CIVIL AVIATION AUTHORITY
OF NEW ZEALAND

AIRCRAFT ACCIDENT REPORT

OCCURRENCE NUMBER 01/44

BELL 204 (UH-1F)

ZK-HVY

WELLINGTON

15 JANUARY 2001

Glossary of abbreviations used in this report:

AD	Airworthiness Directive
CAA	Civil Aviation Authority
CAR	Civil Aviation Rule(s)
CPL(A)	Commercial Pilot Licence (Aeroplane)
CPL(H)	Commercial Pilot Licence (Helicopter)
E	east
ELT	emergency locator transmitter
ft	foot or feet
kg	kilogram(s)
kPa	kilopascals
IIC	Investigator-in Charge
lb	pound(s)
m	metre(s)
M	magnetic
MHz	megahertz
mm	millimetre(s)
MS	Military Standard
NZDT	New Zealand Daylight Time
PMO	Principal Medical Officer
psi	pounds per square inch
TO	Technical Order
US(A)	United States (of America)
USAF	United States Air Force
UTC	Coordinated Universal Time

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OCCURRENCE No 01/44

Aircraft type, serial number and registration:	Bell 204 (UH-1F), 7095, ZK-HVY
Number and type of engines:	1 General Electric T58-GE-8F
Year of manufacture:	1966
Date and time:	15 January 2001, 0940 hours*
Location:	Mount Victoria, Wellington Latitude: S 41° 17.8' Longitude: E 174° 47.7'
Type of flight:	External load operation
Persons on board:	Crew: 1
Injuries:	Crew: 1 fatal
Nature of damage:	Aircraft destroyed
Pilot-in-command's licence	Commercial Pilot Licence (Helicopter)
Pilot-in-command's age	52 years
Pilot-in-command's total flying experience:	9669 hours, 89 on type
Information sources:	Civil Aviation Authority field investigation
Investigator in Charge:	Mr A J Buckingham

* Times are NZDT (UTC + 13 hours)

Synopsis

The Civil Aviation Authority was notified of the accident at 1000 hours on Monday 15 January 2001. The Transport Accident Investigation Commission was in turn notified shortly thereafter, but declined to investigate. Mr A J Buckingham was appointed Investigator-in Charge, and commenced an on-site investigation a short time later.

The helicopter was lifting loads of soil from a building site on Mount Victoria to trucks on a parking area near the summit. As the fifth load was being landed, the helicopter was seen to be flying erratically. The pilot placed the load on the ground and released the longline sling. The helicopter then yawed and rolled to the left, impacting on its left side. The pilot died in the impact.

1. Factual information

1.1 History of the flight

1.1.1 On Monday 15 January 2001, ZK-HVY was being utilised to transport soil excavated from a construction site on the northern face of Mount Victoria to waiting trucks near the summit. The soil was loaded into skips at the site and picked up by the helicopter, which had a 60-foot longline suspended from its cargo hook. The longline incorporated a second cargo hook at its lower end, to which the skips attached; this hook was pilot-operated independently of the main hook on the helicopter.

1.1.2 The pilot was the sole occupant of the helicopter, and was assisted by three ground crewmen, one at the pickup point and two by the trucks. The procedure was that the crewman at the site would attach the full bin to the longline hook, the helicopter would take off towards the north and make a climbing left circuit to approach the drop-off point into the light northerly wind.

1.1.3 On arrival at the drop-off point, the pilot would steady the skip by placing it on the ground close to the truck being loaded, then lift the skip on to the back of the truck. One crewman would then unclip the lifting handle on the skip, and the helicopter would gently raise the skip to tip its contents into the truck. The empty skip would then be conveyed back to the construction site, where by this time another would be ready for pickup.

1.1.4 Just prior to the landing of the fifth load, the helicopter was seen to be flying erratically. The pilot placed the skip by the side of the road, released it from the longline hook, then jettisoned the longline itself. The crewman who had been standing on one of the trucks observed that the helicopter appeared to have developed a vertical oscillation.

1.1.5 Immediately after the longline was dropped, the helicopter commenced a rapid left yaw, appearing to pivot about the tail rotor. As it yawed, it also rolled progressively to the left, and struck the ground above the roadway after having yawed through about 240º and rolled about 120º. The two crewmen and several bystanders rushed to the helicopter to assist the pilot.

1.1.6 The pilot had been sitting in the left seat with the door removed and with only his lap strap fastened, and it was apparent on arrival of assistance that he had been injured. The left windshield was kicked out to enable the pilot's extraction, and he was moved a safe distance from the helicopter. One of the bystanders was a doctor, and rendered assistance until the arrival of emergency services a short time later.

1.1.7 During the retrieval of the pilot, one of the crewmen shut off the engine which had continued running after impact, and extinguished a small fire in the engine tailpipe. On arrival of the emergency services, it was confirmed that the pilot had died as a result of his injuries.

1.1.8 The accident occurred in daylight, at 0951 hours NZDT, on the summit of Mount Victoria, at an elevation of 640 feet. Grid reference 260-R27-803885, latitude S 41° 17.8', longitude E 174° 47.7'.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Other*
Fatal	1	0	0
Serious	0	0	0
Minor/None	0	0	

1.3 Damage to aircraft

1.3.1 The aircraft was destroyed.

1.4 Other damage

1.4.1 Nil.

1.5 Personnel information

1.5.1 The male pilot, aged 52, held a New Zealand Commercial Pilot Licence (Helicopter) endorsed with a Flight Radiotelephone Operator Rating, Agricultural Rating, Chemical Rating and category E Instructor Rating. His flying experience totalled 9669 hours, of which approximately 1315 hours was on aeroplanes, and the balance of 8354 on helicopters.

1.5.2 He held a class 1 medical certificate, valid to 27 February 2001, endorsed with three restrictions:

004 Half spectacles must be readily available;

054 FLEXIBILITY: Hearing or ENT standard[1];

121 Restricted to aircraft with specified controls or specified modifications according to Assessor's letter dated 8 Feb 93.

1.5.3 The pilot had first obtained a CPL in 1971, and subsequently trained as an agricultural (aeroplane) pilot. In October 1975 he was involved in a bulldozer accident. As a result of complications arising from injuries sustained in that accident, his left leg was amputated above the knee. A prosthetic limb was fitted in due course.

1.5.4 In March 1976, the pilot applied to renew his CPL, but his ability to control an aeroplane was assessed by flight test as unsatisfactory, and a Student Pilot Licence was issued to enable him to obtain further practice. He commenced helicopter training around this time, and in October 1976 was medically assessed as fit to CPL standard. His CPL was reissued after he passed his helicopter flight test, and was endorsed "Valid only for approved types of aircraft".

1.5.5 Initially, this restricted him to Hughes 269 helicopters only, but other type ratings were added in subsequent years. For several renewals, his medical assessments were endorsed with the Hughes 269 restriction, which was at variance with the other types endorsed on the licence. However, this was resolved in 1988, by the then Controller of Personnel Licensing, and as the original CPL had become a CPL(H) under the provisions of CASO 12, no endorsement was required on the licence.

1.5.6 With the advent of CA Rules parts 61 and 67, the endorsement 121 (see 1.5.2) was added to the medical certificates issued in February 1993 and subsequently, and the terms of this endorsement were explained to the pilot in a letter from the Senior Medical Officer (see 1.5.2).

1.5.7 The main obstacle precluding the pilot's returning to aeroplane flying was the lack of force and leverage available through his artificial leg to apply toe-operated brakes found on many aeroplane types.

1.5.8 Helicopter flying, however, posed no difficulty for the pilot in respect of his leg. Two types (AS 350D and Bell UH-1F) on which he was rated had hydraulically boosted yaw pedals and required only light forces to operate the pedals. With hydraulic boost off, greater forces were required, and the instructor who had done the pilot's UH-1F type training, as well as some currency training on the AS 350, advised that the pilot did not appear to have any difficulty with "hydraulics off" flight.

1.6 Aircraft information

1.6.1 Bell 204, manufacturer's serial number 7095, was constructed in 1966 as a UH-1F variant for the US Air Force, and allocated military serial number 65-7954.

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[1] Indicates that although the candidate did not meet the pure-tone audiometric requirement, fitness to Class 1 standard was assessed by alternative means.

1.6.2 In 1981, the helicopter was acquired by the California Department of Forestry (CDF), who operated it under a restricted type certificate (number H2NM) issued by the FAA. At the time of transfer, the helicopter had accrued 3430.4 hours in service.

1.6.3 After disposal by CDF in 1995, at 5806.4 hours total time in service, the helicopter was imported into New Zealand in September 1995, and registered as ZK-HVY. It was issued with a Type Acceptance Certificate and a restricted category Airworthiness Certificate, the latter endorsed with the condition that the helicopter be used only on private and aerial work operations.

1.6.4 Originally powered by a General Electric T58-GE-3 turboshaft engine, HVY was fitted with a T58-GE-8F engine, serial number 270964, on 23 July 2000. The –8F engine was substituted for the original by a CAA-approved modification, and a corresponding flight manual supplement was also issued by CAA. The supplement required no change to the operating procedures and limitations already specified by the flight manual.

1.6.5 The most recent scheduled maintenance carried out was a 50-hour check on 12 January 2001, at which time HVY had a total of 6571.6 hours in service, and the engine had run 3131.5 hours since overhaul.

1.6.6 The CDF Type Certificate H2NM was relinquished by CDF, and cancelled by the FAA on 21 May 1996. This cancellation was not discovered by the operator or by CAA until mid-2000. After some negotiation with the operator, the CAA permitted continued operation of HVY under the terms of the original CDF Type Certificate for a 12-month period, provided that the operator applied to another holder of a UH-1F Type Certificate to include HVY on that certificate. At the same time, a replacement Airworthiness Certificate, terminating on 1 August 2001, was issued.

1.6.7 Since its arrival in New Zealand, the helicopter had been maintained in accordance with the CDF UH-1F maintenance schedule (effectively a continuation of the USAF maintenance schedule), which incorporated requirements for checks at specified intervals, both calendar time and hours in service. Applicable ADs were certified in the aircraft logbooks as having been complied with.

1.6.8 The UH-1F flight manual[2] specified (Section V, Limitations) a minimum crew of one pilot, but did not specify which seat he was to occupy. Flight manuals for other UH-1 series helicopters also specify a minimum crew of one pilot, but state also that the pilot must occupy the right seat.

1.7 Meteorological information

1.7.1 Throughout the period of operation, there was a northerly wind of 8 to 11 knots. The weather was fine and clear with unrestricted visibility.

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[2] USAF TO 1H-1(U)F-1

1.7.2 Weather was not a factor in the accident.

1.8 Aids to navigation

1.8.1 Not applicable.

1.9 Communications

1.9.1 The helicopter was equipped with two aeronautical VHF transceivers, one of which was set to the Wellington Tower frequency and the other to a company operations frequency.

1.9.2 No relevant communications prior to the accident were heard by any other station, although when the aerodrome control portion of the Wellington Tower master tape was replayed, a short burst (one to two seconds) of unmodulated "white noise" was found at or close to the time of the accident.

1.10 Aerodrome information

1.10.1 Not applicable.

1.11 Flight recorders

1.11.1 Not applicable.

1.12 Wreckage and impact information

1.12.1 Above the south side of the roadway where the drop-off point was located, was a 5-metre bank, and above this, the ground sloped upward at about 25º to a circular concrete-walled lookout structure on the summit. The distance between the lip of the bank and the lookout was about 18 m.

1.12.2 The helicopter struck the slope in a left roll attitude of about 120º, first contact being made by the main rotor. The outer half of one blade was flung some 75 m to the south-west of the impact point. The fuselage came to rest with the nose 3 m from the lookout, in which two people were sitting at the time.

1.12.3 The heading at rest was 150º M, but the rotor strike marks on the ground indicated that the helicopter had yawed to a heading of about 100º M, before being yawed back to the final heading by the torque reaction from the blade strikes.

1.12.4 Damage noted at the site was consistent with the observed ground impact: crush damage to the upper left side of the fuselage; forward movement of the transmission and surrounding structure as a result of the rotor strikes; a fracture of the tail boom in the region of the synchronised elevator; and tail rotor damage consistent with striking the ground while being driven. The main rotor did not strike the tail boom during the impact sequence.

1.12.5 The main rotor had separated as a result of ground impact, but lay adjacent to and partly under the fuselage. The cabin area suffered little deformation, although the transmission had partially penetrated the aft cabin wall. In the cockpit area, no abnormal indications were noted: the cargo hook switch was in the "armed" position, and instruments and caution lights functioned normally when electrical power was turned on. The collective lever at the left pilot seat was found to be broken below floor level.

1.12.6 A quantity of oil had been ejected through a breather pipe while the engine remained running in the semi-inverted attitude, and a small quantity was present in the engine tailpipe together with evidence of the extinguishing agent from the onboard portable fire extinguisher.

1.12.7 On the roadway immediately beneath where the helicopter had been hovering to unload the skips, was a liberal sprinkling of what appeared to be hydraulic fluid, up to 20 m either side of the drop-off point. The road surface was not conducive to collecting samples, but the oil drops had the pinkish colour and characteristic smell of hydraulic fluid. The aircraft hydraulic reservoir was empty when checked on site, and there was a greater than usual accumulation of hydraulic fluid in the "hell-hole[3]", in the area of the cargo hook.

1.12.8 After on-site examination, the helicopter was removed by crane and transported to the operator's premises for further investigation.

1.13 Medical and pathological information

1.13.1 Post mortem examination determined that the pilot had died from injuries received in the impact. There was no evidence of any pre-existing condition that could have caused in-flight incapacitation.

1.13.2 Routine toxicological tests disclosed no evidence of alcohol, or medicinal or recreational drugs.

1.14 Fire

1.14.1 During the extraction of the pilot, a bystander advised one of the ground crewmen that there was a fire. The crewman, using the hand-held (dry powder) extinguisher from the cockpit, put out the small fire in the engine tailpipe, returned to the cockpit area and shut down the still-running engine. The fire restarted after shutdown, but was again extinguished by the crewman.

1.15 Survival aspects

1.15.1 The pilot was seated in the left front seat, although the right seat is the normal position for the command pilot and for solo flight. He was wearing a protective helmet and was restrained only by a lap belt, even though an inertia-reel shoulder harness was available. The left front door was removed to afford the pilot a better view of the sling loads.

1.15.2 Consequently, there was no protection for the pilot, as he was sitting in the open doorway that bore the brunt of the sideways impact with the ground. His injuries comprised a skull fracture that was considered by the pathologist to be non-life-

[3] The space beneath the transmission

threatening, and a ruptured pulmonary artery, which was the cause of death. The latter was consistent with a lack of upper body restraint.

1.15.3 The cabin-mounted ELT operated on impact and continued to transmit until switched off about an hour after the accident. The 121.5 MHz signal was received by several aircraft operating into and out of Wellington.

1.16 Tests and research

1.16.1 Further examination of the wreckage established that the main rotor and tail rotor control runs were intact prior to impact, and confirmed pre-impact drive train integrity. The left collective lever (see 1.12.4) itself was found not to have fractured but the jackshaft common to both levers exhibited an overload (impact) failure at the point where the left lever attached.

1.16.2 The two rear main-transmission mounts, as well as the "fifth" mount to the centre rear of the transmission, had been pulled apart as the transmission tilted forward at impact. During this sequence, the two cyclic control rods had been trapped between the transmission and the cabin structure, and the collective control rod (to the rear of the transmission) had failed in tension above its hydraulic power cylinder.

1.16.3 The transmission sump, to which the hydraulic pump and rotor brake assemblies were mounted, had broken cleanly away from the transmission housing. After removal of the transmission, the sump, with the hydraulic pump still attached, was left in place to facilitate checking of the hydraulic system.

1.16.4 The main hydraulic pressure and return lines had fractured at the point where they passed through the transmission compartment structure; this structure had been damaged by the movement of the transmission. These lines, and a similarly damaged pump return line, were replaced and the reservoir refilled. A hydraulic test rig was connected to the system, with the object of testing the power cylinders for normal operation.

1.16.5 As soon as test rig pressure was introduced into the system, it became evident that there was a major leak at one end of the pressure line that supplies the collective and tail rotor cylinders. The line was removed and replaced by a temporary line, and the test was continued. All power cylinders operated normally throughout their range, and no further leaks were detected.

1.16.6 The hydraulic pressure warning light bulbs were examined for hot stretch of the filaments, but none was found. This could indicate either that the bulbs were not lit at the time of impact; or, if they were, the impact lacked the severity to cause hot stretch. The hydraulic pump itself was later run on a test rig at an overhaul facility, and was found to operate normally.

1.16.7 The failed line, part number 204-076-191-87, was a 5/16 inch aluminium alloy pipe with MS (Military Standard) flareless fittings at each end. (For a description of MS flareless fittings, see section 1.18: Additional Information). The line was 690 mm in length, and ran between a four-way union at the front of the transmission compartment to a tee connection supplying the collective and tail rotor pitch change cylinders.

1.16.8 In general appearance, the pipe had had a long service life, and at the end where the leak occurred, had tarry deposits of dried hydraulic oil over about 170 mm of its length. The pipe was not readily visible or accessible with the main transmission in place. A general view is shown in Figure A5.

1.16.9 The pipe was sent for metallurgical examination, which found a fatigue crack at the end where the leak occurred. The crack ran circumferentially about halfway round the pipe, in the area of the MS21922 sleeve, adjacent to the slight deformation caused by the cutting edge of the sleeve. The pipe also exhibited bending in the area of the sleeve, and the result of this would have been to transfer bending loads to the end of the pipe where the cutting edge of the sleeve made contact. The fatigue crack had multiple origins and had propagated from the outside of the tube to the inside; it had developed over hundreds rather than thousands of cycles. This could indicate that the crack started developing relatively recently; alternatively, the movement of the tube leading to the cracking may have been present only occasionally, such as at a particular combination of aircraft load and speed, in which case it could have developed over a long period.

1.16.10 The associated MS21921 nut showed considerably more spanner marks on its surface than did the nut at the other end of the pipe. Additionally, file marks were present on the end of the nut, which had been shortened by 2.7 mm. The tube end also showed evidence of overtightening, being compressed and deformed between the tube end and where it emerged from the sleeve. Wear marks on the tube also indicated that the sleeve had been displaced about 1 mm towards the tube end from its original position at installation.

1.16.11 The evidence suggested that the nut had been repeatedly tightened in an attempt to eliminate a “weep” (indicated by the tarry deposits on the pipe) and eventually the nut had run out of travel, bottoming on the reducer. The whole tube assembly had then been removed and the nut filed to permit more travel. The maximum permissible tightening of these nuts on installation is one-third of a turn (two flats); further detail is given in 1.18.14.

1.16.12 With the collective push-pull tube disconnected, the preset collective friction was measured in accordance with the instructions in the maintenance manual. With the pilot-adjustable friction nut backed off, the measured force was 2.54 kg (5.4 lb). With the friction nut set at the position found after the accident, the measured force was 5.2 kg (7.4 lb). Even without the weight of the second collective, these figures are well below the recommended range (see 1.18.7).

1.16.13 However, this discovery was at odds with the operator’s known policy on collective friction. The operator had once experienced collective bounce in another UH-1F, and he was determined that it would not happen again. He had discussed the experience with the IIC on at least one occasion prior to the accident involving HVY.

1.16.14 During the course of the investigations, all pilots and engineers who had worked on the helicopter were contacted and asked if they had any recollection of any hydraulic system abnormalities or problems during their association with the machine. All responses were negative. A search of the aircraft maintenance records and technical logs found no reference to leaking hydraulic lines or excessive fluid consumption.

1.16.15 Some experimentation was carried out with respect to the possibility of the pilot's left foot dropping off the left yaw pedal. The line of enquiry was discontinued, however, as there was no physical evidence to support the possibility.

1.17 Organisational and management information

1.17.1 The investigation disclosed no organisational and management factors that were relevant to the accident.

1.18 Additional information

1.18.1 Hydraulic system: the single hydraulic system is provided to reduce the operational loads of the cyclic, collective and directional control systems. The system comprises: a variable delivery hydraulic pump, a 4 US pint (1.89 litre) reservoir, servo cylinders, irreversible valves, relief valve, check valve, filter, solenoid valve, and connecting hardware. See Figure A1.

1.18.2 The variable-delivery pump is mounted on the transmission lower case and furnishes hydraulic pressure to the servo cylinders, which are connected to the mechanical linkage of the flight control system. The irreversible valves are installed on the servo cylinders to prevent main rotor feedback from being transmitted to the pilot controls in the event of hydraulic system malfunction.

1.18.3 System pressure varies between 950 psi (6550 kPa) at full flow and 1000 psi (6895 kPa) at zero flow. The system relief valve is set to open in the range 1100-1200 psi (7585-8274 kPa). The pressure switch controls the HYD PRESSURE warning light; when system pressure exceeds 900 psi, the light should be off, and when the hydraulic system is turned OFF or system pressure falls below 400 psi, the warning light should illuminate.

1.18.4 The solenoid valve switch (labelled HYD CONTROL) is located on the pilots control pedestal. With the switch selected ON, the solenoid is de-energised and is in its normal position. Selecting OFF energises the solenoid, blocking pressure and flow to the servo cylinders and pressure switch, and simultaneously opening the pressure line to the return line leading to the reservoir.

1.18.5 The 100-hourly inspection schedule for ZK-HVY contained under the section "Hydraulic System", one item relating to the hydraulic lines: "Lines and hoses for leakage and chafing". No specific inspection or rejection criteria for rigid lines, other than permissible leakage rates, were listed in the Maintenance Manual, but standard engineering practices would apply. Examples of defects to look for are: scratches and nicks; improperly radiused bends; dents; bending adjacent to fittings; loose or missing supports; unsupported lengths; missing identification tags.

1.18.6 Hydraulic system failure is described in the flight manual (Section III, Emergency Procedures) as follows:

Hydraulic power failure will be evidenced by an increase in the force required for control movements. When controls are moved, an apparent feedback will be felt, which is actually an intermittent hindrance to movement at main rotor 2/rev frequency[4]*. Control movements will result in normal flight reactions in all respects except that a noticeably increased force will be required for the control movement. No intermittent forces will be felt in the collective or anti-torque systems.*

The collective, with properly adjusted tension-torsion straps, will become increasingly difficult to move as each extreme of displacement is approached. Abrupt control movements or manoeuvres should be avoided. Large lateral cyclic stick movements can result in a roll oscillation that increases in magnitude if the pilot attempts to stop it by using large control movements. This oscillation will stop if the cyclic stick is held in one position long enough to establish a steady attitude. Cyclic correction should be made slowly with light pressure application to the cyclic stick.

Without hydraulic boost the helicopter becomes more difficult to control at low airspeeds so operation at low airspeed near the ground should be kept to a minimum. If a hydraulic failure occurs at a low airspeed and flight is to be continued, accelerate to 50 knots before attempting any manoeuvres. At any airspeed avoid bank angles of 30 degrees or more. Airspeed should be adjusted as desired to obtain the most comfortable control movement level.

When landing without hydraulic control it is recommended that a shallow approach to a slide landing be accomplished. However, the terrain may require a hover landing. Control movements become increasingly difficult as zero airspeed is approached. As crosswind and tailwind increase it becomes progressively more difficult to maintain a stable hover. Whenever possible any hovering and the landing should be accomplished into wind.

1.18.7 Collective pitch control: The collective pitch lever at the right seat position incorporates a pilot-adjustable friction nut. Application of a suitable amount of friction will prevent the lever riding up or down of its own accord, and enables the pilot to remove his left hand from the collective to perform functions such as switch selection and radio tuning. The right hand remains on the cyclic control virtually at all times.

1.18.8 In addition to the pilot-adjustable friction nut, the collective lever also incorporates preset friction, which is ground-adjustable. This is measured by spring balance, at the mid-point of the twist-grip throttle on the collective. If measured with the hydraulic system powered (by test rig), the required range is 8-10 pounds (3.63- 4.54 kg). Without hydraulic power, the (underfloor) push-pull control tube is disconnected from the collective jackshaft, and the measurement

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[4]i.e. the frequency is two cycles per revolution of the main rotor.

taken in the same manner. In this case, the required force is 14-16 pounds (6.35-7.26 kg). The difference in the two values is due to the weight of the two collective levers; this is negated when the hydraulic system is powered.

1.18.9 Collective bounce: The helicopter flight manual (Section VI, Flight Characteristics) refers to collective bounce thus:

The collective control system requires a minimum absolute friction of eight pounds to prevent vertical oscillation. When the absolute friction is less than eight pounds, oscillation can be initiated by sudden pilot input. NOTE: The term "absolute friction" refers to the break-away force required to move the collective stick in an upward direction. The eight-pound value is a true force measured with the hydraulic boost system operative which negates the weight of the collective stick. Vertical oscillation (collective bounce) will manifest itself in any flight regime, including ground operation, by rapid build-up of vertical bounce at approximately three cycles per second. The severity of the oscillation is such that effective control of the helicopter can be lost.

1.18.10 Section III, Emergencies, of the flight manual contains the following under the heading "Recovery from Collective Bounce":

During flight or ground operation, if vertical oscillation is experienced, one or more of the following procedures will aid recovery.

a. Bend elbow (i.e. do not stiff arm collective stick).

b. Increase pilot's adjustable friction.

c. Make a positive change of collective position, either up or down.

d. Turn the hydraulic system OFF. After recovery all control systems may be returned to normal operation.

1.18.11 MS (Military Standard) fittings[5]. This type of fitting eliminates the need for tube flaring, yet provides a safe, strong, dependable tube connection. The fitting consists of three parts: a body, a sleeve and a nut. The body has a counterbored shoulder, against which the end of the tube rests. The sleeve incorporates a cutting edge, and the angle of the counterbore causes the cutting edge to cut into the outside of the tube when the two are joined.

1.18.12 A presetting operation is necessary prior to the fitting of a new flareless tube assembly. The steps are shown in Figure A2. After the tube is cut, and the end squared and deburred, the nut and sleeve are slipped over the end of the tube. The threads of the fitting and nut are lubricated with hydraulic fluid, and the fitting is secured in a vice. The tube is held firmly and squarely on the seat in the fitting, and must bottom firmly.

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[5] Description source: FAA Airframe and Powerplant Mechanics General Handbook, AC 65-9 (1970)

1.18.13 The nut is tightened until the cutting edge of the sleeve grips the tube. This point is determined by slowly turning the tube back and forth while tightening the nut. When the tube no longer turns, the nut is ready for final tightening. For aluminium alloy tubing (as used on HVY), the nut is tightened one to one and one sixth turns (one turn plus one flat).

1.18.14 After the presetting operation, the tube is checked for the following points:

a. The tube should extend 3/32 to 1/8 inch beyond the sleeve pilot;

b. The sleeve pilot should contact the tube or have a maximum clearance of 0.005 inch;

c. A slight collapse of the tube at the sleeve cut is permissible. No movement of the sleeve pilot, except rotation, is permissible.

A properly formed sample fitting is illustrated at Figures A3 and A4.

1.18.15 Final installation of the preset tube assembly is done by tightening the nut to the point of sharp torque rise, then tightening a further 1/6 to 1/3 turn (one to two flats). Tightening beyond this point is not permissible.

1.18.16 The permitted leakage rate from correctly installed flareless fittings is zero.

1.19 Useful or effective investigation techniques

1.19.1 Nil.

2. Analysis

2.1 The investigation established pre-accident engine and drive-train integrity and physical continuity of the main and tail rotor control runs. There was no evidence of any pre-accident incapacity of the pilot.

2.2 The presence of what appeared to be hydraulic fluid on the road, together with the description of the helicopter movements before impact, suggested a loss of hydraulic boost, and the investigation proceeded in this direction after elimination of the various other possibilities.

2.3 A major leak was found in the pressure side of the hydraulic system; although not physically large, it would have been sufficient to cause a rapid loss of the system contents at the working pressure of 1000 psi. The leak was due to a fatigue crack in a particular tube; the crack had been propagating for some time, and the ultimate failure occurred as the helicopter was brought to the hover to drop off the fifth load.

2.4 The fatigue crack was probably due to a combination of factors: reversed bending stresses (exacerbated by vibration) on the tube in the area of the fitting, previous wear and tear and the fact that the fitting had been repeatedly tightened in apparent attempts to stop a slow leak. When and by whom the attempted rectification was carried out could not be established. No pilots or engineers who had been associated with the helicopter during its time in New Zealand were aware of any instance where a hydraulic leak had been present, nor was there mention in any New Zealand maintenance record of a hydraulic leak.

2.5 In any case, it is reasonable to expect that an aircraft maintenance engineer would be familiar with the characteristics and limitations of the MS flareless fittings and would not attempt to overtighten a fitting to stem a leak. The overtightening and filing are more likely to have been performed by somebody with mechanical skills, but with no training in aircraft maintenance. The simple remedy is to replace a leaking line; the components are readily available and are not expensive. The overtightening could have been done at any time in the past, and once the leak had been remedied, could have gone undetected until the failure occurred.

2.6 In forward flight, a loss of hydraulic pressure on this type of helicopter is normally a manageable event; forward flight can be continued and a run-on landing made on a suitable landing area. In the hover, maintaining control is much more difficult, requiring more control force, and if control inputs are too large, it is easy for the pilot to get out of phase with the control responses. The observed behaviour of the helicopter after the pilot jettisoned the load was consistent with this. The recommended recovery action for loss of hydraulic boost in the hover is for the pilot to attempt to establish forward flight, and proceed to a suitable landing site. Attempting a landing from the hover is a last resort.

2.7 The pilot had an artificial left leg, with which he could exert normal control forces when the hydraulic system was operational, and with which he had demonstrated the ability to cope with a loss of hydraulic system pressure. There was no evidence to suggest that the strength or mobility of his left leg was a factor in the accident.

2.8 It was not possible to say with certainty if true collective bounce occurred just prior to the loss of control; the observed vertical oscillation could have been due to the pilot manipulating the collective, or intermittent pulsing of hydraulic power when the system ingested air as the fluid was lost. One of the corrective actions for collective bounce is to turn off the hydraulic system; the loss of pressure would probably have had a similar effect.

2.9 The investigation discovered that the preset collective friction was below the recommended range, and although this could have predisposed the helicopter to collective bounce, there is also the possibility that the friction setting had been affected by the impact sustained by the collective jackshaft when the accident occurred. The low reading was also at odds with the operator’s known desire to have the collective friction correctly set.

2.10 Although sitting in the left seat afforded the pilot a better view of the loads and the operating areas than he would have obtained from the right, this introduced some handling disadvantages. Sitting in the right seat, the pilot can let go of the collective with his left hand (and then generally only in forward flight, when large changes in collective pitch are not required) and manipulate switches or controls on the centre pedestal or overhead console. In the left seat, he must transfer the left hand to the cyclic and use his right hand for the ancillaries. Thus there is an inherent delay if a switch or control needs urgent attention.

2.11 The lack of damage in the area of the right seat suggests that the pilot's chances of survival would have been enhanced had he occupied that seat, particularly if his shoulder harness was fastened. However, had the helicopter impacted on the right side, the result may well have been the same, so it is not possible to comment with any certainty on the survivability aspects of the accident.

2.12 In summary, the pilot experienced a hydraulic system failure in the worst possible situation: in the hover with an underslung load. He successfully jettisoned the load in a manner that minimised danger to the ground personnel, but lost control almost immediately afterwards, in a situation that most pilots would have been hard-pressed to deal with successfully.

2.13 No specific safety recommendations were made as a result of this investigation.

3. Conclusions

3.1 The pilot was licensed, rated and experienced for the task being undertaken.

3.2 The helicopter had been operating normally up to the time of the accident.

3.3 A hydraulic system failure occurred as the fifth load was being landed.

3.4 As a result of the hydraulic failure, the pilot lost control of the helicopter.

3.5 The failure was due to a major leak, at a fatigue crack, in a pressure line.

3.6 The fatigue crack probably initiated from excessive local stresses due to repeated attempts to tighten the fitting, and progressed through in-service reversed bending.

3.7 There was no record of any hydraulic leak in the maintenance records for the period the helicopter had operated in New Zealand.

3.8 No pilot or engineer associated with the helicopter since its arrival in New Zealand could recall any leaks or abnormalities in the hydraulic system.

3.9 Whether or not collective bounce occurred during the accident sequence could not be determined.

3.10 There was no evidence that the pilot's artificial leg was a factor in the accident.

3.11 The situation in which the pilot found himself was an extremely difficult one, with only minimal chances of a successful recovery.

4. Safety actions

4.1 After the hydraulic leak and the low level of collective friction were found, other operators of UH-1 series helicopters with single hydraulic systems were advised by telephone of the discovery. Copies of this report will be sent to the same operators; technical detail has been included in the report for educational purposes.

4.2 A *Vector* article is to be produced, describing flareless fittings, as their use is not confined to helicopters.

4.3 CAA is currently conducting a review of the operation of ex-military helicopters in New Zealand. The scope of review includes all ex-military helicopters in the restricted or special experimental airworthiness category. The review is still in progress at the time of writing of this report.

Richard White
Manager Safety Investigation
8 January 2002

APPENDIX

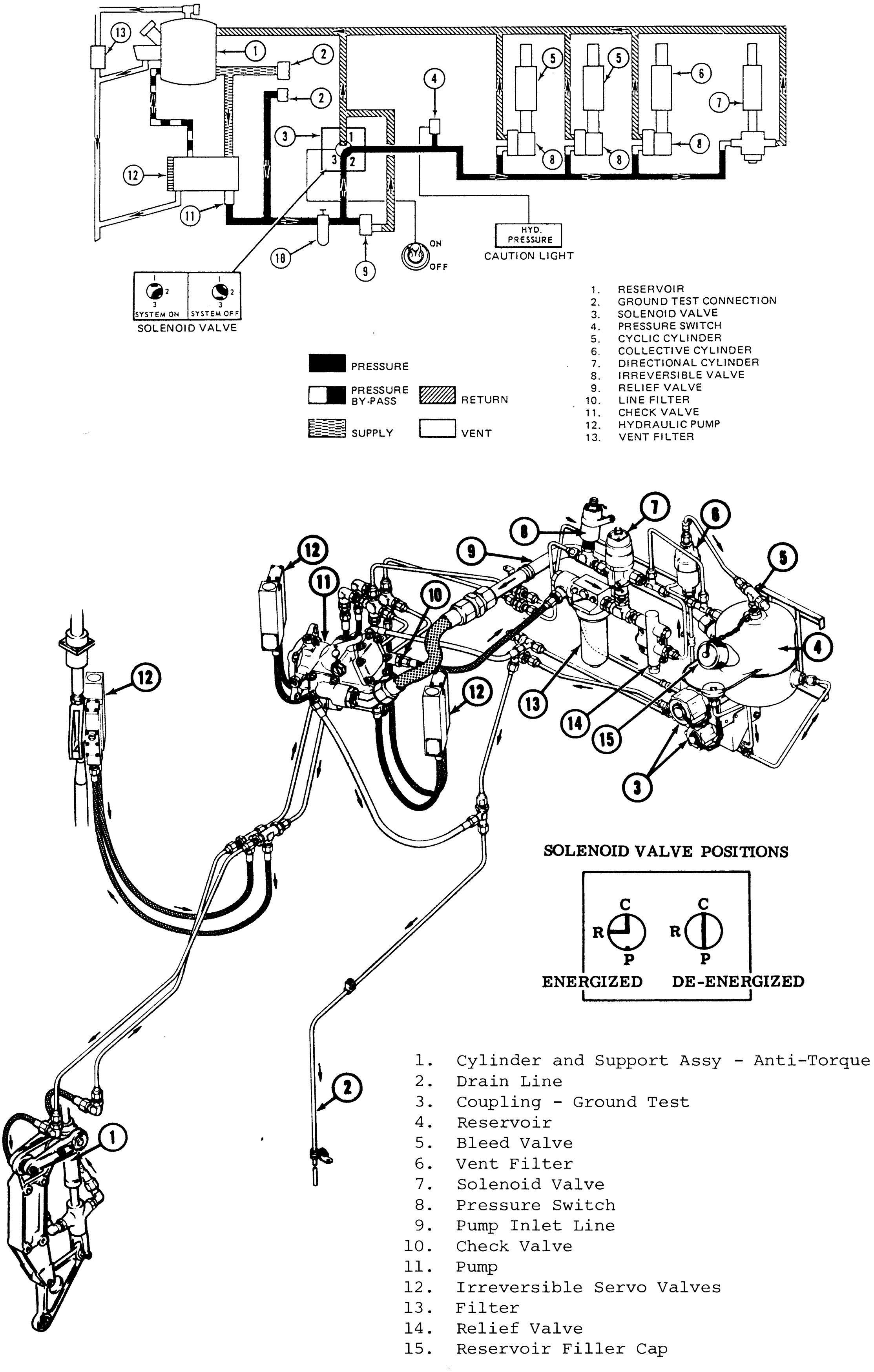

Figure A1: Hydraulic system, schematic and component layout

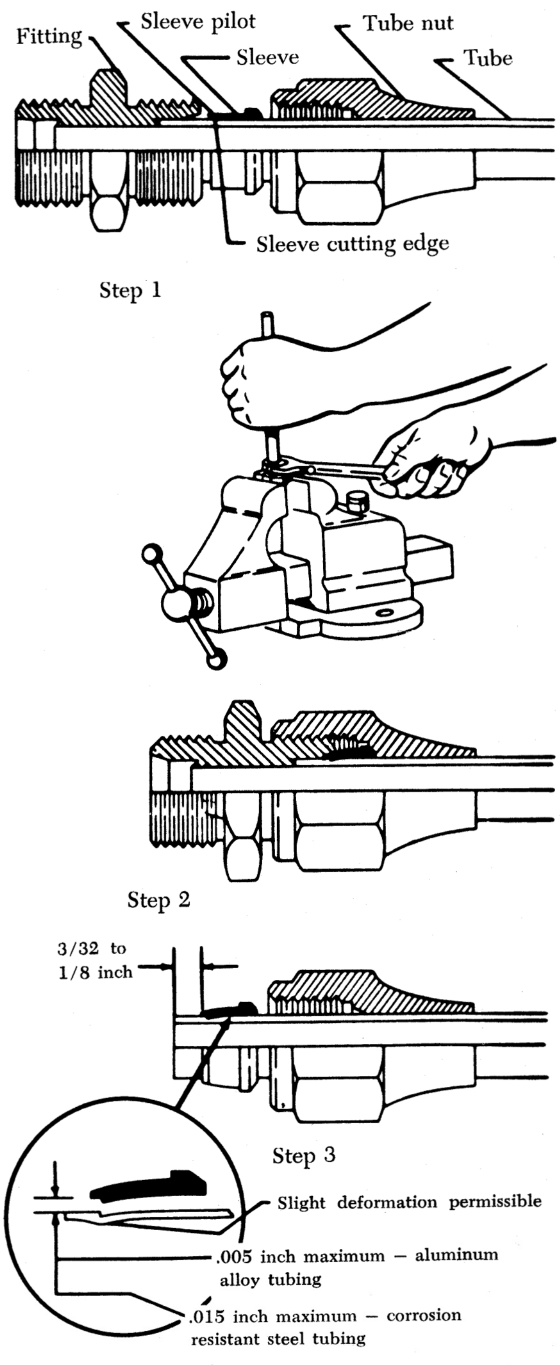

Figure A2
Presetting MS flareless fitting

Sleeve and nut configurations differ slightly from those illustrated in Figures A3 and A4.

Figure A3
MS flareless fitting components
(Tube, MS21921 nut, MS21922 sleeve, MS21916D reducer)

Figure A4
Properly formed tube end (new)
(Permissible deformation is visible inside tube end)

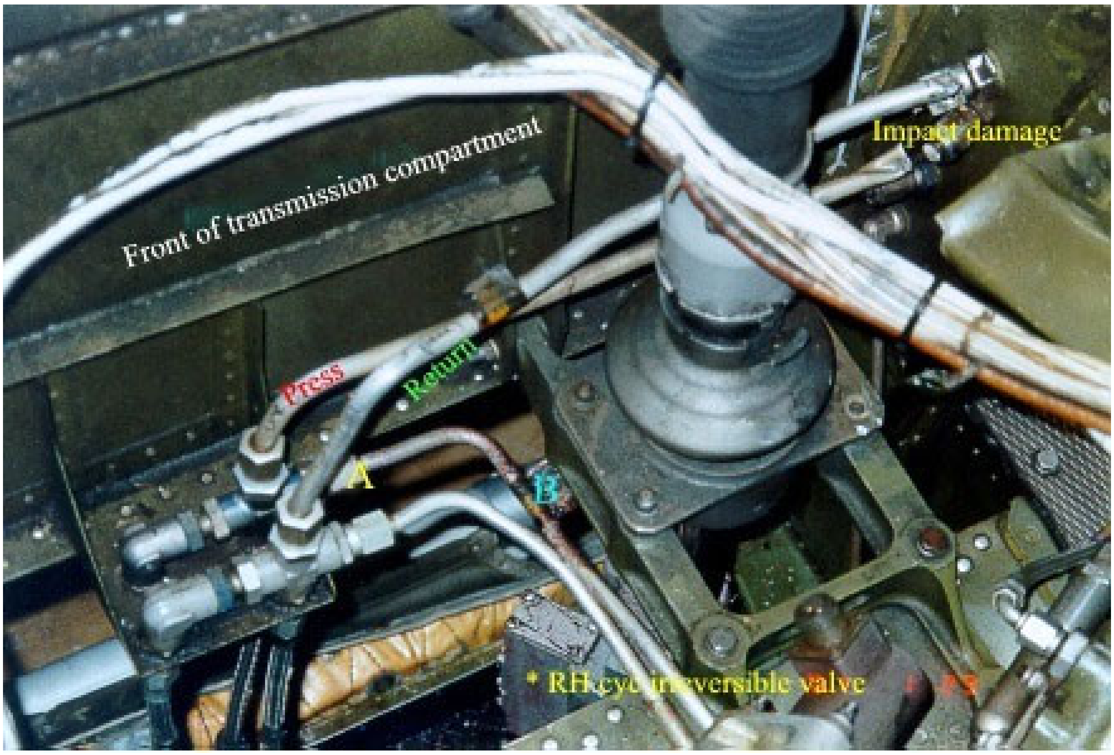

Figure A5: Hydraulic lines in transmission compartment – transmission removed
A indicates the area of the leak; B indicates hydraulic fluid residue.