior to touchdown.**

### Collided with trees, shrubs or bushes

All but two of these accidents related to pilot factors.

| | |
|---|---|
| Diverted attention from operation of aircraft | 5 |
| Improper in-flight decisions or planning | 4 |
| Misjudged clearance | 3 |
| Inadequate preflight preparation | 3 |
| Allowed rotor RPM to decay | 3 |
| Did not obtain translational lift | 3 |

The problems of diverted attention seen here, reflect the information processing limitations of the pilot (in other words, the pilot can only pay attention to one thing at a time).

### Wirestrike

All 40 wirestrikes involved pilot factors. The two major factors were:

| | |
|---|---|
| Inadequate preflight preparation | 12 |
| Diverted attention from flying the aircraft | 9 |

Contrary to the pattern among fixed wing accidents, just over half the helicopter pilots did not know of the wires before the collision.

| | |
|---|---|
| Knew of wires | 10 |
| Did not know of wires | 14 |
| Not recorded | 16 |
| **Total** | **40** |

Unlike fixed wing aerial agriculture wirestrikes, where the pilot typically flies into known wires, helicopter wirestrikes have involved a much greater proportion of pilots who flew low without adequately checking for wires.

*Case study 5*

**The purpose of the flight was to film a moving train from an Agusta Bell 206B . The pilot had extensive experience in aerial photography operations and had logged over 5000 hours on the aircraft type.**

**Before the commencement of filming, the pilot spent about half an hour making an aerial inspection of the area, mentally noting the various obstructions. On the second filming run the pilot descended to approximately 30 feet and tracked next to the locomotive at about 20 kts. The helicopter collided with unseen power lines and struck the ground about 50 metres beyond the point of collision. It then bounced and came to rest on its side. One of the power poles had been hidden from the pilot's view by a large tree. The pilot later considered that he had flown outside the area originally surveyed.**

**Controlled impact with level terrain**

Of the 35 accidents, 28 involved pilot factors. The most common were:

| | |
|---|---|
| Misjudged altitude | 12 |
| Pilot distracted by cattle (during mustering) | 8 |
| Improper in-flight decisions or planning | 5 |
| Attempted operation beyond experience or ability | 4 |

As can be seen, this type of accident is closely related to the perceptual problem of misjudging altitude during low level operations, mainly mustering.

The pilot relies on a number of cues to perceive depth. These include:

1. texture (a finely textured surface will appear to be further away);
2. the size of familiar objects;
3. the apparent relative movement of the ground in the opposite direction to the movement of the helicopter (the greater the distance between the helicopter and the ground, the slower this movement will be);
4. binocular cues, which come from the slightly different images that each eye receives.

During helicopter operations many of these cues may be unavailable or obscured by dust. Furthermore in the hover, the relative movement cue is of course not available.

**Loss of control**

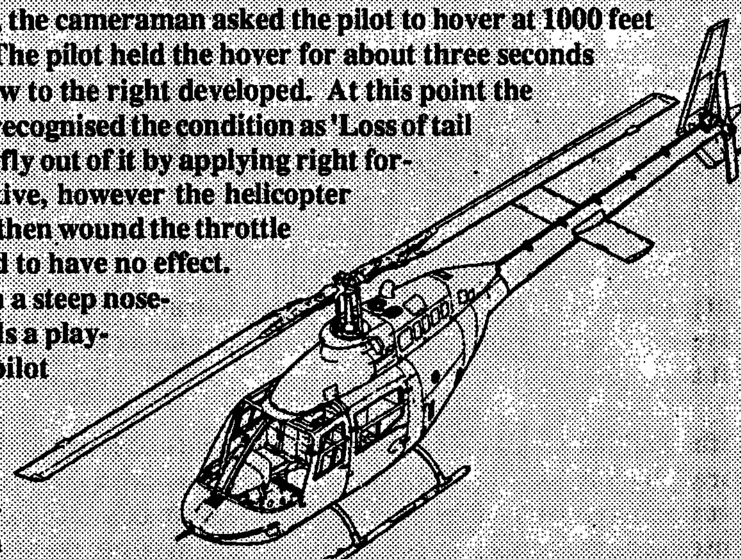
Twenty-four of the 36 loss of control accidents involved pilot factors. The most common were:

| | |
|---|---|
| Improper operation of primary flight controls | 11 |
| Allowed rotor RPM to decay | 8 |
| Attempted operation beyond experience or ability | 7 |
| Improper in-flight decisions or planning | 6 |
| Lack of familiarity with aircraft | 5 |
| Encountered circumstances beyond capability | 4 |

'Improper operation of primary flight controls' included a number of cases of overpitching and several cases of inexperienced pilots losing control in windgusts. At least four loss of control accidents have involved 'Loss of tailrotor effectiveness'.

*Case study 6*

A Bell 206-B had been chartered to cover a 'fun run' for a television station. After having taken shots of the race from various angles, the cameraman asked the pilot to hover at 1000 feet to allow more shots of the runners. The pilot held the hover for about three seconds at 70 per cent torque, until a slow yaw to the right developed. At this point the pilot was applying full left pedal. He recognised the condition as 'Loss of tail rotor effectiveness' and attempted to fly out of it by applying right forward cyclic and lowering the collective, however the helicopter flicked rapidly to the right. The pilot then wound the throttle back to flight idle but this too seemed to have no effect. The helicopter continued to spin with a steep nose-down attitude as it descended towards a playing field. Just before impact the pilot pulled on the collective to try and arrest the rate of descent. On impact the skids were torn off and the helicopter rolled to the left. All four occupants evacuated the helicopter within a few seconds.



# FATAL HELICOPTER ACCIDENTS

Between 1969 and 1988 there were 35 fatal helicopter accidents with a total of 62 fatalities. The 35 fatal accidents represented approximately 7 per cent of all accidents. In addition, 104 people were seriously injured in helicopter accidents in this period. However, it is worthy of note that 80 per cent of accidents resulted in nil or minor injuries. This is very similar to the situation of fixed wing general aviation where in the period 1987-88, 83 per cent of accidents involved nil or minor injuries.

Table 5 presents a summary of the 35 fatal accidents which occurred between 1969 and 1988. There were no fatal training or agricultural accidents during this period.

**Table 5 - Fatal accidents - Type of flying**

| | *Fatal accidents* | *Fatalities* |
|---|---|---|
| Commercial mapping/photo/survey | 7 | 14 |
| Aerial mustering | 6 | 8 |
| Private/Business | 4 | 7 |
| Ferry* | 3 | 4 |
| Passenger charter | 2 | 3 |
| Commercial power/pipe line patrol | 2 | 6 |
| Non-commercial survey | 2 | 3 |
| Aerial ambulance | 1 | 2 |
| Fire control | 1 | 3 |
| Construction | 1 | 1 |
| Test | 1 | 2 |
| Search and rescue | 1 | 3 |
| Hunting | 1 | 3 |
| Other | 3 | 3 |
| **Total** | **35** | **62** |

* One accident which occurred on a private ferry flight is reported here as a 'ferry' accident rather than a 'private/business' accident.

Table 6 expresses estimated fatal accident rates for various periods in the 1980s.

In table 6, 'charter' is passenger or cargo charter only, a flight which involved a chartered aircraft on a survey or photography flight was classified as 'mapping/photo/survey'. Some areas of helicopter operation, such as hunting, ambulance and construction work are not included in table 6 as activity data was not available for these operations.

**Table 6 - Estimated fatal accident rates for periods in the 1980s.**

| | *Sample period* | *Fatal Accs. in sample period* | *Hours flown in sample period* | *Fatal accident rate /100 000 hrs* |
|---|---|---|---|---|
| Charter | 80-87 | 2 | 173,400 | 1.2 |
| Mapping/Photo/Survey | 80-87 | 3 | 143,707 | 2.1 |
| Mustering | 82-87 | 3 | 289,599 | 1.0 |
| Training | 80-87 | 0 | 67,399 | 0 |
| Private/Business | 81-87 | 2 | 95,340 | 2.1 |
| Test/Ferry* | 80-87 | 3 | 44,497 | 6.7 |
| Agriculture | 80-87 | 0 | 31,653 | 0 |
| All operations | 80-87 | 21 | 1,148,000 | 1.8 |

* No fatal test accidents occurred in the sample period.

Note table 6 should be interpreted cautiously, as the fatal accident rates have been calculated on the basis of a very small number of accidents. The sample period is not the same for all groups as activity data was not available for some years in the early 1980s.

Table 6 indicates that the overall fatal accident rate for the years 1980-87 was 1.8 fatal accidents per 100 000 flying hours. This figure is similar to that for the United states, where in 1985 the helicopter fatal accident rate was estimated to be 1.6 fatal accidents per 100 000 hours. By comparison, the fatal accident rate for all Australian GA operations for the period 1983-87 was 1.1 fatal accidents per 100 000 flying hours. Helicopter operations in Australia have a fatal accident rate approximately equivalent to the GA Private/Business fatal accident rate, which was 1.7 ~~in the~~ period 1983-87.

The very small numbers involved in the calculations preclude any firm conclusions about the relative safety records of different types of flying. Nevertheless, the high fatal accident rate in the ferry category is cause for concern.

# WEATHER AS AN ACCIDENT FACTOR

Weather was cited as a factor in about 10 per cent of accidents. There were ten accidents attributed to updrafts or downdrafts and five to tailwinds (although it is likely that more accidents than this actually involved tailwinds). Only three accidents occurred after a VFR flight was continued into adverse weather. Thunderstorm turbulence was a factor in only one accident. Weather factors which occurred more than once were:

| | |
|---|---|
| Updrafts or downdrafts | 10 |
| Tailwinds | 5 |
| Poor visibility due to smoke, haze or dust | 4 |
| Whiteout | 4 |
| High density altitude | 2 |
| Carby icing conditions | 2 |
| Snow | 2 |
| Windshear | 2 |
| Sudden windshift | 2 |
| Clear air turbulence | 2 |
| Willy-willy | 2 |

In most cases, the weather itself did not cause an accident. Rather, the accident resulted from a combination of pilot factors and the weather condition. An inaccurate weather forecast was a factor in only one accident.

# SPECIAL HAZARDS OF HELICOPTER OPERATIONS

**Vortex ring state**
Also known as 'settling under power', this condition occurs when the helicopter loses lift due to recirculation of air through the main rotors. The condition is most likely to occur during descent at low forward speeds or whilst hovering out of ground effect. Although this is one of the textbook traps of helicopter operations it has featured infrequently in Australian accidents, or else has gone un-reported. There have been two recorded accidents resulting from vortex ring state.

**Ground resonance**
Principally a problem in helicopters with main rotor blade drag hinges and sprung landing gear, ground resonance is a severe lateral shaking of the fuselage when in contact with the ground. The resonance occurs when the main rotor is unbalanced and landing gear damping is inadequate. The rotor may be out of balance prior to ground contact, or else ground contact may induce the imbalance. There have been ten ground resonance accidents in Australia since 1969. Seven of these have involved Hughes 300 machines. The accidents occurred during both takeoffs and landings. Incorrectly set landing gear struts were factors in four of the accidents.

**Loss of tail rotor effectiveness**
Or unanticipated right yaw (unanticipated left yaw in European helicopters) can occur when the helicopter is operated out of ground effect at low speed (below about 30 knots) with crosswinds opposing the induced flow through the tail rotor. At least four accidents have resulted from this phenomenon (see case study 6). There is evidence to suggest that low hours pilots may be particularly susceptible.

**Sling loads**
Since 1969 there have been seven accidents involving cargo slings. All of these occurred in the 1980s. No two accidents were the same, perhaps the only common element was the extra workload of carrying slung loads.

**Retreating blade stall**
At high forward airspeeds, the airflow over the advancing main rotor blade becomes very fast whilst the airflow over the retreating blade slows down. The low relative airspeed may cause the retreating blade to stall, particularly if steep turns are made, if density altitude is high, RPM has been lost or the helicopter is at a high all up weight.

Although retreating blade stall is a well recognised danger, it has never been cited as a factor in an Australian accident. Some operators, however, believe that it may be an unrecognised element in some loss of control accidents.

# ACCIDENTS AND TYPE OF FLYING

**Table 7 - Type of flying**

| | *Cases* | *%* |
|---|---|---|
| Aerial mustering | 137 | 30 |
| Commercial mapping/photo/survey | 67 | 15 |
| Private/Business | 47 | 10 |
| Charter | 50 | 11 |
| Training | 42 | 9 |
| Agriculture | 29 | 6 |
| Ferry | 27 | 6 |
| Non commercial agriculture/aerial survey | 14 | 3 |
| Other | 46 | 10 |
| **Total** | **459** | **100** |

Table 7 shows that more accidents have occurred on mustering flights than on any other operation. Commercial mapping/photo/survey flights had the second largest number of accidents followed by charter flying. Figures 6 and 7 illustrate time trends across two periods, 1969-80 and 1981-88. As can be seen, over this period the proportion of accidents occurring on commercial mapping/photo/survey flights has decreased markedly. Charter flying also makes up a smaller proportion of the accidents than it did previously. However, private/business flying is now more represented among the accidents than before. To some extent, the increase in accidents has occurred simply because there is now more private/business flying than there once was. However, the accident rate for private/business category has increased over this period. Between 1969 and 1980 the accident rate for private/business flying was 18.3 accidents per 100 000 flying hours, yet in the period 1981-87 the rate was 29.4 accidents per 100 000 hours. Private/business flying is now a significant source of helicopter accidents.

**Figure 6. Helicopter accidents 1969-80 (type of flying)**

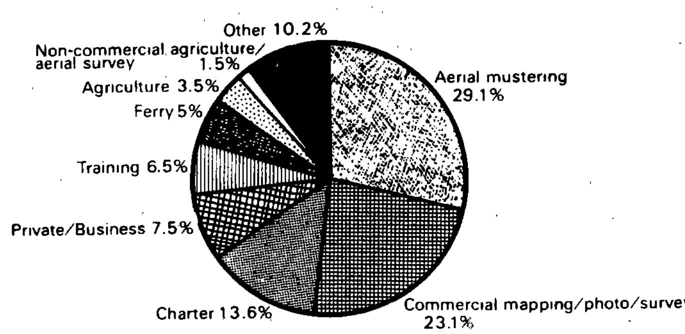
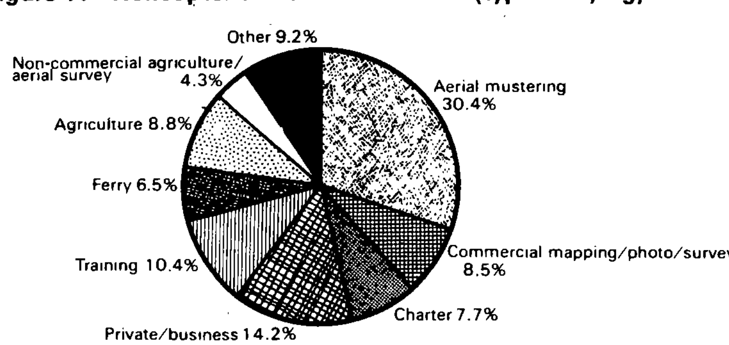



**Figure 7. Helicopter accidents 1981-88 (type of flying)**



**Accident rates for seven types of flying**

It should be stressed that these figures are estimated accident rates. The sample period is not the same for all types of flying as figures were not available for some years in the early 1980s.

**Table 8 - Accident rates for seven types of flying**

| | *Sample period* | *Accidents in sample period* | *Hours flown in sample period* | *Accident rate/ 100 000 hours* | |
|---|---|---|---|---|---|
| | | | | *Helicopter* | *GA* |
| Charter | 80-87 | 22 | 173,400 | 12.7 | (8.1) |
| Mapping/Photo/Survey | 80-87 | 24 | 143,707 | 16.7 | N/A |
| Mustering | 82-87 | 56 | 289,599 | 19.3 | N/A |
| Training | 80-87 | 26 | 67,399 | 38.6 | (7.0) |
| Private/Business | 81-87 | 28 | 95,340 | 29.4 | (20.8) |
| Test/Ferry* | 80-87 | 19 | 44,497 | 42.7 | N/A |
| Agriculture | 80-87 | 22 | 31,653 | 69.5 | (28.0) |

*Includes only one test accident

(Figures in brackets are average general aviation (GA) accident rates 1980-84).

As GA accident rates are not available for all types of flying, the nearest comparison group for photo/survey, mustering and test/ferry is GA 'other aerial work' which had an accident rate during 1980-84 of 15.2.

Table 8 shows that aerial agriculture had by far the worst accident rate while charter had the safest record. Despite the large number of mustering accidents, mustering had a better safety record than several other types of flying (better for example than private/business GA flying). However, the mustering accident rate may be an underestimation if some accidents are unreported. Ferry flying had a surprisingly high accident rate - these accidents will be described in more detail in a later section. Note that although most private/business accidents involved private pilots, this category also includes accidents on corporate flights with professional pilots.

Comparing the accident rates of fixed wing and rotary wing aircraft is not entirely fair, as helicopters perform very different jobs to fixed wing aircraft. Nevertheless, the reader may be interested in how the two types of flying measure up. The table indicates that helicopter operations generally have a higher accident rate than (predominantly fixed wing) GA flying. The exception is charter flying which has achieved an accident rate nearly as low as GA charter operations.

**Type of accident by type of flying**

***Mapping/photo/survey***

| | |
|---|---|
| Wirestrikes | 6 |
| Engine failed due to material failure | 6 |
| Engine failed for undetermined reason | 5 |
| Roll over | 5 |
| Fuel exhaustion due to miscalculation | 3 |
| Exhaust started grass fire | 3 |
| Tail rotor failure | 3 |
| Overpitched main rotor | 3 |
| Loss of control (reason unknown) | 3 |
| Person walked into rotor | 2 |
| Poor visibility, collided with object | 2 |
| Main rotor failure | 2 |
| Rotor struck object | 2 |
| Main or tail rotor drive train failure | 2 |
| Other miscellaneous | 20 |
| **Total** | **67** |

Wirestrikes and engine failure due to material failure were the most common first occurrences for this type of flying. Four of the wirestrikes occurred during filming. Two of the roll overs involved anthills.

*Bell 47- survey flight , overpitched in high density altitude*

Just under half of the mapping/photo/survey accidents involved pilot factors. The most common were:

| | |
|---|---|
| Lack of preflight preparation | 9 |
| Poor in-flight decisions or planning | 8 |
| Misoperation of primary flight controls | 7 |
| Selected unsuitable area for landing or takeoff | 6 |
| Allowed rotor RPM to decay | 6 |
| Improper landing flare | 4 |
| Diverted attention from flying the aircraft | 3 |

Failing to look adequately for wires was also a major problem.

### *Agriculture*

| | |
|---|---|
| Wirestrike | 12 |
| Engine failure for unknown reason | 3 |
| Engine failure due to fuel exhaustion | 2 |
| Sink after turning downwind | 2 |
| Misjudged clearance, collided | 2 |
| Miscellaneous | 8 |
| **Total** | **29** |

In common with fixed wing agricultural flying, wirestrike was the most frequent accident.

Pilot factors were involved in 21 of the 29 agricultural accidents. The most common were:

| | |
|---|---|
| Lack of preflight preparation | 7 |
| Diverted attention from flying the aircraft | 4 |
| Operated carelessly | 3 |
| Misjudged clearance | 2 |

Generally, the pilots who did not adequately prepare for flight either did not check for wires or carried insufficient fuel. Half of the wirestrike pilots knew of the wires before the accident.

*Non - commercial pleasure*

| | |
|---|---|
| Engine failure | 6 |
| Loss of control in wind gust | 2 |
| Hard landing | 2 |
| Miscellaneous | 15 |
| **Total** | **25** |

The great proportion of private/business accidents occurred on non-commercial pleasure flights. A great variety of accidents occurred in this type of flying. Three of the engine failures were for undetermined reasons. The other three were due to fuel starvation, fuel contamination and a material failure. Examples of the miscellaneous accidents are a tail rotor strike, a wirestrike, a tail rotor gearbox failure and a roll over.

Just under half of the non-commercial pleasure accidents involved pilot factors. In general these pilots had difficulties with handling technique and basic flying skills. The most common factors were:

| | |
|---|---|
| Diverted attention from flying aircraft | 4 |
| Lack of familiarity with aircraft | 3 |
| Improper operation of primary flight controls | 3 |
| Allowed rotor RPM to decay | 2 |
| Improper operation of powerplant controls | 2 |
| Improper landing flare | 2 |
| Inadequate preflight preparation | 2 |

The problem of diverted attention among this group may reflect the higher levels of concentration that infrequent fliers must give to flying.

*Training*

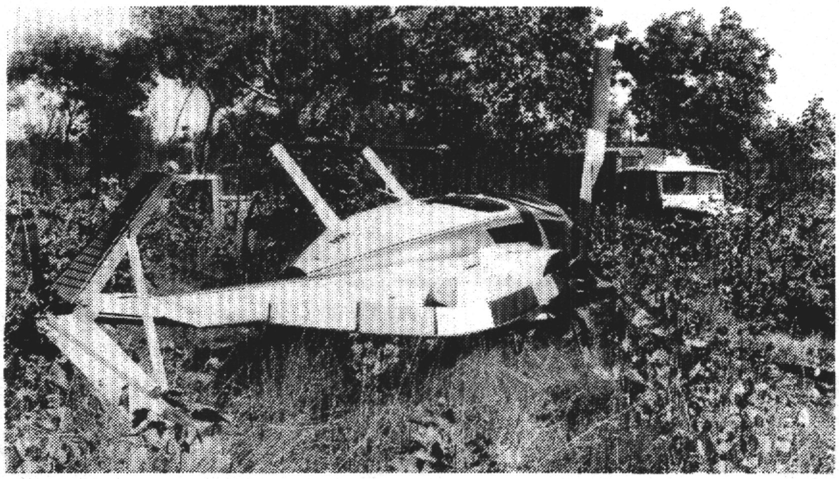
| | |
|---|---|
| Hard landing after a practice autorotation | 18 |
| Hard landing other than autorotations | 7 |
| Loss of control in windgust | 2 |
| Roll over | 2 |
| Landing gear collapsed, normal landing | 2 |
| Miscellaneous | 11 |
| **Total** | **42** |

Just under half of the training accidents involved practice autorotational landings. In all, there were 25 hard landings. The two landing gear failures were due to metal fatigue.

Pilot factors were involved in 80 per eent of training accidents. The most common factors were:

| | |
|---|---|
| Improper landing flare | 14 |
| Inadequate supervision | 14 |
| Lack of familiarity with aircraft | 11 |
| Misjudged altitude | 6 |
| Did not maintain rotor RPM | 6 |

Twelve of the improper landing flares occurred during autorotational landings.



*Hughes 500 - ferry flight fuel starvation*

| | |
|---|---|
| Engine failure due to material failure | 5 |
| Wirestrike | 4 |
| Fuel starvation | 4 |
| Taxied into building or tree | 3 |
| Loss of control for unknown reason | 2 |
| Fuel exhaustion | 1 |
| Other | 8 |
| **Total** | **27** |

The most common occurrence was a material failure of the engine. None of the fuel starvations resulted from pilot actions. Three of the four wirestrikes occurred at landing, only one was during cruise. About half of the accidents involved pilot factors.

| | |
|---|---|
| Inadequate preflight preparation | 6 |
| Improper in-flight decisions or planning | 6 |
| Did not see wires | 4 |
| Improper landing flare | 3 |
| Allowed rotor RPM to decay | 3 |
| Diverted attention from flying the aircraft | 3 |
| Did not follow approved procedures | 3 |
| Exercised poor judgment | 3 |

Inadequate preflight preparation related to a variety of areas including not properly closing latches and miscalculating fuel consumption. The three problems with landing flares all occurred during autorotational landings. It is possible that some pilots have been over-casual about ferry flights, perhaps because of the short distances frequently involved.

*Mustering*

| | |
|---|---|
| Engine failure or malfunction | 31 |
| Undetermined cause | 11 |
| Engine structure material failure | 5 |
| Inadequate maintenance | 5 |
| Fuel system failure | 2 |
| Fuel leak | 2 |
| Sticking valves | 3 |
| Throttle disconnected | 2 |
| Oil exhaustion | 1 |
| Tail rotor struck ground or water | 16 |
| Main or tail rotor drive train failure | 9 |
| Fuel exhaustion | 8 |
| Pilot unable to stop sink | 8 |
| Rotor struck tree (main or tail) | 8 |
| Wirestrike | 7 |
| Started grass fire | 5 |
| 'Bullstrike' | 4 |
| Tail rotor fatigue failure | 4 |
| Hard landing | 4 |
| Ground resonance | 3 |
| Loss of control in wind or turbulence | 2 |
| Tail rotor pitch control failed | 2 |
| Collided with truck | 2 |
| Main rotor failed | 1 |
| Other | 23 |
| **Total** | **137** |

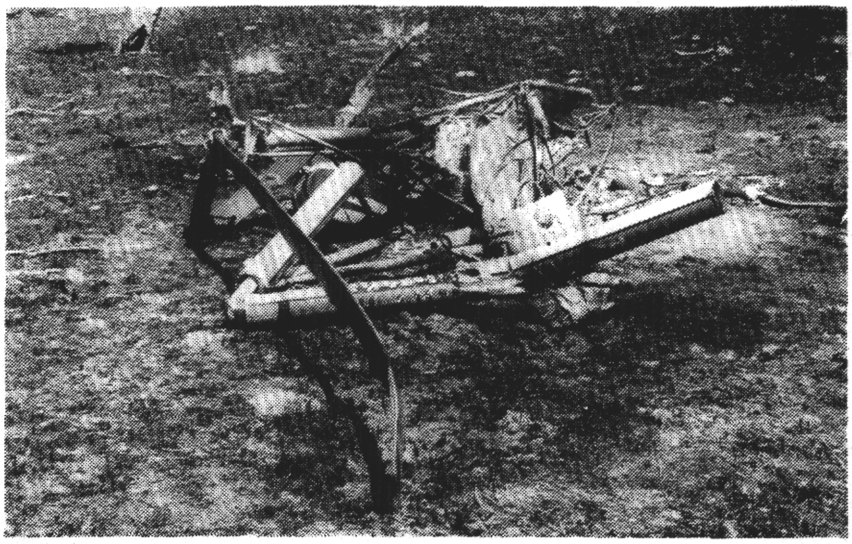
Engine failure or malfunction was the most frequent type of occurrence during mustering operations. Material failure and inadequate maintenance were the most common causes of engine failure. In three of the eight fuel exhaustion accidents the pilot had continued the flight knowing that he was low on fuel. The eight cases of 'pilot unable to stop sink' reflect the high density altitudes experienced in northern Australia.

Five Hughes 300 helicopters were destroyed by fire when their exhaust systems ignited dry grass. Such grass fire accidents continue to occur despite publicity.

Over half of the mustering accidents involved pilot factors. The most common were:

| | |
|---|---|
| Improper in flight decisions or planning | 20 |
| Did not see or avoid object or obstruction | 16 |
| Misjudged altitude | 13 |
| Diverted attention from flying aircraft | 12 |
| Inadequate preflight preparation | 9 |
| Did not maintain adequate rotor RPM | 9 |
| Operated carelessly | 7 |

'Improper in flight decisions or planning' included three cases in which the pilot exhausted the fuel supply after being aware that he was low on fuel. In a further three cases, the pilot continued the flight after a serious problem had developed. Two pilots failed to plan for wind conditions. As would be expected, those pilots whose attention was diverted from the aircraft were generally paying attention to cattle.



*Hughes 300 - cattle mustering, loss of control, possibly as a result of tail rotor contact with tree .*

***Charter***

| | |
|---|---|
| Fuel exhaustion | 5 |
| Collided with parked aircraft (2 accidents involving a total of 4 helicopters) | 4 |
| Engine failure due to material failure | 3 |
| Loose object struck tail rotor | 3 |
| Wirestrike | 2 |
| Passenger threw object into rotor | 2 |
| Loss of control due to misoperation of controls | 2 |
| Miscellaneous | 29 |
| **Total** | **50** |

There was no typical accident for this type of flying, perhaps reflecting the varied nature of the operations. Fuel exhaustion, however, seems to have occurred more frequently than would be expected. Two of the fuel exhaustion accidents occurred after the pilot continued the flight knowing he was low on fuel. All but five of the accidents occurred on passenger flights. Of the two accidents where a passenger threw an object into the main rotor, one occurred after the passenger had been asked to unload the object, the other involved a drunken passenger throwing a bottle. Examples of the large number of miscellaneous accidents are a snagged skid, a case of ground resonance and an airframe failure.

Approximately 60 per cent of charter accidents involved pilot factors. The most common factors were:

| | |
|---|---|
| Inadequate preflight preparation or planning | 9 |
| Improper operation of primary flight controls | 6 |
| Operated carelessly | 5 |
| Improper in-flight decisions or planning | 4 |
| Selected unsuitable area for landing or takeoff | 4 |

A surprising number of accidents were due to misoperation of flight controls. Recurring preparation and planning problems were poorly planned takeoffs, overweight aircraft and insufficient fuel.

Five passenger charter accidents occurred in the Australian Antarctic Territory, two of these involved whiteouts, a further two helicopters were damaged in a single ship-board accident, one helicopter collided with the ground after losing translational lift, the fifth accident occurred when a pilot attempted to take off with tiedown ropes attached.

# PILOT DATA

If certain pilots are more likely to contribute to accidents than others, (perhaps due to inexperience or age) then it would be expected that pilots who contributed to their accidents would have different age and experience profiles to those pilots who were involved in accidents beyond their control. To test this idea, the accident pilots were sorted into two groups; those who contributed human factors to the accident and those who had accidents with no pilot factors. As can be seen from figures 8 to 11 the age and experience profiles of the two groups are almost identical. The profiles almost certainly reflect the age and experience pattern of the industry in general. Unfortunately no information is available on the age or experience level of the average helicopter pilot.

In general, whether or not a pilot contributes to an accident is not statistically related to age or experience. The absence of any effect of total hours may reflect a tendency for the very inexperienced pilots to be trainees under the supervision of an instructor.

However, even when check or training flights are excluded, there is still no evidence that some pilots are more likely to contribute particular factors or be involved in particular types of accidents than others. Even pilots who had hard landings, and who might be expected to have had relatively little experience, in fact had about average experience on type.

**Figure 8. Age of helicopter pilot: pilot contributed to accident vs did not contribute**

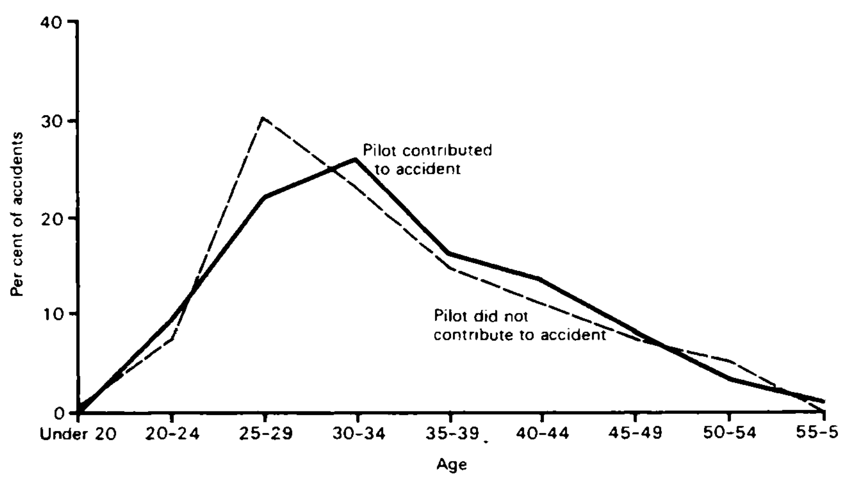



**Figure 9. Helicopter pilot total hours: pilot contributed to accident vs did not contribute**

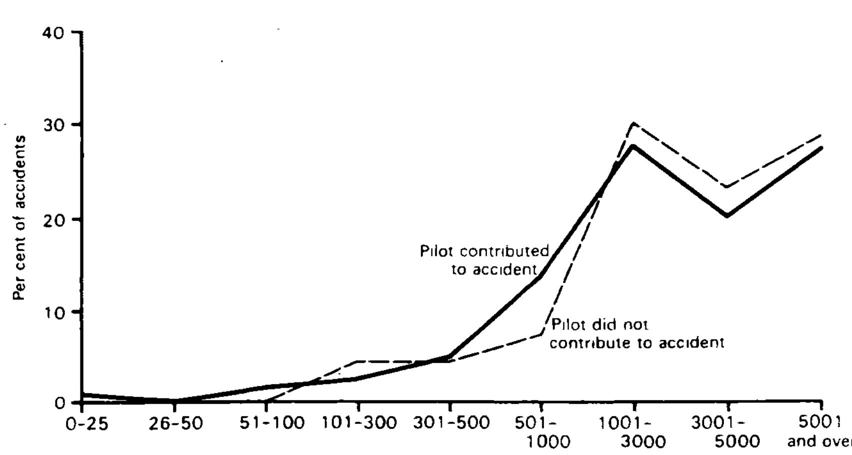


Figure 10. Helicopter pilots hours, 90 days preceding accident: pilot contributed to accident vs did not contribute

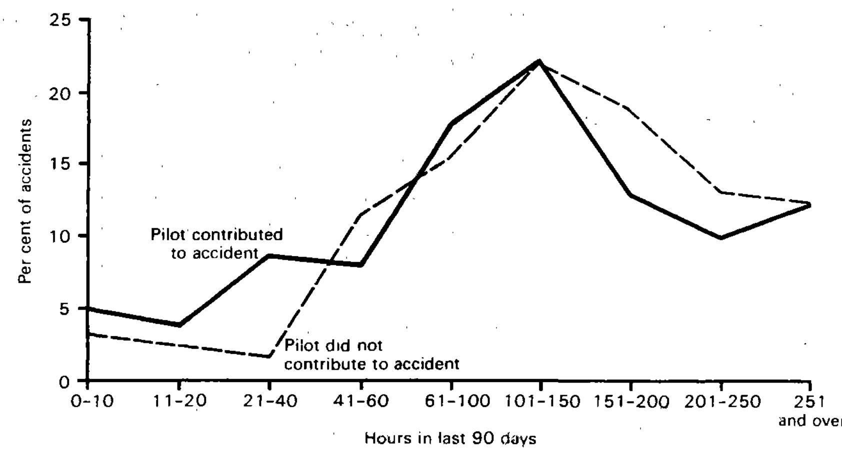
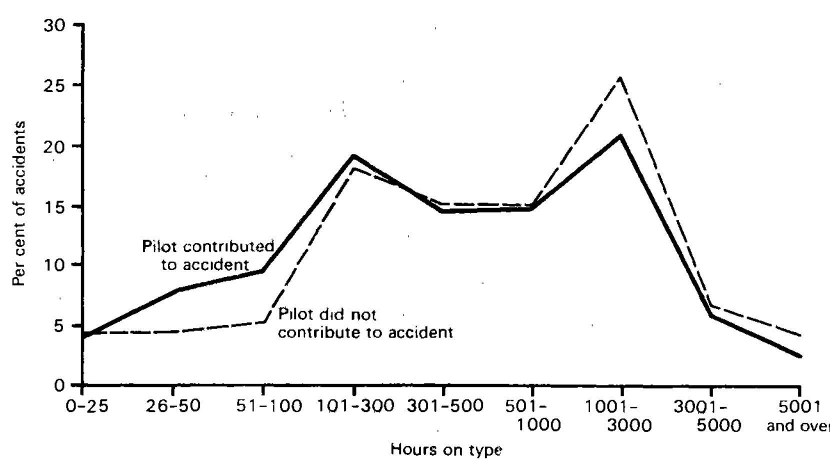



Figure 11. Helicopter pilot hours on type; pilot contributed to accident vs did not contribute




# AUTOROTATIONS

Thirty-three accidents resulted from practice, check or training autorotations. All but one of these accidents were due to human factors. The major factors were:

| | |
|---|---|
| Improper flare | 16 |
| Inadequate supervision | 9 |
| Misjudged altitude | 9 |
| Allowed rotor RPM to decay | 9 |
| Lack of familiarity with aircraft | 5 |
| Misoperation of primary flight controls | 5 |

Note that more than one factor was present in most accidents. Inadequate supervision generally means that the instructor or check pilot was slow to take over the controls. Six cases of improper flare occurred with Hughes 300 helicopters, three with Bell 47s, two with the Bell 206 and no more than once with other types.

It had been expected that a loss of rotor RPM would be most common with helicopters with low inertia blades, such as Robinsons. However, 'decay of rotor RPM' was surprisingly most common with the Bell 206 where there were four cases. Two Bell 47s and two Hughes 300s were also involved in 'decay of rotor RPM' accidents. 'Decay of rotor RPM' has never been cited as a factor in a Robinson autorotation accident.

# INADEQUATE MAINTENANCE AS A CONTRIBUTING FACTOR

There were 48 cases in which inadequate maintenance was considered to have contributed to the accident. In five of these cases, the investigator considered that the pilot had inadequately inspected or serviced the aircraft. The remaining 43 accidents involved inadequate servicing by maintenance engineers.

Problems which occurred more than once are outlined below:

| | |
|---|---|
| Undetected fatigue failure | 9 |
| Fuel system | 9 |
| Improperly installed engine component | 5 |
| Compressor assembly | 4 |
| Tail rotor pitch control system worn | 3 |
| Inadequate lubrication | 3 |
| Undetected transmission wear | 3 |
| Collective control improperly installed | 2 |
| Abrasion tape lifted | 2 |
| Cyclic pitch control system | 2 |

Fatigue failures generally occurred in blades or main rotor head assemblies. Fuel system problems included dirty filters and damaged fuel lines. Several of the compressor assembly problems occurred with helicopters operating in dusty conditions, however this problem has not occurred during the 1980s, perhaps due to greater awareness.

As table 9 indicates, maintenance problems were not equally common in all states. Maintenance appears to be a particular problem in Western Australia, the Northern Territory and Queensland.

**Table 9 - Maintenance related problems in all states.**

| | *Total accidents* | *Maintenance related accidents* | *Percent of accidents related to maintenance* |
|---|---|---|---|
| WA | 90 | 15 | 17 |
| NT | 92 | 13 | 14 |
| QLD | 143 | 14 | 10 |
| NSW | 67 | 3 | 4 |
| VIC | 28 | 1 | 4 |
| TAS/SA/ACT and overseas | 39 | 2 | 5 |
| **Total** | **459** | **48** | |

As might be expected, maintenance problems were most common for operations in remote areas. Table 10 breaks down maintenance related accidents by type of flying.

**Table 10 - Maintenance related problems by type of flying.**

| | *Total accidents* | *Maintenance related accidents* | *Percent of accidents related to maintenance* |
|---|---|---|---|
| Mapping/photo/survey | 67 | 12 | 18 |
| Ferry | 27 | 4 | 15 |
| Mustering | 137 | 18 | 13 |
| Passenger charter | 45 | 5 | 11 |
| Non-commercial pleasure | 25 | 2 | 8 |
| Agriculture | 29 | 2 | 7 |
| Other | 129 | 5 | 4 |
| **Total** | **459** | **48** | |

As can be seen, inadequate maintenance was a particular problem with mustering and mapping/photo/survey operations, reflecting an absence of nearby maintenance support.

## MULTI ENGINED HELICOPTER ACCIDENTS

There have been eight accidents involving multi engined helicopters since 1969. The seven accidents where investigations have been finalised are:

| | |
|---|---|
| Cowling separated and struck main rotor | 2 |
| Pilot under instruction failed to arrest descent | 1 |
| Gearbox failed due to unbalanced tail rotor blades | 1 |
| Developed sink while moving backwards | 1 |
| Tail rotor failed in flight | 1 |
| Main rotor blade spindle lug fractured | 1 |

An additional two accidents involved crew injuries related to winching and rapelling. As can be seen from the table, there have been no accidents due to engine problems. Note that given the small number of twin engined helicopters operating in Australia, it would not be advisable to draw any conclusions about their relative safety from the above figures.

# PISTON vs TURBINE ENGINES

Seventy-three per cent of accidents involved piston engined helicopters and 27 per cent involved turbine engined helicopters. The breakdown of piston vs turbine accidents is illustrated in figure 12. The distribution of accidents for each engine type is shown in figure 13. It can be seen that engine failures and malfunctions made up just over 20 per cent of the total accidents for both types of helicopter. Hard landings and loss of control also made up equal percentages of the accidents for both types. The stage of flight of accidents in turbine and piston engined helicopters is shown in figure 14. It can be seen that the pattern is much the same for the two types.

**Figure 12. Helicopter accidents 1969-87**

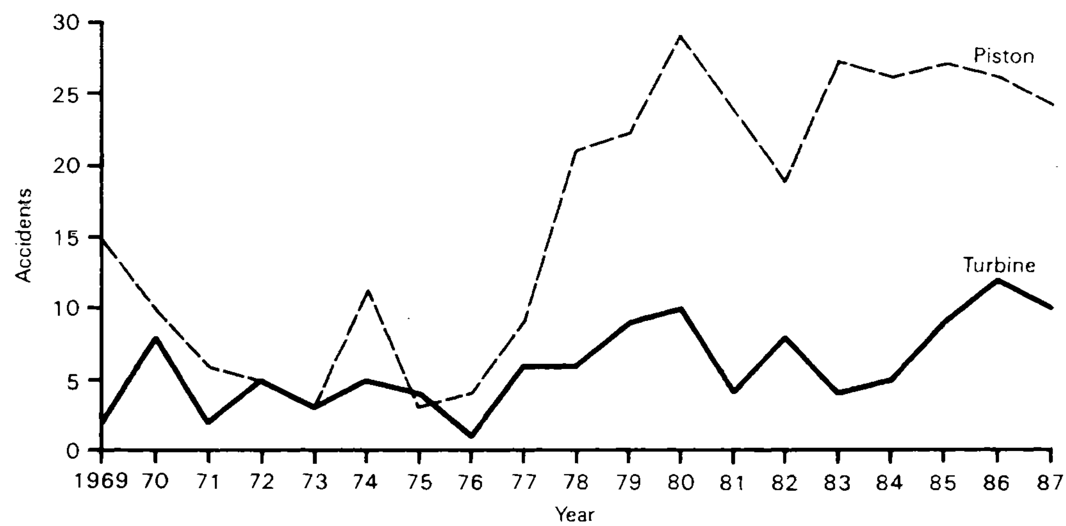
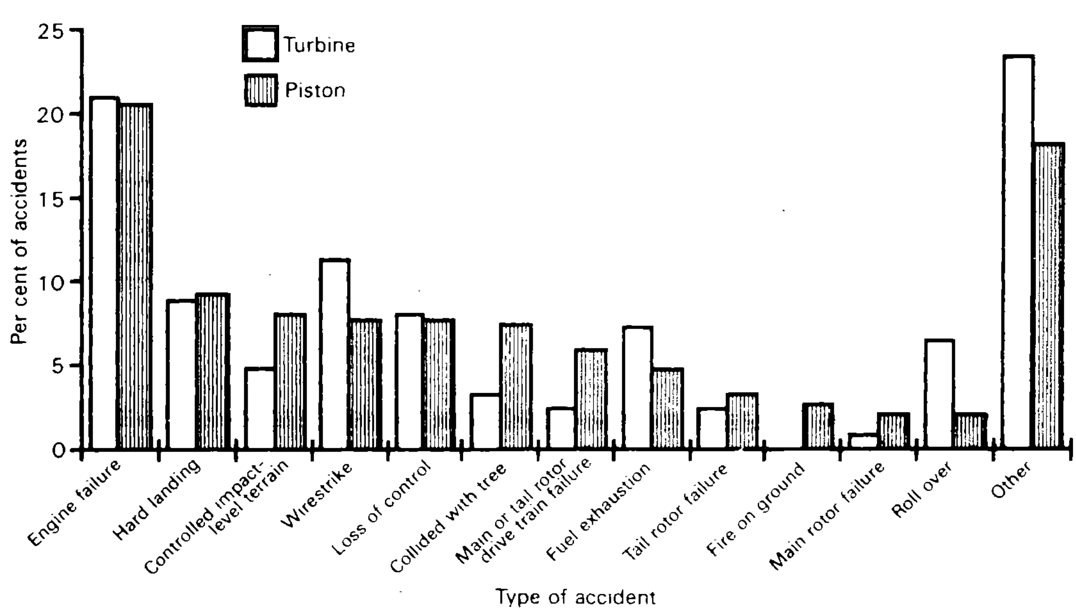



**Figure 13. Percentage breakdown of piston and turbine helicopter accidents**



## Figure 14. Helicopter accidents 1969-88

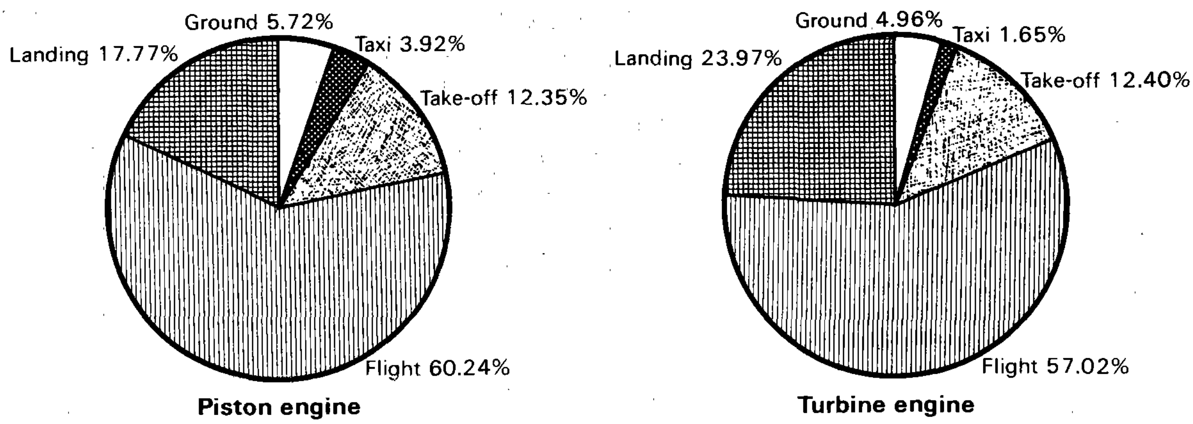
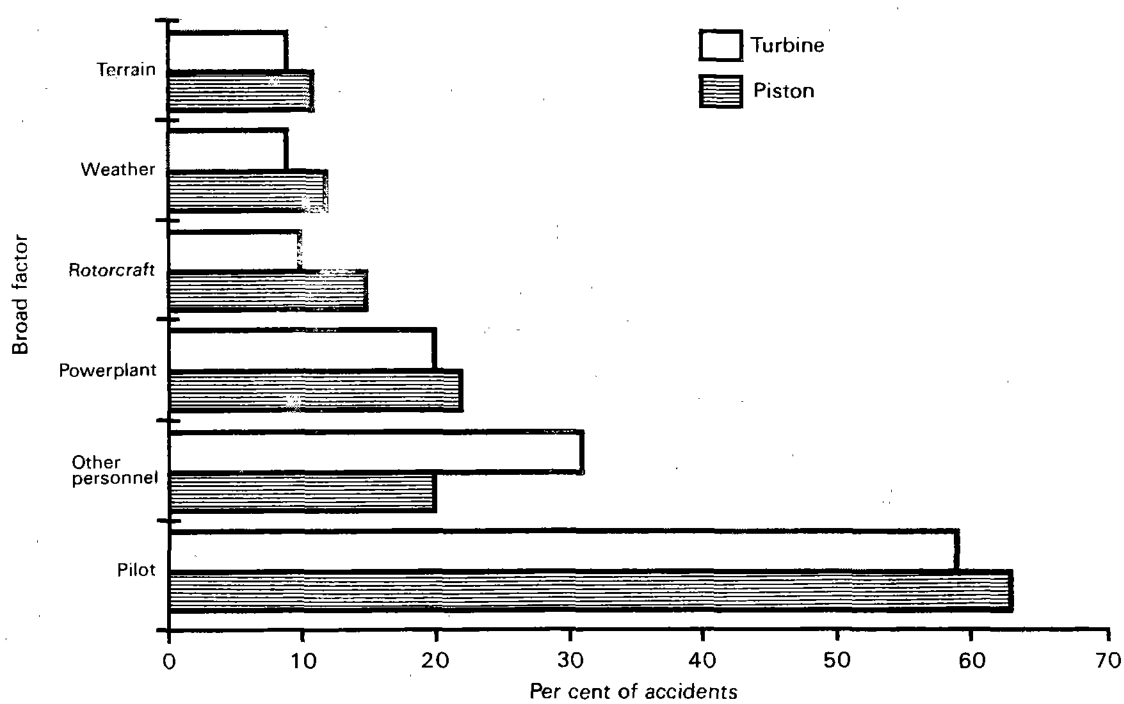



Figure 15 gives a broad breakdown of the factors involved in accidents for piston engine and turbine engine helicopters. The figure shows that accidents have occured for the same general reasons in both aircraft types. The exception is the greater role of 'other personnel' (mainly LAMEs) in turbine helicopter accidents. ('Rotorcraft' refers to components specific to helicopters).

## Figure 15. Broad factors, piston vs turbine engine helicopters



# SUMMARY AND CONCLUSIONS

The report examined 459 helicopter accidents from the Bureau's computer data base. It was found that the yearly number of accidents was closely related to flying activity. Although the most rapid increase in accidents occurred in the late 1970s, accidents and flying activity are continuing to increase steadily. The accident rate is currently steady at around 21 accidents per 100 000 hours of flying. The boom in helicopter activity after 1976 was accompanied by a very large but short-term increase in the accident rate. The implication of this finding is that safety standards in the helicopter industry are likely to suffer a temporary setback during the initial stages of any future period of rapid growth.

One in five accidents occurred after engine failures. The major cause of engine failures was material failure of engine components. Other common accidents (in order of frequency) were hard landings, wirestrikes, loss of control, controlled impact with level terrain, collisions with trees, fuel exhaustion and failure of the main or tail rotor drive train. The hard landings typically occurred after autorotations. At least four, but possibly more of the losses of control occurred after 'loss of tail rotor effectiveness'.

Six out of every ten accidents involved pilot factors. The most frequently cited factors were 'Inadequate preflight preparation or planning', 'Did not see or avoid objects or obstructions' and 'Improper in-flight decisions or planning'.

In the human factors section of the report, four basic types of pilot factors were outlined. These were perceptual difficulties, information processing difficulties, problems of execution and finally, procedural problems. Although each of these broad areas were linked to accidents, the majority of the helicopter accidents which involved pilot factors can be summarised as procedural problems, most frequently poor judgment, inadequate planning or poor decision making.

Any action to improve the helicopter accident record in Australia must address the area of pilot judgment and decision making. Pilot judgment training is one possible option. In the United States, at least one large operator has found measurable improvements in helicopter safety following the introduction of pilot judgment training.[1]

Unlike pilots of fixed wing aircraft, helicopter pilots are not subjected to mandatory biennial flight reviews. A helicopter pilot who is not flight checked under an approved company check and training system or who is not subject to instrument rating renewals, may hold a licence and fly for many years without undergoing a flight check. The introduction of a helicopter biennial flight review may help to reduce human factor accidents.

The problem of overpitching, particularly at high density altitudes, may call for more flying at high all-up weight during training.

Pilots who were partially or totally responsible for accidents were generally no less experienced than other pilots. There was no statistical evidence that low experience pilots were more likely than others to have particular types of accidents or contribute particular pilot factors. Although this finding may be surprising it is consistent with overseas experience and illustrates that 'any pilot has the potential for a human error caused accident.'[2]

More accidents occurred during aerial mustering than during any other type of flying. However, mustering is the largest area of helicopter use in Australia and the 100 000 hour accident rate for mustering operations is among the lowest for helicopter flying.

Although charter flying had a relatively low accident rate, charter flights had an unusually high incidence of fuel exhaustion accidents. Possibly, some pilots are trying to satisfy passengers at the expense of safe flying.

Ferry flying, although a relatively minor area of helicopter activity, produced an accident rate well above expectations. Although about half of the ferry accidents resulted from airworthiness problems not of the pilot's making, the high accident rate may be due in part to a casual attitude to ferry flights. The industry should be aware that ferry flights are no less hazardous than other types of operations.

Agricultural flying, again a relatively small area of helicopter activity, had the highest accident rate. However in the period covered by this study, there were no fatalities in this category of flying. Just under half of the agricultural accidents were wirestrikes.

Not only are an increasing number of accidents occurring in the private/business category, but the accident rate for this type of flying is now higher than it was in the 1970s. If this trend continues, this group may eventually overtake mustering as the largest single accident group. In view of this, the CAA should consider directing accident prevention measures towards private fliers, perhaps in the form of a periodical flight check.

In general, the same pilot factors occurred regardless of the type of flying. There were a number of exceptions, including a tendency for pilot factors in training accidents to be skill-related. In addition, pilots on non-commercial pleasure flights tended to make uncommon, skill-related mistakes instead of the more usual procedural errors. For this reason, it is likely that periodical flight checks, if introduced, would be particularly beneficial for recreational flyers.

Inadequate maintenance emerged as a factor in about one in ten accidents. In most cases, these were accidents on mustering or mapping/photo/survey flights in the north of Australia. For example, whereas 17 per cent of accidents in Western Australia involved inadequate maintenance, the figure was only 4 per cent in Victoria and New South Wales. This almost certainly reflects the difficulties of maintaining aircraft in remote areas. The two most frequent maintenance problems were fuel system problems and undetected fatigue failures. Increased pilot awareness of the problem may go some way to rectifying the situation, there may also be a need for more surveillance by the CAA.

Weather, in most cases local wind conditions, contributed to about one in ten accidents. Only three accidents resulted from continuing VFR flight into adverse weather.

In conclusion, this study has demonstrated once again the well-established principle that most accidents can be traced back to the actions of people. Helicopters are not as dangerous as the public may believe and in fact 80 per cent of the accidents in this report involved no serious injuries or fatalities. However, the future role of helicopters in Australia will depend to a large extent on the public perception of helicopter safety. If the industry wishes to improve the safety record and reputation of helicopters it could start at no better place than the 67 per cent of accidents which are related to pilot factors. Human factor accidents, such as the 25 occurrences of fuel exhaustion should, in theory, be the most preventable accidents.

**Notes**

[1]Roy E. Fox, Helicopter Accidents Trends, paper presented at AMS-FAA-HAI National specialist meeting, Vertical Flight Training Needs and Solutions, Arlington, Texas, 17-18 September 1987.

[2]R. Adams and J. Thompson, Aeronautical Decision Making for Helicopter Pilots, DOT/FAA/PM-86/45, FAA, 1987.

# RECOMMENDATIONS

1. The CAA should consider a requirement for more flying at high all up weight as part of check and training, in order to make pilots more familiar with operations on the edge of the helicopter's performance envelope.

2. The CAA should consider the introduction of Biennial Flight Reviews for those helicopter pilots who are not already receiving regular checks.

3. The CAA should direct further action towards the maintenance problems of helicopters in remote areas. More spot checks by the CAA may be appropriate.

4. Both the CAA and the industry should examine ferry flight practices - with a view towards providing explanations for the relatively high accident rate.

5. Further education on 'loss of tail rotor effectiveness' should be distributed to the industry, with an emphasis on how to avoid getting into the condition.

6. Pilots should be reminded once more of the dangers of grass-fires, particularly when operating Hughes 300 helicopters.

7. The industry should be made aware of the high incidence of fuel exhaustion. Charter operators in particular may need to review their procedures to ensure that sufficient fuel is always carried.

8. The CAA should consider the introduction of pilot judgment training for helicopter pilots. Such training could occur during initial flight training or could take the form of a publication or video to be distributed to operators.

9. Pilots on low level filming missions should consider more effective methods to avoid wires. Options include better aerial reconnaissance and the use of observers or ground markers to high-light the presence of powerlines.