AIRCRAFT ACCIDENT REPORT

No. 91-004

Robinson R22 Beta

ZK-HDD

Off Piercy Island, Bay of Islands

21 February 1991

Transport Accident Investigation Commission
Wellington - New Zealand

Transport Accident Investigation Commission
Wellington

Chief Commissioner
Transport Accident Investigation Commission

The attached report summarises the circumstances surrounding the accident involving Robinson R22 Beta aircraft ZK-HDD off Piercy Island, Bay of Islands on 21 February 1991 and includes suggested findings and safety recommendations.

This report is submitted pursuant to Section 8(2) of the Transport Accident Investigation Commission Act 1990 for the Commission to review the facts and endorse or amend the findings and recommendations as to the contributing factors and causes of the accident.

13 February 1992

R CHIPPINDALE
Acting Chief Executive

APPROVED FOR RELEASE AS A PUBLIC DOCUMENT

12 March 1992

M F DUNPHY
Chief Commissioner

AIRCRAFT:	Robinson R22 Beta	**OPERATOR:**	Mr B R Langley
REGISTRATION:	ZK-HDD	**PILOTS:**	Mr B R Langley (Pilot in Command) Miss A S Hine (Pilot Flying)
PLACE OF ACCIDENT:	Off Piercy Island Bay of Islands	**OTHER CREW:**	Nil
DATE AND TIME:	21 February 1991, 1025 hours	**PASSENGERS:**	Nil

SYNOPSIS:
The aircraft was in a high hover. It was seen to rotate about its vertical axis and fall into the sea. The Co-Pilot escaped underwater and was rescued but the Pilot lost his life. Mr D.V. Zotov was appointed Investigator in Charge and commenced the on-site investigation next morning.

1.1 HISTORY OF THE FLIGHT:
See page 4.

1.2 INJURIES TO PERSONS:
Pilot: 1 Fatal
1 Serious

1.3 DAMAGE TO AIRCRAFT:
The aircraft was damaged beyond economical repair

1.4 OTHER DAMAGE
Nil

1.5 PERSONNEL INFORMATION:
See page 6.

Pilot in Command Flight Times

	Last 90 days	Total
All Types	126	7641
On Type	78	1192

Co-Pilot Flight Times

	Last 90 days	Total
All Types	24	221
On Type	12	200

1.6 AIRCRAFT INFORMATION:
See page 6.

1.7 METEOROLOGICAL INFORMATION:
See page 9.

1.8 AIDS TO NAVIGATION:
Not Applicable.

1.9 COMMUNICATIONS:
Nil

1.10 AERODROME:
Not Applicable

1.11 FLIGHT RECORDERS:
Nil

1.12 WRECKAGE AND IMPACT INFORMATION:
See page 9.

1.13 MEDICAL AND PATHOLOGICAL INFORMATION:
See page 10.

1.14 FIRE:
There was no fire

1.15 SURVIVAL ASPECTS:
See page 11.

1.16 TESTS AND RESEARCH:
See Page 12.

1.17 ADDITIONAL INFORMATION:
See page 13.

1.18 USEFUL OR EFFECTIVE INVESTIGATION TECHNIQUES:
Nil

2. ANALYSIS:
See page 16.

3. FINDINGS:
See page 25.

4. SAFETY RECOMMENDATIONS:
See Page 26.

5. REGULATORY:
See Page 27.

6. OBSERVATIONS
See Page 27.

* All times in this report are NZDT (UTC + 13 hours)

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 The purpose of the flight was to take publicity photographs in the vicinity of the Bay of Islands for a firm in the tourist industry. The day before the accident the photographer, who was also the pilot in command, flew from Paihia, with the firm's Managing Director, in order to determine what photographs should be taken.

1.1.2 When the pilot started the engine for this preliminary flight, the belt clutch which coupled the engine to the drive train was found to be engaged. The engine start-up loads were applied to the drive train, but the inertia of the rotor system prevented the assembly from responding smoothly. The pilot said that the same thing had happened previously and he thought someone had been interfering with the switches.

1.1.3 He did not inspect the drive train or operate any circuit breakers, but disengaged the clutch before starting the engine. The flight proceeded normally. Subsequently the aircraft was refuelled to capacity with premium motor spirit. The object was to ensure there was sufficient fuel to complete the planned photography in one sortie, both to avoid a long transit flight to refuel and to take advantage of a cloudless sky which might not last.

1.1.4 On the day of the accident the right hand seat was occupied by the pilot flying. The pilot in command sat in the left seat, with the left door removed and the left cyclic control extension removed. (It was, however, still possible for him to fly the aircraft by holding the centre portion of the cyclic control). The procedure adopted was for the pilot flying to fly the aircraft to the vicinity of each subject to be photographed, whereon the pilot in command would position the aircraft exactly where he wanted it. He would then hand over control to the co-pilot and take the photograph through the open door.

1.1.5 One of the subjects to be photographed was the motor catamaran "Tigerlily" and it was intended to photograph the vessel as it emerged from the "Hole in the Rock", a tourist attraction at Piercy Island off Cape Brett. The "Hole in the Rock" passed right through the island from north-west to south-east and was sufficiently large for sizable vessels to sail through it.

1.1.6 The "Tigerlily" was photographed en route to Piercy Island and the helicopter then landed at Cape Brett to await the vessel's passage through the Rock. It got airborne again as the "Tigerlily" approached.

1.1.7 It was the usual practice to fly the aircraft at a low forward speed (of the order of 30 knots) while taking photographs, repositioning the aircraft for a further attempt if necessary by flying a racetrack pattern. This avoided the necessity to place the aircraft within the boundaries of the "avoid curve" (see 1.17.7 and diagram 4). However, this procedure was not possible at Piercy Island, because the "Tigerlily" would be in the position required for the photograph for a few seconds only. It was therefore decided to hover in position, with the Hole in the Rock in frame, all set to take the picture as the vessel emerged. It was realised that the aircraft would be within the avoid curve but, as the period in the danger zone would be short, this was considered to be acceptable.

1.1.8 The pilot in command positioned the aircraft to the south-eastern side of Piercy Island on a northerly heading so that the Hole from which "Tigerlily" would emerge would be in view through his open doorway, whereon he handed control to the pilot flying. The aircraft was at half the height of the island (which was 498 feet high). The flying conditions were smooth.

1.1.9 The low rotor rpm (rrpm) warning horn sounded. The pilot flying recalled that the pilot in command took control, whereon the aircraft descended rapidly into the sea.

1.1.10 She remembered seeing water flooding into the cockpit and having considerable difficulty in finding the buckle of her seatbelt. By the time she got it undone the water appeared black, but she was able to leave through her doorway (the door having come off on impact) and to swim to the surface. She also had some difficulty in finding the inflation toggle of her lifejacket, but ultimately succeeded. She was rescued by a fishing vessel crew who had seen the accident.

1.1.11 At the time of the accident the vessel was about 200m to the north. The deckhand, who was preparing hapuka lines, had seen it hovering and it appeared to him to be quite stationary. He saw the aircraft rotate rapidly through two or more turns about its vertical axis and shouted to draw the skipper's attention to this event. The skipper saw one turn. The aircraft then fell vertically to the sea; it appeared to be virtually in free fall and the fishermen estimated the time of fall (independently) to be 4 or 5 seconds. There was however, no perceptible splash. The sea at this time was fairly calm with a south-easterly surface wind of 10 to 15 knots and a strong north-west-going tidal current in the vicinity.

1.1.12 The accident site was 80 m off the eastern corner of Piercy Island; grid reference 331 698, NZMS 260 sheet Q05 "Bay of Islands", latitude 35°10'S longitude 174°20'E. The accident occurred in daylight at 1025 hours.

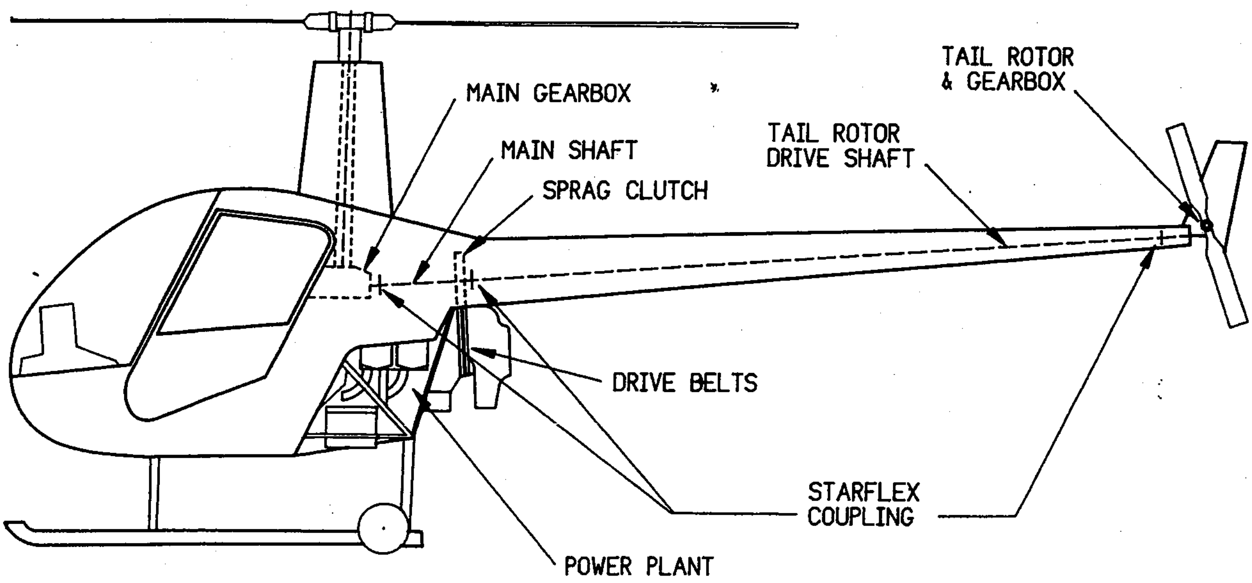

Diagram 1 — Robinson R22 Transmission Layout

1.5 Personnel information

1.5.1 The pilot in command, Brian Reginald Langley age 50, held Commercial Pilot Licence - Aeroplane number 2498 and Commercial Pilot Licence - Helicopter (CPL-H) number 144. He held Instructor Ratings of A Category - Aeroplane and C Category - Helicopter. The validity certificate associated with his helicopter licence was current until 10 May 1991.

1.5.2 At the time of his latest medical examination for the renewal of his pilot licences, in October 1990, he was assessed fit, subject to having corrective half-lenses readily available. His weight was 91 kg. Of his total recorded flight time of 7641 hours, 1446 hours were on helicopters.

1.5.3 The pilot flying, Angela Susan Hine, age 32, held CPL-H number 30829, which was issued on 19 September 1990 and valid to 18 June 1991. At the medical examination for the issue of her licence she was assessed fit. Her weight was 49 kg.

1.5.4 Except for half an hour of flying fixed wing aircraft, all of her flight time was on helicopters.

1.5.5 She had not been cleared to fly the R22 from the left hand seat.

1.5.6 The pilot in command had been the flying instructor of the pilot flying for the greater part of her helicopter training.

1.5.7 At the completion of her training for her CPL-H, she had had 138 hours dual instruction and had flown 36 hours as pilot in command. The Chief Flying Instructor advised that she had had some difficulties during training, including difficulty in coordinating the controls, which had resulted in her having a greater portion of her flying as dual instruction than was usual. However, she reached the necessary standard to pass the issue flight test for her licence.

1.6 Aircraft information

1.6.1 Robinson R22 Beta helicopter serial number 1603 was constructed in 1990 and imported new into New Zealand where it was registered as ZK-HDD. It was issued with a Certificate of Airworthiness in the Standard Category valid until 23 January 1995.

1.6.2 The aircraft was equipped with a Lycoming O-320-B2C engine serial number L16431-39A, which was installed new. The engine had an updraught carburettor, mounted below the engine as installed in the aircraft.

1.6.3 The Maintenance Release was valid until 19 August 1991 or 100 hours total airframe time, whichever was the sooner. At the time of the accident both engine and airframe had operated for 53.4 hours.

1.6.4 The aircraft was fitted with main and auxiliary fuel tanks, giving a total fuel capacity of 30.7 US gallons (116.1 litres).

1.6.5 The maximum permitted mass was 1370 pounds (622 kg). At the time of the accident the mass was estimated to have been 1309 pounds (594 kg) and the centre of gravity was within the permitted limits.

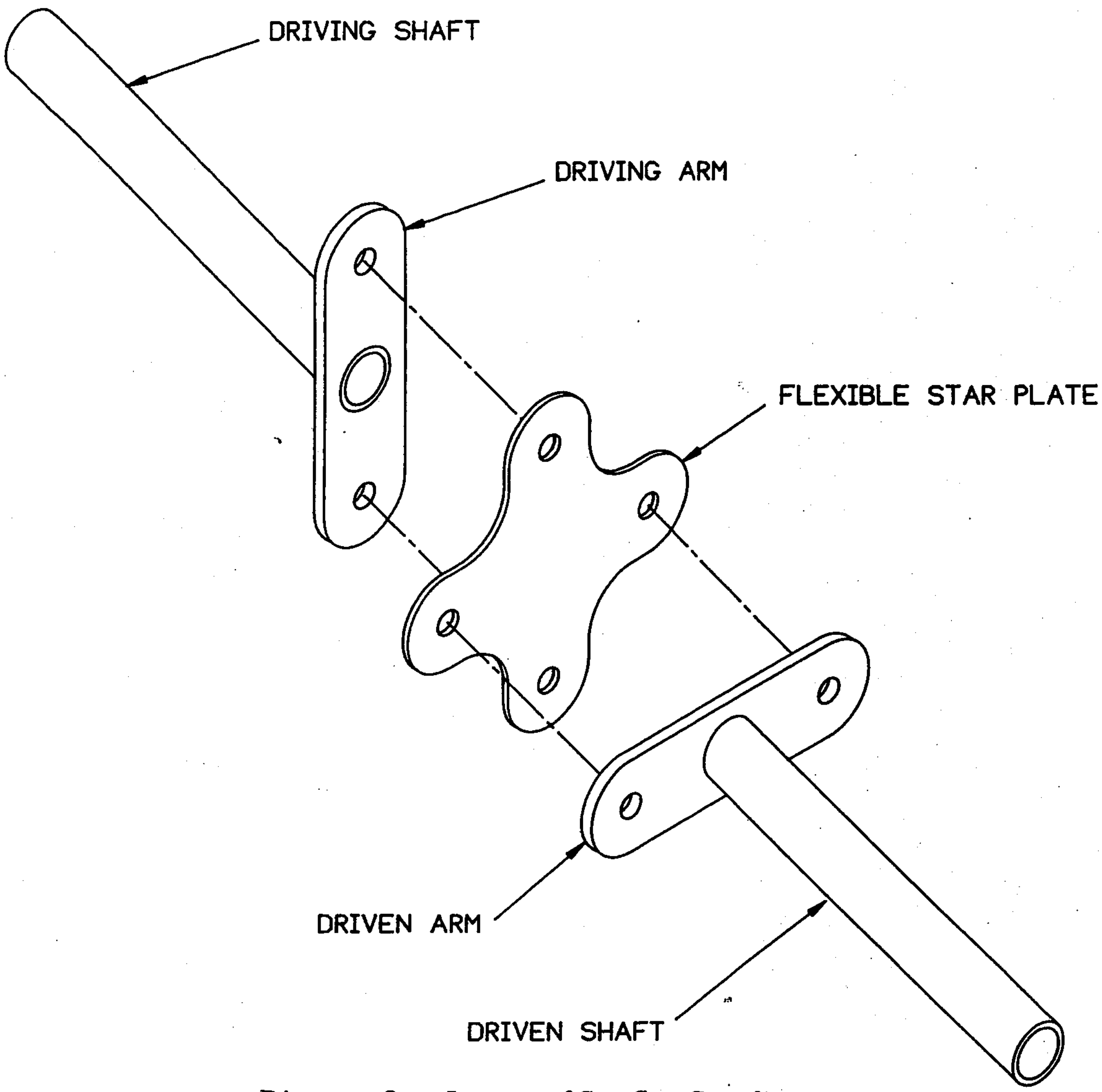

Diagram 2 — Layout of Starflex Coupling

1.6.6 Power was transmitted from the engine to a sprag clutch on the main drive shaft (see diagram 1). From the main drive shaft power was transmitted forward to the main gearbox, from which the main rotor was driven, and aft through the tail rotor drive shaft and gearbox to drive the tail rotor (the main function of which was to prevent the aircraft from rotating to the right, under torque from the main rotor drive shaft, as the main rotor was driven). The tail rotor, mounted on the left side of the tailboom, rotated anticlockwise when viewed from the left side.

1.6.7 The function of the sprag clutch was to permit the rotors to continue to rotate in the event of engine failure; unless the engine was rotating at a speed lower than the driveshaft rpm the clutch would be engaged. It was therefore necessary to make separate provision to disengage the engine for starting, so that the entire mechanism did not have to be rotated and this was done by means of a screwjack which moved the main driveshaft bearings (and thus the driveshaft) up and down in relation to the engine. This tensioned or slackened the driving belts so that these could act as a slipping clutch. This clutch was operated by a toggle switch on the instrument panel. The switch was guarded against inadvertent operation, but there was no interlock to inhibit the use of the starter switch while the clutch was engaged. It took some 60 seconds for the screwjack to travel between the engaged and disengaged positions.

1.6.8 Because the position of the main driveshaft was not fixed, the alignment between it, the main gearbox input shaft, and the tail rotor driveshaft, could not be exact. The necessary tolerance was provided by star-flex couplings (see diagram 2) at each end of the main driveshaft and at the tail rotor gearbox input shaft.

1.6.9 The tailboom consisted of a light alloy monocoque tube, fabricated as a number of separate lengths which were joined by circumferential rivets. At the forward end it was mounted to a tubular steel framework which was in turn fixed to the main steel framework holding the engine and main gearbox, and to which the fuselage pod was mounted. The star-flex coupling, which joined the main driveshaft and tail rotor driveshaft, revolved within the steel tailboom mounting frame.

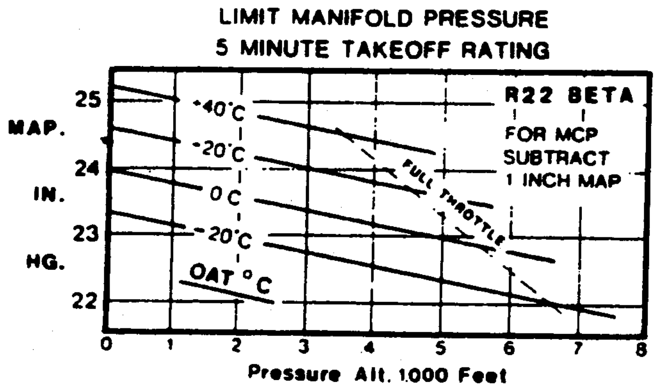

Diagram 3 — R22 Beta
O-320-B2C Engine Limitation Placard (Actual Size)

1.6.10 The two main rotor blades were of lightweight construction, comprising an extruded aluminium leading edge and honeycomb core, covered with a glass reinforced plastic skin. They were arranged as a teetering rotor system, free to teeter within limits dictated by the rotor head geometry, and to cone. The lower coning limits were set by droop stops but no freedom in lead or lag was provided.

1.6.11 The pilots' seats consisted of medium density upholstery foam cushions on glass fibre pans. These pans, hinged at the front, formed the lids of boxes the sides of which were made of thin gauge light alloy. The bottom of the box was the lower skin of the aircraft. Static tests on these seats had shown that they would buckle when the occupant experienced a vertical deceleration of about 10g.

1.6.12 The pilots' harnesses were of the lap and diagonal pattern attached to strongpoints on the rear cockpit bulkhead and the aircraft floor.

1.6.13 While this particular aircraft had not been issued with an approval to operate on premium motor spirit, the engine type had been generally approved for such operation.

1.6.14 The throttle linkage was stiff, as was normal for a new aircraft. The pilot flying advised that a slight movement of the throttle twist grip towards the "throttle closed" position seemed to result in a disproportionate loss of rotor rpm by comparison with other R22's she had flown. However, she considered this to be of nuisance value only. These reductions in rotor rpm were experienced in cruising flight and were never so great as to cause the low rpm warning horn to sound.

1.6.15 The low rpm warning horn sounded when the rotor rpm reduced below 95% of normal.

1.6.16 To hover out of ground effect at 1309 pounds (594 kg) mass with an air temperature of +20°C, required a power setting of 25 inches manifold pressure at maximum permitted rpm. The maximum permissible power setting, at sea level at +20°C, was 24.6 inches; this was the 5 minute takeoff rating and could be deduced from a graph displayed on the lateral beam where the perspex joined the framework, over the pilot's head (shown actual size in diagram 3). The manifold pressure gauge (which was calibrated in inches of mercury) was marked with a yellow arc (caution range) between 21.0 and 25.2 inches, with a red radial (do not exceed) at 25.2 inches. The manufacturer advised that the engine limitations were due to cooling considerations and also defined the power limits to which the transmission was certified.

1.7 Meteorological information

1.7.1 An anticyclone over the Tasman Sea extended a ridge onto South Island. The flow over the northern part of New Zealand was southerly or south-easterly.

1.7.2 Witnesses said the sky was clear at Cape Brett. There was a north-easterly swell of 250 mm and a steady south-easterly breeze of 10 to 15 knots (this estimate agreed well with other observations).

1.7.3 The barometric pressure was 1015 hPa.

1.7.4 At the automatic weather station at Puerua, about 25 km west-north-west of Cape Brett, 230 feet above mean sea level, the air temperature was 20°C. (The sea temperature in the area, from satellite soundings, was 21°C).

1.12 Wreckage and impact information

1.12.1 ZK-HDD was found, upright on its skids, in 83 metres of water, some 80 m offshore. The right door lay on the seabed beside the aircraft; it had been retained by becoming snagged on the cord of a headset. The aircraft was otherwise complete and largely intact.

1.12.2 The pilot in command was still in his seat, hands and feet on the controls. He was not wearing a helmet. The perspex panel above him had been broken upwards as by a blow from below; the cabin was slightly distorted, but the perspex "bubble" was intact.

1.12.3 One of the main rotor blades exhibited buckling rearward at about half span. The tail rotor was intact and undistorted. The tailboom was bent downwards where it had broken halfway along its length, but remained in place. When the main rotor was moved, the tail rotor also turned.

1.12.4 A video recording was made of the aircraft before recovery was attempted.

1.12.5 A harness was slipped over each main rotor blade and snugged up at the hub. After initial difficulties the aircraft was brought to the surface. Some additional damage was incurred in the process, but this could be identified by comparison with the video recording.

1.12.6 After draining the fuel tanks, the aircraft was immersed for 24 hours in a freshwater lake, sprayed with water repellent and taken to an engineering facility for further examination.

1.12.7 Crush lines indicated that the aircraft struck the sea with its longitudinal axis parallel to the surface, and its lateral axis slightly left side low. The crushing depth of the fuselage belly skin was 150mm.

1.12.8 Control continuity and freedom of movement before impact was established. The tail rotor, associated linkages and gearbox all operated correctly. The drive from the main driveshaft through the main gearbox to the rotor head functioned. One linkage at the rotor head had failed under tensile overload and the droop stops were broken, otherwise the main rotor head was in order.

1.12.9 The tailboom had failed downwards at a construction joint halfway along its length. The rivets holding this joint had sheared. Buckling of the skin, to the rear of the break, was consistent with a downward load on the end of the boom; whereas buckling at the root of the boom indicated an upward load in that region. The video recording confirmed that the buckling existed before the recovery occasioned additional damage.

1.12.10 The starflex coupling between the main driveshaft and the tail rotor driveshaft had failed. One arm of the star plate had broken and the plate was twisted between the driving and driven arms which were themselves bent. Nevertheless, the coupling still connected the driving and driven shafts. When it failed, the coupling had hammered against the tubular steel tailboom mounting structure and produced deformation of the order of 9mm. The tail rotor driveshaft was running eccentrically at its forward end, but was centred at its rear starflex coupling which was unaffected.

1.12.11 The tail rotor drive shaft had been broken halfway along its length during the recovery operation. There was combined bending and torsional failure at this point.

1.12.12 Both pilots' seats had collapsed downward under impact loading; the deformation of the seats suggested that the load had been greater on the left side than on the right of each seat. The left seat had collapsed to a greater extent than the right. When the seats were dismantled, it was found that further downward travel of the right fibreglass seat pan had been prevented by a firmly packed first aid kit. Travel of the left seat had been unobstructed and there was an imprint of the seat pan on the aircraft skin below the seat.

1.12.13 The tachometer glass had been broken by a blow from some object moving forward. The glass of the other instruments was intact.

1.12.14 All engine control settings were normal.

1.12.15 The collective lever was well down, but prevented from moving fully down because the metal from the left seat frame had spread out beneath it.

1.13 Medical and pathological information

1.13.1 The pilot in command died from drowning. His injuries were essentially minor.

1.13.2 Pathological and toxicological investigation disclosed no evidence of any condition which might have affected the pilot's ability to control the aircraft.

1.13.3 The pilot flying experienced bruising, especially to her thighs, and five spinal compression fractures.

She had little recollection of events at about the time of the accident.

1.15 Survival aspects

1.15.1 Both pilots were wearing combined seatbelts and diagonal shoulder harnesses. Both wore lifejackets; neither wore safety helmets.

1.15.2 A properly restrained seated human could have tolerated short term upward vertical acceleration of the order of 25g (ie the acceleration would be such that weight was increased twenty-five times) without injury. However, if restrained only by a seatbelt, or if "submarining" (slipping under the seatbelt) occurred, spinal injury could be experienced at as little as 4g.

1.15.3 The rebound induced by a resilient foam cushion, under impact conditions, was taken, conventionally, as doubling the peak g load experienced by the occupant.

1.15.4 The R22 was designed to standards of the Federal Aviation Administration (FAA) of the United States. The emergency landing conditions in force until 1989 stipulated load factors of:

4g downwards to 1.5g upwards
4g forwards
2g sideways

(Federal Aviation Regulations 27.561)

It was suggested that above 4g downwards, the seat should deform to help absorb impact loads. The R22, which was certificated in 1979, was demonstrated to meet these requirements. Under static loads, the seat structure began to deform at 10g.

1.15.5 In the 1960's and 1970's the United States Army performed work on survivability in aircraft accidents, published in the US Army Aircraft Crash Survival Design Guide. This work resulted, in the 1980's, in studies by the FAA and helicopter industry, to improve the crashworthiness of civil helicopters. In 1989 the FAA issued Amendment 27-25 to FAR 27 prescribing revised static load factors for the design of seats and defined two dynamic tests. The static load factors are:

Upward:	4g
Forward:	16g
Sideways:	8g
Downward:	20g, after any stroking of an attenuation system

The dynamic tests, with anthropomorphic dummies, were required to demonstrate occupant protection:

(a) In a near vertical impact with some forward speed, applying 30g deceleration from a minimum velocity of 30 feet per second

(b) A horizontal impact with 10° yaw, applying a minimum of 18.4g deceleration from a minimum of 42 feet per second

However, these rules applied only to new designs, not to existing aircraft types nor to their derivatives. They did not therefore apply to the R22.

1.15.6 New Zealand airworthiness practice was to accept United States certification.

1.16 Tests and research

1.16.1 The engine was dismantled and inspected. All mechanical components were in good condition. Notwithstanding that the updraft carburettor was the first part of the engine to enter the water, there was no deformation consistent with hydraulic shock from ingestion of seawater. One magneto was defective but this was found to be due to seawater ingress into the capacitor through a flaw in the seal. Sludge in the carburettor was found to be a gel formed by seawater and petrol; the accelerator pump and jets functioned normally. There was therefore no reason found why the engine should not have been capable of delivering normal power, but equally there was no evidence that it was delivering significant power at water entry.

1.16.2 Fuel from the underground storage tank from which the aircraft was last refuelled was tested; it was free from contamination and conformed to the specifications for premium motor spirit.

1.16.3 The tachometer, which was the only instrument with potentially useful indications, was examined in detail. When first seen underwater, both engine and rotor rpm were at the top of their scales. After recovery, the engine rpm was indicating 100%; the rotor rpm remained at maximum, being retained there by a shard of glass. The dial was deformed as well as the glass being broken inwards, consistent with impact by some hard object.

1.16.4 Microscopic examination of the dial for needle imprints was inconclusive. It was found that the engine rpm needle was prevented from going below 100% by a shard of glass. When the movements were removed from the case it was found that the hairsprings and pivots were intact and the needles returned to zero.

1.16.5 The needles were balanced, so that impact accelerations were unlikely to have displaced them. A short circuit could not have deflected the needles to maximum: the system counted digital pulses from hall-effect senders. The needles returned rapidly to zero when power was removed. It was concluded that the trapped indications were representative of conditions at impact.

1.16.6 A light helicopter (H269B) was set up in the following conditions, to see if the events reported by witnesses could be produced:

Hover out of ground effect
Moderate tailwind
Near maximum all-up mass

Precise values were not recorded since the experiment was intended to see if the effects happened at all, rather than to take quantitative measurements. The aircraft was allowed to sink somewhat: this was considered realistic, since holding height by reference to a vertical feature 80m away would be less precise than when hovering in ground effect. Such an effect could also result from a momentary reduction of tailwind, which could reduce the lift from rearward translation.

1.16.7 The experienced instructor flying the aircraft believed that the aircraft entered a main rotor vortex ring state. The nose dropped and extra power to hold the height precipitated uncommanded right yaw. This was checked as the aircraft came round into wind. There was a considerable height loss and the main rotor blades came close to the tailboom. It was decided not to pursue the experiment and that to try it with an R22 would be unwise.

1.16.8 The star plate of the failed coupling appeared to have broken in two distinct stages. However, examination under an electron microscope showed an absence of polishing in the outer part of the break. This indicated that the two events were closely related in time.

1.16.9 Detailed examination of the failed ends of the tail rotor driveshaft indicated that separation would have occurred rapidly had the shaft continued to rotate after the failure occurred. The sense of the torsional failure was with the forward end driven in the direction of rotation and the rear end held back.

1.16.10 There were two separate dents in the bottom member of the tubular steel tailboom mounting frame. The star-flex coupling was resting in one of these dents when the aircraft was recovered. Microscopic examination of these dents and the coupling showed little indication of metallic transfer. One of the dents contained parallel scoring, indicative of continued rotation while the dent was being formed. It was not possible to establish the number of rotations that might have occurred, but it was considered more likely to have been in the region of ten or so, rather than a hundred. The other dent, about 9mm deep, appeared to have been made by a single blow.

1.16.11 There was no significant damage to the tail rotor gearbox, hub, or blades.

1.16.12 Analysis of the bending loads induced in the tailboom at impact, by the mass of the tail rotor and gearbox, indicated that the failed construction joint was in the region of maximum bending stress.

1.17 Additional information

Uncommanded Yaw

1.17.1 Uncommanded yaw could be experienced on any helicopter the main rotor torque of which was controlled by a tail rotor. The yaw was to the right in helicopters the main rotors of which turned anticlockwise when viewed from above and was due to inability of the tail rotor to produce enough thrust to counteract main rotor shaft torque. It was also known as "Loss of Tail Rotor Effectiveness". This did not mean that the tail rotor was stalled, since studies had shown that this was not the case. Uncommanded yaw could arise from a number of causes, in low speed flight:

(a) Weathercock stability, when the relative wind was more than about 5 knots within a sector 60° either side of the tail

(b) Tail rotor vortex ring state, when the relative wind was from the left between 210° and 310° relative to heading and greater than about 7 knots

(c) Main rotor disc vortex intercepting the tail rotor, when the relative wind is 285° to 315° relative and greater than about 10 knots

(d) Loss of translational lift (all azimuths)

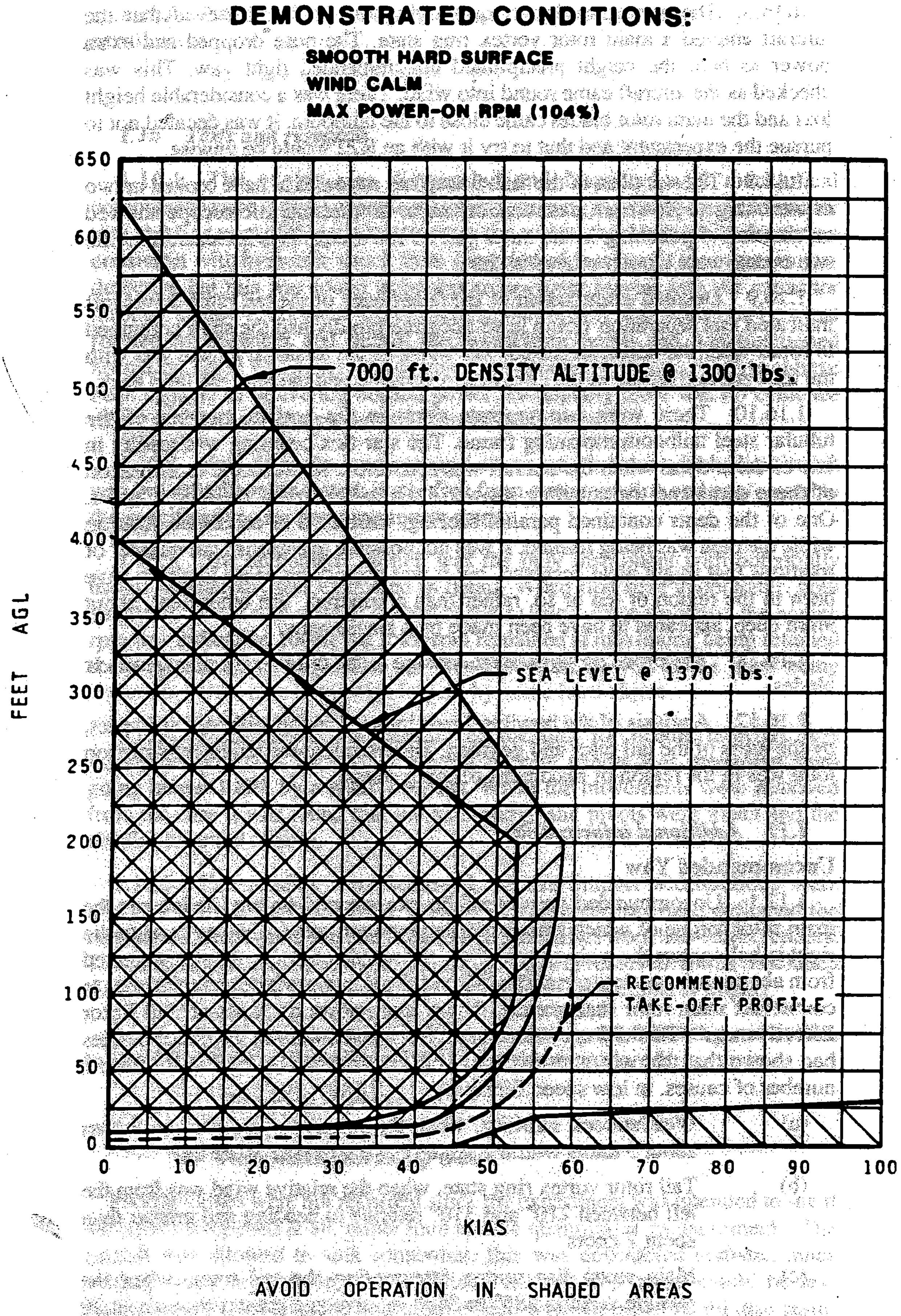

Diagram 4 — Robinson Model R22 "Avoid Curve"

1.17.2 Factors predisposing to uncommanded yaw were those resulting in high main rotor driveshaft torque, such as high mass, and hover out of ground effect. Loss of rotor rpm would have the effect of reducing tail rotor thrust (the percentage reduction being roughly twice the percentage loss of rrpm) and thus reduced ability to counter the right yawing tendency. If an attempt was made to regain rrpm by use of the throttle without reducing collective pitch, uncommanded yaw might be initiated.

1.17.3 Once the turn was initiated, the movement of the tail rotor displaced it into its own disturbed airflow, which resulted in an effect exactly analogous to vortex ring settling in relation to the main rotor. The tail rotor might then be unable to check the angular rotation until the driving torque from the main rotor driveshaft was reduced, or the aircraft flown away from the region of disturbed airflow by the use of forward cyclic, or both. Either corrective action would result in height loss.

1.17.4 The recommended recovery from uncommanded yaw was to apply and maintain full pedal against the direction of rotation and to ease the cyclic forward so that the tail rotor moved out of its own disturbed airflow and became effective. If this action was ineffective, or if space available prevented forward flight, it would be necessary to lower the collective or enter autorotation, but a considerable height loss could ensue.

1.17.5 Information on uncommanded yaw had been available since 1983, when Bell Helicopters published the results of United States Army trials. In 1985 the New Zealand Flight Safety magazine published a summary of this information. However, there was no source of information readily available to helicopter pilots who had begun flying since the article was published. The pilot flying was not aware of the phenomenon and the Chief Flying Instructor of the organisation which employed the pilot in command thought it unlikely that he would be aware of it, unless he had seen the article by chance; he had done most of his helicopter flying since 1985. There was no requirement, in the helicopter training syllabus, for instruction in uncommanded yaw.

The Avoid Curve

1.17.6 In general, a single engined helicopter should have been operated in such a way that in the event of an emergency, it could make a safe autorotative landing. Autorotation could be required not only in the event of engine failure, but also to cope with transmission failure, tail rotor malfunction, or to escape from uncommanded yaw. However, there were combinations of height and speed such that a safe landing from autorotation could not be performed. The boundaries of these height/speed combinations were determined by flight testing, and published as an "Avoid Curve"; that for the R22 being shown at Diagram 4. Should an event occur that necessitated autorotation while the helicopter was operating within the shaded area bounded by the Avoid Curve, it might not be possible to land the aircraft without damage.

1.17.7 The published avoid curve assumed zero or forward airspeed. If there was any rearward velocity the upper part of the low speed curve was raised considerably, since height had to be consumed in gaining forward airspeed prior to touchdown.

Mechanical Damage on Starting

1.17.8 On a number of occasions, pilots of R22 helicopters had been observed attempting to start the engines of their aircraft with the belt drive clutch engaged. On some of these occasions the pilot had not inspected the drive train subsequently before starting the engine.

1.17.9 Damage had been caused by such attempts. This damage, apparently localised in the star-flex coupling between the main driveshaft and the tail rotor driveshaft, varied from edge cracking of the star plate, to buckling of the components, and destruction of the weld between the driven arm and the tail rotor driveshaft. Such damage was not necessarily evident on a cursory inspection.

1.17.10 The checklists relevant to stopping and starting the engine were:

(a)	SHUTDOWN	Idle at 70 to 80%	Head Temp Drop
		Throttle	Closed
		Clutch Switch	Disengage
		Wait 30 sec	Pull Idle cut-off
		Mixture Guard	On Trim Knob
		Wait 30 sec	Apply Rotor Brake
		Clutch Light Off	All switches off
	BEFORE STARTING ENGINE	All switches/ avionics	Off
		Clutch	Disengaged
		Mixture	Full Rich
		Mixture Guard	Installed
		Carb heat	Off
		Rotor Brake	Disengaged
	STARTING ENGINE	Master Switch	On
		Throttle	Closed
		Area	Clear
		Ignition Switch	Start then both

2. ANALYSIS

2.1 Pilot in Command

2.1.1 Mr Langley made the command decisions throughout: for example, he decided to refuel the aircraft to capacity although this would minimise the power margin available for hovering, and he decided to take the photographs at Piercy Island from hover out of ground effect, although this would put the aircraft in the avoid curve. He knew what he wanted the aircraft to do and where he wanted it: in the absence of specific briefing Miss Hine could not have known this.

2.1.2 Mr Langley planned and organised the operation and was thus responsible for the operation of the aircraft. In the case of the positioning at Piercy Island, he positioned the aircraft in a particular configuration and so was responsible for the safety of the aircraft. He was, therefore, the pilot in command. As he had always been pilot in command when flying with Miss Hine, he would have seen no reason to brief her specifically on this point.

2.1.3 Miss Hine, by contrast, did none of the decision making. Her role was to fly the aircraft as directed. Her role was therefore that of pilot flying.

2.2 Mechanical Factors

2.2.1 While sudden engine failure would produce a rapid yaw to the left, this would be countered immediately by right pedal pressure; it was unlikely that the aircraft could make one, let alone two or more complete rotations from this cause. This view was supported by the complete lack of evidence of any malfunction of the engine. On the other hand, failure of the tail rotor drive, or the phenomenon of uncommanded yaw, could cause the aircraft to commence a rapid yaw to the right; to recover control it would be necessary to enter autorotation.

2.2.2 On two occasions, the pilot attempted an engine start with the belt drive clutch engaged and on the second occasion a bystander reported loud mechanical noises arising from this attempt. Without dismounting to examine the drive train, the pilot disengaged the clutch, started the engine and flew the aircraft on an uneventful sortie. It was therefore inferred that he was unaware of the potential for damage in such an attempted start. On the next flight the aircraft was observed hovering at about 250 feet, when it rotated rapidly about its vertical axis, ceased rotating and fell to the sea.

2.2.3 When ZK-HDD was recovered from the water, the star-flex coupling between the main driveshaft and the tail rotor driveshaft exhibited damage similar to that resulting from an attempted start with the clutch engaged.

2.2.4 If the shutdown checks were completed and the master switch was turned off before the screw jack had disengaged the clutch (which took about 60 seconds) then the belt drive clutch would remain tensioned and the clutch warning light would be extinguished. The tension on the belts could be detected on a walk round inspection before the next start, but for a variety of reasons (for example a brief shutdown during a period of operations) such inspections were not always made.

2.2.5 Attempts at starting the engine of the R22 with the belt drive clutch engaged were unsuccessful because the starter motor was unable to overcome the inertia of the gearboxes and rotors. There was however, the potential for damage to occur to the drive train components, which were not designed to withstand the impulsive loadings inherent in such an attempt. Such damage had occurred in the past. While catastrophic damage would be easy to discern, more subtle damage might only be detectable by an engineering inspection. Damage had been found in the vicinity of the star-flex coupling between the main driveshaft and tail rotor driveshaft, but in principle it was possible that other damage, for example to gear teeth or to the tail rotor driveshaft, could occur.

2.2.6 There was little warning in the startup checks to show that the belt drive clutch was engaged prior to an attempted engine start. The clutch switch, set to "Disengaged", would be ineffective until the Master Switch was selected "ON" immediately before attempting to start; likewise the clutch light would be off until then.

2.2.7 It was apparent that:

(a) There was a potential for catastrophic damage to result from an attempted start with the clutch engaged

(b) Other R22's had been subjected to such attempts

(c) Generally pilots were not aware of the potential consequences of such attempts

Accordingly, it was recommended to the Ministry of Transport that they: warn pilots of the hazard arising from an attempted start with the belt-clutch engaged; require an engineer's inspection after such an attempt, before next flight; and require inspection of the R22 fleet in case aircraft were flying with damaged couplings. It was also recommended to the importer and manufacturer that an interlock be designed to inhibit the starter switch while the clutch was engaged; and that the checklists be modified to reduce the possibility of leaving the clutch engaged on shutdown, and of not detecting this error at the next start.

2.2.8 Since ZK-HDD flew successfully after the second attempted start, there had not been a total failure. However, there were the possibilities either of low cycle fatigue cracking propagating from an initial edge crack, tearing starting from such a crack, or that the flexplate had slightly deformed and subsequently failed in flight when a high demand was placed on it.

2.2.9 The possibilities of low cycle fatigue failure of the flexplate, and tearing from an initiating crack, were eliminated by microscopic examination. This showed that the two parts of the tear happened more or less contemporaneously; had the initial crack been present from the start of the flight, polishing of the broken face would have been evident. However this did not eliminate the possibility of more subtle damage leading to failure when high thrust was required from the tail rotor. Slight buckling would have resulted in the coupling resisting loads in bending rather than in shear. The light gauge steel would have been much less able to resist load in bending than in shear.

2.2.10 The load on the tail rotor was high in out-of-ground-effect hover, and higher still if this hover was at a high all-up mass, since high torque was being applied to the main rotor while there was little favourable weathercock effect (as there would be in forward flight) to help it. A worse case could have arisen if right yaw commenced when little or no left pedal was being applied, as could happen with a tail-to-wind hover. Rapid application of left pedal, in an attempt to prevent rotation could have produced large loads. The tail rotor would have been producing little thrust and would have been at a correspondingly low pitch angle. Application of full left pedal to stop yaw could increase the tail rotor blade pitch by 20° or more. Since the induced airflow velocity through the tail rotor could not change instantaneously, the tail rotor blades would be suddenly forced to operate at large angles of attack and the tail rotor would absorb much more power than usual during the short time required for the induced flow to develop. There was thus the potential to impart loads to the coupling which were much greater than in level flight and so precipitate failure of a damaged part.

2.2.11 The partial failure of the star-flex coupling would not have interrupted the drive to the tail rotor but would have resulted in considerable noise and vibration if it occurred in flight and could well cause the pilot in command to decide on an immediate ditching before worse befell. The wreckage was therefore examined in detail to see whether this hypothesis could be supported.

2.2.12 The sequence of events involved in the mechanical failures had to account for the following features:

* Indications of downward bending of the rear section of the tailboom
* Indications of upward bending of the forward section of the tailboom
* Failure of the tailboom riveted joint at approximately mid length
* Combined bending and torsional failure of the tail rotor driveshaft at the same point, but without complete separation
* Partial failure and folding of the star-flex coupling between the main driveshaft and the tail rotor driveshaft
* Two separate dents in the tailboom mounting frame, one apparently made by components of the tail rotor driveshaft while rotating and one by straight impact without rotation
* Lack of evidence of prolonged rotation of the star-flex coupling after failure
* Lack of damage to the tail rotor
* Damage to one blade of the main rotor

2.2.13 If the star-flex coupling had failed at the time the aircraft was seen to spin round, there should have been some 250 strikes on the surrounding frame; because both components were steel, metal-to-metal transfer should have been evident. Instead, only a few strikes could be counted and there was little indication of metal-to-metal transfer.

2.2.14 Since the tail rotor driveshaft did not separate completely at impact, but would have done so very quickly had the shaft continued to rotate, it was inferred that the shaft stopped rapidly at the moment of failure. The trapped tachometer readings indicated that the main rotor was overspeeding somewhat at the moment of impact with the sea. For the tail rotor driveshaft to cease rotating rapidly on each side of the failure and thus avoid separation, both the tail rotor and the main rotor would need to stop very rapidly. The tail rotor would have to stop first, since resistance from the tail rotor to torque transmitted down the driveshaft was the only means of providing the torsional stress on the shaft which was involved in the failure.

2.2.15 The aircraft struck the sea at a moderate vertical velocity in a level attitude. The tailboom would have required a downward deflection of about 0.7 m for the tail rotor to touch the sea at initial impact. The amount of bending of the driveshaft would have accommodated this deflection.

2.2.16 At impact the inertia of the tail rotor and its gearbox, applied to the end of the tailboom, would have resulted in downward bending of the boom. The design of the tailboom structure was such that the maximum bending stress on the boom occurred very close to the failed joint. If the joint failed at the same time as the tail rotor driveshaft was being deflected, but prior to the tail rotor striking the water, the direction of rotation of the rotor was such as to drive the boom structure forwards and upwards, applying upward bending to the front part of the boom.

2.2.17 In the state in which the star-flex coupling was recovered, it was unlikely that it could have provided the torque to cause the driveshaft failure without itself separating completely. It was thus deduced that the star-flex coupling partial failure occurred at the same time as the partial failure of the tail rotor driveshaft and that both the complete tailboom and the drive mechanism were intact until impact with the sea.

2.2.18 The damage to the tailboom mounting frame was consistent with this thesis. The first dent, showing evidence of rotation as well as impact, could have been made by the damaged coupling during the initial contact with the sea and before the shaft had stopped rotating. It seemed likely that the second dent, with no sign of rotation, was caused by the failed coupling giving one last "kick" as the main rotor stopped abruptly.

2.2.19 The damage to one main rotor blade was consistent with water drag on the tip of that blade, with the inertia of the other blade providing the force which produced the rearward bending. The main rotor was of low inertia and would have stopped rapidly when the tip entered the water, thus removing the driving force to the tail rotor driveshaft.

2.2.20 There was thus an explanation for the damage found in terms of contact with the sea; conversely there was no evidence to support the alternative hypothesis that any part of the structure or the drive mechanism failed in the air.

2.2.21 The absence of hydraulic damage to the engine does not preclude the possibility that the engine was producing significant power at impact. The filters and inlet ducting (which was crushed) could have prevented the rapid ingress of water; the absence of air would then result in a rich cut. Also, the inertia of the collective lever, and of the pilot's hand on it, would result in the collective being lowered during the impact sequence, whereon the correlator would have closed the throttle thus minimising the potential for hydraulic damage. Evidence that the engine was producing at least some power was the high indicated engine rpm, which were greater than would have resulted solely from the action of the correlator when the collective pitch lever was raised to cushion the impact.

2.2.22 There was thus no evidence of mechanical failure prior to impact and the engine was probably producing significant power.

2.3 Uncommanded Yaw

2.3.1 There were a number of factors which would have predisposed the aircraft to commence a rapid, uncommanded yaw to the right. Once begun, it would probably have been necessary to enter autorotation to escape from this condition (even supposing that the pilot diagnosed it correctly rather than assuming failure of the tail rotor drive):

(a) The aircraft was hovering tail-to-wind. While the general south-easterly wind would have been from the right quarter, the local wind influenced by the proximity of Piercy Island may have been almost astern. Such a wind would have made the aircraft directionally unstable, requiring continuous attention to maintain direction and prevent a rapid yaw-rate building up.

(b) The aircraft was hovering out of ground effect, at high all-up mass. This required high power and in turn, this would produce high torque at the main rotor driveshaft.

(c) Any tendency for the aircraft to settle would be countered instinctively by increase of collective pitch. Such settling could occur for several reasons:

(i) Large application of left pedal might be required to maintain direction at times. This would leave less power available for the main rotor and rrpm would tend to droop, with consequent loss of lift.

(ii) The 15 knots (approximately) of tailwind would have put the aircraft on the verge of the translational lift regime. A slight lull in the wind, or any tendency to creep forward over the surface, would have resulted in the loss of translational lift and consequent sink.

(iii) The vertical reference was the rock face some eighty metres away. Hovering by such a remote reference was necessarily less accurate than hovering with reference to an adjacent horizontal surface, as with hover in ground effect. It would be unsurprising if the aircraft climbed and descended while attempting to maintain a constant height.

2.3.2 Small adjustments of collective pitch should have been automatically compensated by corresponding adjustments to the throttle via the correlator linkage, but correlators were not perfect. The consequence of inexact correlation could be that, unless the throttle opening was increased manually when additional collective pitch was applied, the rotor rpm would droop. The droop in rotor rpm would reduce the available tail rotor thrust proportionately, at a time of maximum demand.

2.3.3 While a tendency to settle could of itself produce a predisposition to uncommanded right yaw, it also produced the potential for the main rotor to encounter vortex ring formation. This would occur if the main rotor descended into air which it had already disturbed; recirculating flow could then result in loss of lift to the extent that available power could not arrest the descent unless the aircraft was also flown away from the region of disturbed flow. Vortex ring settling was a high drag configuration and could result in rrpm droop, predisposing the aircraft to uncommanded yaw. Vortex ring formation could be encountered at rates of descent in excess of 300 feet per minute through the air. Where the aircraft was flying in an updraught such an encounter might happen with a lower or zero rate of descent relative to the ground. The aircraft was flying adjacent to a cliff face oriented across the onshore breeze, and it was conceivable that it was hovering in an appreciable updraught.

2.3.4 Compounding the tendency to settle was the high mass of the aircraft. In the ambient conditions, the power required for hovering out of ground effect marginally exceeded the 5 minute takeoff power permitted and was substantially in excess of the continuous rated power. There was, therefore, no margin of "legal" power.

2.3.5 The limitations on power available to hover were not readily apparent from the Pilot's Operating Handbook for the R22. The pilot flying and other pilots interviewed, thought that the only limit was the red line on the manifold pressure gauge and erroneously referred to the yellow caution zone as the "green sector" (or normal operating region). The pilot flying thus believed that she could use up to 25.2 inches of manifold pressure rather than 24.6 inches shown on the limitations placard. Even so, 25.2 inches was no more than the power setting required to hover out of ground effect. While there was a physical reserve of power (a further 5 inches of manifold pressure) the pilot would have felt inhibited by the red line from using it in normal operations. In circumstances where the maximum power which the pilot was prepared to use was being absorbed, any additional demand (e.g. application of left tail rotor pedal) would cause the aircraft to start sinking. Attempting to counter this sink by increasing collective pitch, while limiting manifold pressure to the red line, would result in the rrpm decaying: it is unsurprising therefore, that there was a low rrpm warning.

2.3.6 The literature on uncommanded yaw stressed the need for immediate action to prevent a yaw to the right from becoming out of control. This implied that the pilot must concentrate on directional control. Any factor tending to distract the pilot, such as a low rotor rpm warning or difficulty in maintaining rrpm or a level hover, would militate against the necessary instant response. Where the pilot was inexperienced, the possibility of delayed response leading to loss of directional control became considerable, when factors predisposing to uncommanded yaw were already present. In the light of these predisposing factors and the absence of any mechanical causation, the rapid rotation seen by the witnesses was considered to have been uncommanded yaw.

2.3.7 Since the circumstances - tail-to-wind hover, hovering out of ground effect and high mass - were all likely to produce uncommanded yaw, the question arose as to why the pilot in command elected to place the aircraft in this position. It would have been simple when the aircraft landed at Cape Brett to take the right door off and for the pilots to exchange seats. However, there were a number of factors dictating that the photographs be taken as attempted:

(a) The requirement to take the photographs from a particular angle for best effect would have determined the altitude.

(b) Three factors combined to make it necessary to photograph from the left seat:

(i) The right hand cyclic extension could not be removed and was likely to have been in the way if photography was attempted from the right hand side.

(ii) The pilot flying was not rated to fly the R22 from the left side.

(iii) If the pilot flying had flown from the left side she would not have had the cyclic extension available, as it had previously been removed. She would therefore have had to control the aircraft by reaching across to the cyclic in the centre of the cockpit and she had no experience of flying in that manner.

(c) The requirement was to photograph the "Tigerlily" emerging from the Hole in the Rock, so it was necessary to be in the right place in advance. This might have been difficult to arrange simply by flying past the Hole at low airspeed, as with suitable airspeed (say 30 knots) the wind would have resulted in a considerable groundspeed. Each pass would allow only a limited photographic opportunity and if the first pass was unsuccessful, there might be insufficient time to reposition the helicopter before the vessel was clear of Piercy Island. There was thus a need to make use of the helicopter's ability to hover.

2.3.8 Notwithstanding these considerations, the scheme was potentially hazardous. The pilot in command had been responsible for much of the pilot flying's training for her Commercial Pilot Licence and was thus aware of her limitations. He was also aware of her lack of command experience and it seems likely from the method of operating that he was taking the opportunity to give her command practice. It could be expected that he would avoid placing her in situations where control could be difficult, unless he could monitor her actions closely. He could not do so while preparing to take photographs through the doorway of the aircraft.

2.3.9 The explanation probably lay in the lack of information readily available to pilots about uncommanded yaw and the consequent lack of appreciation of the hazard, even by experienced pilots. There was evidence that the pilot had previously operated tail-to-wind without difficulty and other pilots thought there was nothing out of the ordinary about the operation. There was nothing in the training syllabus either for Private or Commercial Pilot Licences, to warn pilots of the potential hazard and, in the opinion of the Chief Flying Instructor for whom the pilot worked, it was unlikely that the pilot was aware of it.

2.3.10 It was recommended to the Ministry of Transport that uncommanded yaw be included in the training syllabus for both Private Pilot and Commercial Pilot licences, and that copies of the 1985 Flight Safety article be sent to all licensed helicopter pilots.

2.3.11 Having encountered uncommanded yaw, the pilot had the option (if he diagnosed the problem correctly) of applying forward cyclic to enter forward flight and thus remove the tail rotor from the region of disturbed air reducing its effectiveness. However the possibility of stabilising in forward flight pointing at the adjacent rock face probably would have dictated the alternative of entering autorotation. In any event, he had little time to appreciate there was an emergency, take control, assess the situation and attempt recovery - the whole sequence took only a few seconds. Having decided to enter autorotation while within the avoid curve, impact with the sea was inevitable.

2.4 Survivability

2.4.1 It was not possible to calculate the impact velocity and g loads experienced by the pilots. However, a number of factors made a reasonable assessment possible:

(a) The minimal mechanical impact damage to the airframe, with only six inches of fuselage crushing, combined with the absence of a splash at impact, point to a relatively low impact velocity.

(b) While the aircraft was operating in the avoid curve and thus could be expected to receive damage on touchdown from autorotation, in this instance engine power was available to cushion the touchdown and the pilot appears to have used it.

(c) The framing of the seats had partially collapsed. Static tests indicated that the frames buckled at 10g. These tests were not necessarily representative of dynamic loads, which might tend to produce greater mechanical damage than static loads.

(d) At 10g, with 150 mm of crush distance and assuming 150 mm of water displacement, the impact velocity would have been about 10 feet per second, which was consistent with (a) above.

(e) The pilot flying's injuries were consistent with a 10g impact, if proper restraint was lacking.

The impact was probably of the order of 10g, at an impact velocity of the order of 10 feet per second. As there was no lack of survivable space, the impact should have been survivable, without injury, by both pilots.

2.4.2 While a seat which collapsed downward under impact could attenuate the impact loads, two criteria had to be met in order for the pilot to benefit:

(a) The pilot had to be and continue to be properly restrained by his harness during the downward motion.

(b) Energy had to be absorbed (usually by the production of heat from the deformation or crushing of materials) during the downward motion.

The need was for the pilot to be decelerated more slowly than the aircraft structure, by a steady force and thus experience lower peak g loads. This objective could not be met if the seat merely collapsed (in the extreme case, using a cardboard box as a seat would result in a considerable bump on hitting the floor). The seat frames in the R22 comprised unframed light alloy boxes. The load was taken on the edge of the sheet metal in compression. Once the metal started to buckle (at about 10g) the load was resisted only in bending. Such an arrangement had little energy absorbing capacity. Once the walls of the box started to collapse the pilot would be essentially in free fall until such time as he contacted the (already stopped) aircraft skin. He would then stop almost instantaneously, experiencing a high peak g load in the process.

2.4.3 The rebound which the pilots experienced from the resilient seat cushions had the potential to be exacerbated by the springiness of the fibreglass seat pan which in the case of the pilot in command, deflected downward some 150 mm during the impact sequence.

2.4.4 The pilot flying was wearing a combined seatbelt and diagonal shoulder harness and this remained intact during the impact sequence. However, this harness was attached to the aircraft structure and would have become slack as soon as her seat frame started to collapse. It could provide no support in the subsequent secondary impact when the downward movement of her seatpan was arrested by the first aid kit. The resulting spinal flexure would account for the 5 fractured vertebrae which she suffered.

2.4.5 There may have been some forward motion at impact, as suggested by the fractured tachometer glass. While a slack shoulder harness can result in pulmonary oedema as the pilot was thrown forward into the harness (See Report No 85-039), medical advice was that that did not occur in such manner in this accident.

2.4.6 Notwithstanding the deformation of the cockpit and the fracture of the perspex panel above the head of the pilot in command, the pathological examination did not show evidence of a severe blow to the skull. Rather, it was probable that the pilot was stunned by the high peak g load experienced when his seat pan bottomed on the aircraft skin. This would have been made even worse by the cushion of medium density resilient foam mounted on top of the seat pan: such a cushion could have the effect of doubling the g load which would otherwise have been experienced.

2.4.7 The aircraft seats and structure did not meet present day safety requirements but the aircraft had demonstrated its compliance with the regulations pertaining to seating and harnesses at the time of its type acceptance. These specifications, in the light of more recent knowledge, provided little pilot protection in even a mild accident and in so far as they advocated that seats should deform at a relatively low loading, were counterproductive. A simple, rigid seat together with a high-hysteresis cushion, would have protected pilots from injury up to much higher impact levels and such a modification should have been straightforward and inexpensive. Accordingly, it was recommended to the manufacturer that he investigate the design of such seats for the R22.

3. FINDINGS

3.1 Both pilots were properly licenced to conduct the flight.

3.2 The aircraft had a valid Certificate of Airworthiness and was properly maintained.

3.3 The aircraft's mass and balance were within approved limits.

3.4 The aircraft did not suffer any mechanical defect before impact.

3.5 There was no margin of power, within the aircraft limitations, for hovering out of ground effect.

3.6 While the aircraft was positioned to take photographs, it was placed in conditions conducive to uncommanded yaw.

3.7 Uncommanded yaw was not included in the syllabus of training for helicopter pilots.

3.8 The aircraft was being operated in the "Avoid Curve".

3.9 The aircraft experienced uncommanded yaw, which was allowed to develop into continuous rotation.

3.10 During the subsequent autorotation the aircraft struck the surface of the sea at a moderate vertical velocity.

3.11 The pilots' seats collapsed on impact and their harnesses went slack in consequence.

3.12 The pilot in command experienced a high peak g load when his seat pan struck the aircraft floor.

3.13 The pilot in command was stunned by the impact and did not attempt to escape.

3.14 The pilot flying's seat was prevented from striking the aircraft skin by the first aid pack beneath it and this reduced the secondary impact which she experienced.

3.15 The pilot flying was not restrained effectively by her harness at the time of the secondary impact and suffered spinal injuries in consequence.

3.16 The pilot flying had difficulty releasing her harness and escaped when the aircraft had sunk to a considerable depth.

3.17 The aircraft's seats and harnesses complied with the requirements in force at the time of the aircraft's certification.

3.18 The certification standards had changed prior to the accident but the aircraft was not required to comply with the new standards.

3.19 The impact forces ought to have been survivable without injury, had the seats and harnesses been suitably designed.

3.20 The probable cause of this accident was the absence of any prescribed training in uncommanded yaw, from the training syllabus for helicopter pilots. In consequence, the pilots lacked knowledge of the hazardous situation in which they were placing the aircraft. Contributory factors were the lack of a reserve of power while hovering out of ground effect and operation in the Avoid Curve. The pilots' primary injuries were caused by the unsatisfactory design of their seats.

4. SAFETY RECOMMENDATIONS

4.1 It was recommended to the Managing Director, Robinson Helicopters that he:

Issue a Safety Notice warning pilots of the potential damage resulting from an attempt to start R22 helicopters with the clutch engaged and requiring an engineer's inspection if an attempt is made to start with the clutch engaged, and

Design a modification to inhibit the starter switch unless the clutch is disengaged, and

Amend the engine starting sequence to include a check that the clutch light is OFF after selecting the master switch ON, and

Consider having the validity of suggested changes to the seat design evaluated, and

Review the desirability of incorporating such changes to improve the survivability of accidents which may occur to aircraft with the existing seat design.

4.2 It was recommended to the Director, North Shore Helicopters, that he:

Develop and submit to the Airworthiness Branch, Air Transport Division, a modification to inhibit the starter switch unless the clutch is disengaged during ground starting.

4.3 It was recommended to the General Manager, Air Transport Division, Ministry of Transport that he:

Require a mandatory inspection of the flexible star plate coupling immediately behind the clutch on Robinson R22 helicopters, to determine whether damage has already occurred, and

Publish an alert bulletin warning all Robinson R22 operators of the potential damage from an attempt to start with the clutch engaged, and requiring an engineer's inspection if an attempt is made to start with the clutch engaged.

4.4 It was recommended to The Director, Civil Aviation Safety, Ministry of Transport that he:

Incorporate in the helicopter training syllabus for PPL and CPL an item dealing with uncommanded yaw, and

Make available to each qualified helicopter pilot a copy of the article on uncommanded yaw published in Flight Safety in 1985, and

Review the minimum flight times specified for issue of a CPL-H and amend the requirements accordingly.

5. REGULATORY

5.1 Pursuant to Section 14(5) of the Transport Accident Investigation Commission Act 1990 the pilot flying and the legal personal representatives of the pilot in command were invited to avail themselves of the opportunities afforded to them thereunder.

5.2 As a result of representations received the report was amended and amplified to clarify some of the points raised.

5.3 The representations made to the undersigned are not to be taken as an admission of liability on the part of the parties concerned and their statements are without prejudice to their right to act in any way they may consider fit in any proceedings or action which may be based on the events to which this report refers.

6. OBSERVATION

6.1 Difficulty in escaping from a sinking helicopter was by no means uncommon and escape trainers had been designed which gave crews and passengers experience in the conditions they were likely to encounter after ditching. Some overseas operators made such training mandatory for crews and passengers who fly over water in helicopters. Such training was available in New Zealand and had the potential to be of benefit to helicopter occupants who might fly over water.

12 March 1992

M F DUNPHY
Chief Commissioner