Report 01-003

Hughes 369D

ZK-HMN

in-flight engine flameout

12.5 km northwest of Milford Sound

23 March 2001

Abstract

On Friday 23 March 2001, at 0705, Hughes 369D helicopter ZK-HMN experienced an engine flameout as the pilot applied collective control normally to arrest the helicopter's descent. The pilot landed the helicopter in trees on a mountain slope at about 3000 feet, some 12 km northwest of Milford Sound. The pilot and the crew member on board the helicopter were uninjured.

Investigation showed a defective engine fuel control unit was responsible for the flameout. The fuel control unit had been repaired by an Australian component overhaul facility and released to service. After the fitment of the fuel control unit, the maintenance providers did not trace repeated engine overspeeding problems to the fuel control unit.

Because of the involvement of an Australian component overhaul facility, the Australian Transport Safety Bureau was invited to join the investigation. Because of initial concerns of a quality assurance problem with the facility, the Australian Transport Safety Bureau initiated a systemic investigation into its performance. The Bureau will report on the investigation results separately.

A survey of the main New Zealand maintenance organisations, and Civil Aviation Authority records, did not reveal other similar incidents involving fuel control units and power turbine governors.

Other safety issues identified were trouble-shooting procedures by maintenance providers, and the monitoring of service bulletins.

The Transport Accident Investigation Commission is an independent Crown entity established to determine the circumstances and causes of accidents and incidents with a view to avoiding similar occurrences in the future. Accordingly it is inappropriate that reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The Commission may make recommendations to improve transport safety. The cost of implementing any recommendation must always be balanced against its benefits. Such analysis is a matter for the regulator and the industry.

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Abbreviations

ATSB	Australian Transport Safety Bureau
CAA	New Zealand Civil Aviation Authority
CASA	Australian Civil Aviation Safety Authority
CEB	Commercial Engine Bulletin
FAA	United States Federal Aviation Administration
FCU	fuel control unit
km	kilometre(s)
mm	millimetre(s)
N_1	gas producer turbine speed
N_2	power turbine speed
P_C	compressor discharge pressure
psi	pounds per square inch
PTG	power turbine governor
P_X	acceleration bellows pressure
P_Y	governor bellows air pressure
UTC	Universal Coordinated Time

Data Summary

Aircraft registration:	ZK-HMN
Type and serial number:	Hughes 369D, 470108D
Number and type of engines:	one Rolls-Royce Allison 250-C20B
Year of manufacture:	1977
Operator:	Milford Helicopters Limited
Date and time:	23 March 2001, 0705[1]
Location:	12.5 km northwest of Milford Sound latitude: 44º 33.7´ south longitude: 167º 51.8´ east
Type of flight:	commercial transport, airborne deer hunting
Persons on board:	crew: 2 passengers: nil
Injuries:	crew: nil
Nature of damage:	substantial
Pilot's licence:	Commercial Pilot Licence (Helicopter)
Pilot's age:	29
Pilot's total flying experience:	approximately 3000 hours (850 on type)
Investigator-in-charge:	K A Mathews
Other sources of information:	the Commission is grateful for the assistance and information provided by the Australian Transport Safety Bureau

[1] Times in this report are New Zealand standard time (UTC +12 hours) and are expressed in the 24-hour mode.

1. Factual Information

1.1 History of the flight

1.1.1 On Friday 23 March 2001, at 0645, Hughes helicopter 369D, ZK-HMN, operated by Milford Helicopters Limited (the operator), took off from Milford Sound Aerodrome with the pilot and the owner as a crew member on board. That morning the helicopter was engaged in airborne deer hunting. Usually the helicopter was utilised for other commercial transport operations and air transport tourism work.

1.1.2 The helicopter had been refuelled from a bulk fuel supply at Milford Sound Aerodrome, and the fuel tank filled. This gave a safe endurance of about 1.6 hours, and a total endurance of around 2 hours, flight time. The pilot said he took fuel samples from the helicopter belly drain and airframe fuel filter prior to the flight. No fuel contamination was detected.

1.1.3 The helicopter had started normally and departed without incident to the northwest. The weather conditions were reported as a high overcast, clear and calm. Visibility was very good with no rain or snow.

1.1.4 About 10 minutes after departure the pilot noticed an unusual response from the helicopter, as though it had flown through its own turbulence. At the same time he noticed the engine re-ignition amber light glow. There were no cockpit indications of any other abnormalities. About 5 minutes later, when the helicopter was approaching a 3500-foot knoll to drop off a deer carcass attached to a sling, the pilot felt the helicopter "twitching" and said later that the helicopter "didn't feel right". There were no cockpit indications of any abnormalities.

1.1.5 About a minute after leaving the knoll the crew saw 2 deer running down the side of a hill. The pilot said he lowered the collective lever and reduced engine power to about 15 to 20 pounds per square inch (psi) of torque and descended after the deer. The helicopter descended some 500 feet before the pilot applied collective normally to arrest the descent. The engine did not respond to the demand for increased power. Instead, there were multiple audio and visual cockpit warnings that the helicopter engine had lost power. The pilot also noticed the engine gas producer turbine speed (N_1) decaying.

1.1.6 The pilot quickly bottomed the collective lever and momentarily reapplied some collective to see if there was any engine response. There was no response so he bottomed the collective lever, flared the helicopter and landed nose-first in the top of beech trees at about 3000 feet on the side of a mountain slope. The helicopter came to rest having rolled through about 120º onto its left side, and nose on to the slope. No fire occurred. The 2 occupants were uninjured.

1.1.7 The crew used a radio to call for assistance and were rescued by another helicopter.

1.2 Pilot information

1.2.1 The pilot was aged 29. He held a Commercial Pilot Licence (Helicopter) and a Class 1 Medical Certificate valid until 14 April 2001.

1.2.2 At the time of the accident the pilot had amassed some 3000 flying hours and around 850 hours on Hughes 369 helicopters.

1.3 Helicopter information

1.3.1 ZK-HMN was a Hughes 369D single-engine helicopter, serial number 470108D, constructed in the United States in 1977. The helicopter was fitted with a Rolls-Royce Allison 250-C20B engine, serial number CAE 821211F.

1.3.2 The helicopter was maintained in accordance with the manufacturer's maintenance manual. At the time of the accident the helicopter had amassed 7278.55 airframe hours and 8073.31 engine hours. The last inspection was a 300-hour check on 22 February 2001 at 7212.2 airframe hours. The next inspection due was a 100-hour check at 7312.2 airframe hours or on 22 August 2001, whichever occurred first.

1.3.3 A new compressor was fitted to the engine during the 300-hour check.

Fuel control unit

1.3.4 The engine was fitted with a Honeywell Bendix fuel control unit (FCU), part number 2524644-29, serial number 336660, at the time of the engine flameout. An Australian component overhaul facility (Lucas Aerospace, now TRW Aeronautical Systems) last overhauled the FCU in December 1996 and released it from its exchange stock on 8 January 1997. In New Zealand, a maintenance engineer who had carried out ZK-HMN's maintenance fitted the FCU, with zero hours since overhaul, to the engine on 17 March 1997.

1.3.5 On 31 December 1997, after 237 hours since overhaul, the maintenance engineer removed the FCU from the engine because it ran constantly at 110% power turbine speed (N_2). The FCU was returned to TRW for repair. Records showed the FCU had 2 cracks in the governor (drive body) housing. The cracks allowed the housing to twist, which affected the normal operation of the FCU. The repair job card recorded the on-receipt condition of the unit, stating that there was "different L/W [lock wire] on bellows screws. Cut L/W [lock wire]." The governor housing was replaced, along with a seal and nut. The defect investigation report stated the governor housing had been crack checked at overhaul and that no cracks were detected. The repair records stated the flow body assembly was not dismantled. The repair was completed on 24 June 1998. The operator believed the cracking occurred during service because the starter-generator developed vibrations.

1.3.6 The FCU Authorised Release Certificate, dated 7 July 1998, stated the FCU was repaired and fully tested in accordance with the Honeywell Bendix overhaul manual, appendix A2. This included running the FCU on a test bench. The maintenance engineer refitted the FCU to the engine in New Zealand on 31 July 1998, where it remained until after the accident on 23 March 2001.

1.3.7 On 15 March 1999 the engine manufacturer issued Alert Commercial Engine Bulletin (CEB) A-1361, for the FCU, Revision 1. The CEB, first issued on 5 October 1998, called for replacement of the internal springs. The compliance time was within 150 operating hours following receipt of the bulletin, but not later than 31 October 1999. The bulletin had not been implemented. The springs had not failed in service. Immediate engine deceleration would result from any such spring failure.

1.3.8 Implementation of service bulletins was not normally mandatory, but could be made mandatory by an airworthiness directive. In this case the United States Federal Aviation Administration (FAA), as the authority for the engine's country of origin, had not issued an airworthiness directive mandating the requirements of CEB A-1361. The New Zealand Civil Aviation Authority (CAA) would normally mirror any FAA airworthiness directive, but likewise it had not issued an airworthiness directive mandating the requirements of CEB A-1361. Although the operator's operations manual stated that the operator shall maintain the helicopter in accordance with the manufacturer's service bulletins, it was not intended that all service bulletins should automatically be implemented, which was in line with normal aviation practice. The operator's operations manual stated that whenever airworthiness directives or service bulletins were received that may affect ZK-HMN, the approved maintenance organisation's (Flightline Aviation) chief engineer was to liaise with the maintenance controller (the operator) to decide upon any action that may be necessary to achieve compliance.

1.3.9 The operator did not receive service bulletins and said he was not aware of CEB A-1361. Flightline received service bulletins but did not pass them on to the operator. Flightline's chief engineer said he normally reviewed all applicable service bulletins, but would not necessarily discuss them all with the various operators, because administratively it was very difficult to achieve. In this instance he was not aware of CEB A-1361 and, therefore, had not discussed it with the operator. CEBs were received by Flightline's engine shop manager and filed. The shop manager said he took no action because the requirements would be fulfilled at the next overhaul.

Power turbine governor

1.3.10 The engine was fitted with a Honeywell Bendix power turbine governor (PTG), part number 2524769-14, serial number 24612, at the time of the engine flameout.

1.3.11 From 1998 the operator recalls having concerns with the engine overspeeding when power was reduced, and "not holdings its revs". This was especially noticeable in turbulence. He said if the collective lever was lowered fully the engine would overspeed and the collective had to be raised to prevent it. The operator was not satisfied with the ability of the helicopter to maintain its selected rotor speed. The pilot said the rotor speed would fluctuate around the selected value, and the fluctuations were particularly noticeable in turbulence. He said the rotor speed had to be monitored closely during turbulence. He thought the helicopter did not hold its rotor speed like the helicopter type should.

1.3.12 On 7 April 1999 the maintenance engineer checked the PTG rigging because of the operator's continued concerns.

1.3.13 After April 1999 Flightline became the operator's approved maintenance organisation for the helicopter.

1.3.14 On 6 August 1999 Flightline removed the PTG because of the speed control concerns, and the operator sent it for overhaul. The PTG had run 1316 hours, time-in-service since its last overhaul. A loan PTG with 74 hours since overhaul was fitted.

1.3.15 The operator said that although there seemed to be some improvement with the loan PTG fitted, the engine speed control was still not right.

1.3.16 On 5 April 2000 Flightline refitted the newly overhauled PTG to the engine.

1.3.17 On 26 June 2000, a different maintenance organisation, at Flightline's request, removed the PTG after 67 hours in service and refitted the loan PTG, because of engine overspeeding. The PTG was returned to TRW for examination and testing. Flightline requested the investigation report, which stated the unit was governing slightly early (0.8%) at normal governing range, but was governing slightly late at overspeed conditions. The unit was recalibrated to overhaul limits and released to service.

1.3.18 On 24 October 2000, the different maintenance organisation, on Flightline's request, refitted the PTG to the engine.

1.3.19 On 16 January 2001, the different maintenance organisation, again at Flightline's request, removed the PTG because of engine overspeeding concerns and fitted the loan PTG. The PTG had operated for 146 hours since it was last examined. The PTG was returned to TRW for further examination and testing.

1.3.20 On 22 February 2001, during the 300-hour check, Flightline refitted the PTG to the engine. After the maintenance the helicopter was run several times to track the rotor blades. During the first ground run, engineers noticed the engine hunting[2] (about 3%). This seemed to the engineers as though the pilot was adjusting the engine speed manually. On a second ground run the engine hunted about twice, and once on a third run. The hunting did not occur on subsequent runs. A test flight was carried out and the pilot and engineers were satisfied with the helicopter's performance. The chief engineer advised the operator of the situation and asked him to monitor the engine. A few days later the chief engineer asked the operator about the helicopter and the operator indicated he was satisfied with it. The operator, however, had not subjected the helicopter to demanding operations, such as deer hunting, at that point.

1.3.21 Flightline said some PTGs had caused previous problems and they could be sticky after overhaul, until they had operated for a few hours. This could cause engine speed fluctuations. This was especially so when a new heavier spring had been fitted to the PTG.

1.3.22 After a few hours of flying the helicopter's engine speed control problems persisted. The operator said he was not satisfied with the engine speed control and, before the accident, had planned to again remove the PTG. The operator did not advise Flightline of his concern or plan. The engine had operated for 66 hours since the 300-hour check, when the accident occurred.

1.3.23 The maintenance manual and the FCU and PTG manufacturer's operation and service manual contained a trouble-shooting section. Part of the section referred to engine N_1 and N_2 overspeed incidents, and included a probable cause as being a defective FCU or PTG. A maintenance diagnostic technique to isolate which component may be at fault was to note the idle speed during a ground run, with the throttle twist grip at the 30° position. If idle speed was normal the PTG was suspect; if the idle speed was high the FCU was suspect. Flightline advised because the engine problems had not specifically been reported as overspeeding incidents this part was not followed. The concern was more about unstable or erratic engine operation.

1.3.24 The operator and pilot said they had not previously noticed the particular symptoms that were displayed by the helicopter on the morning before the accident.

1.4 Wreckage and impact information

1.4.1 The helicopter impacted the trees with low vertical and forward velocity, but was extensively damaged in the accident. The tail boom was severed near the vertical fin by a tree bough. The main rotor blades were destroyed. The main rotor head and transmission remained attached to the helicopter. The transmission was undamaged. The main rotor head drag dampers remained intact and were undamaged. One pitch change link was bent.

1.4.2 Examination of the helicopter rotor systems and drive train indicated the engine was delivering little or no power at the time of impact. Examination of the engine showed it was not rotating at impact. The engine, engine compartment and engine mounts were intact and undamaged. The engine remained attached to its mounts and the helicopter.

1.4.3 The nose perspex was smashed. The nose structure was buckled and ripped, especially on the left side near the pilot's seat. The collective lever sustained some impact damage. The left skid was broken forward of its front leg. The belly of the helicopter was undamaged.

1.5 Tests and research

1.5.1 The helicopter was recovered to the operator's residence for examination, and was later transported to Flightline's hangar for further examination.

[2] To run alternately too fast and too slow; to oscillate.

1.5.2 The engine manufacturer sent a representative to New Zealand to be involved in the examination.

1.5.3 The Milford Sound bulk fuel supply installation was examined. The fuel met all required specifications and was not contaminated.

1.5.4 Examination of the helicopter fuel system did not reveal any deficiencies or fuel contamination. There was adequate fuel available to the engine. All filters and screens were clean. Fuel was present throughout the system to the fuel nozzle. There were no fuel leaks. The fuel venting system was not blocked. A vacuum check of the fuel system lines and components did not reveal any air leaks in the fuel delivery system.

Engine examination and testing

1.5.5 All fittings to the engine were secure. The control linkages were intact and rigged appropriately. The engine turned freely and no mechanical defects were evident. The drive to the main rotor gearbox was intact and undamaged. The main rotor and tail rotor gearboxes rotated freely.

1.5.6 The engine was removed from the helicopter. A pneumatic air pressure test did not reveal any leakages in the pneumatic system. The engine had not ingested any foreign objects. There was no evidence of the engine rotating at impact. The engine chip plugs were clean.

1.5.7 The engine was crated and shipped to Melbourne to run on a test stand under the Commission's and the manufacturer's supervision. The engine started normally on the test stand and ran satisfactorily at idle with about 10 psi engine torque. As engine power was increased to around 15 psi torque the engine began hunting (see footnote 2). At 30 psi torque the hunting became pronounced with the torque rapidly fluctuating some 15 psi either side. The fuel flow fluctuated rapidly between about 78 pounds per hour and 160 pounds per hour. Minimum normal engine fuel flow at idle is around 79 pounds per hour.

1.5.8 Engine torque was increased slowly and the hunting subsided as power was increased above about 50%. At maximum power the engine parameters were within specifications. As power was reduced below about 50% the hunting recommenced, with the same results. Rapid acceleration and deceleration tests were not performed because of the hunting. No FCU adjustments were attempted during the engine runs.

1.5.9 The PTG was replaced with a different serviceable unit, and the engine retested. There was no change and the engine continued to hunt. The PTG was refitted. The FCU was removed and replaced with a recently overhauled unit. With the different FCU fitted the engine started and accelerated normally throughout its power range, with no evidence of any hunting. Rapid acceleration and deceleration tests were conducted and the results were well within required specifications. The engine did not overspeed. At maximum power the engine delivered 6% more than rated power.

Component testing

1.5.10 The FCU, PTG and engine fuel pump were sent to an independent Australian component overhaul facility for testing and examination under the Commission's supervision. Orange coloured torque seal was applied in various places before shipping to the overhaul facility, to ensure component integrity.

FCU

1.5.11 The FCU is the main component of the engine fuel controlling system. The unit is a pneumatic mechanical device, which schedules the fuel flow delivered to the engine to provide proper engine operation during all operating conditions. The unit is mounted on the engine accessory gearbox and driven at a speed proportional to engine N_1.

1.5.12 The FCU was equipped with a set of 2 flyweights that rotated in proportion to engine N_1 during normal operation. As N_1 increased the flyweights travelled outwards because of centrifugal force. If N_1 increased beyond normal values the flyweights' travel would cause the FCU's governor lever to bleed off governor bellows air pressure (P_Y), and bring about a fuel flow reduction to prevent the engine overspeeding. N_2 was normally held constant by the PTG, but as collective pitch was changed the load on the power turbine changed, tending to change N_2. Fuel flow was increased or decreased to affect the gas flow velocity, and the gas producer turbine may change its speed accordingly, to supply the power required to help maintain a constant $N_{2.}$

1.5.13 The FCU was fitted to a test bench for a "run as received" test in accordance with the manufacturer's specifications. A direct telephone communication link with the manufacturer was established for the testing. The necessary test requirements under test points 9 (maximum governor spring setting) could not be achieved. Following various checks the ambient air pressure vent screen was removed to allow viewing of the flyweights. The flyweights' clip weight stops were observed to be set incorrectly, thus restricting the flyweights' travel. Removal of the drive shaft assembly and subsequent measurement of the flyweights' clip showed the weight stops were set to allow one flyweight to travel 0.042 inches (1.067 mm) and the other 0.044 inches (1.118 mm). The clip should have been set to allow the flyweights to travel 0.100 to 0.105 inches (2.540 to 2.667 mm). (See Figure 1.)

1.5.14 Examination of a new unadjusted flyweights' clip from the manufacturer showed it would restrict the flyweights' travel, similar to that found on the faulty FCU. (See Figure 2.)

1.5.15 The flyweights' clip was adjusted correctly and the FCU reassembled for further test bench runs, with improved results achieved. An increase in the compressor discharge pressure (P_C) to acceleration bellows pressure (P_X) bleed off was observed between the test bench runs.

1.5.16 The FCU was disassembled in stages and examined. The P_X (P_C to P_X) air bleed restrictor was examined and viewed under a 40-power microscope. The P_X air bleed restrictor orifice was enlarged on one end and misshapen, resembling an egg-shape. Two prominent score marks (like cracks) resembling a "V" shaped groove emanated from the orifice at the misshapen end. The surface around the orifice was scratched. A screwdriver slot on the opposite end of the restrictor, to allow for its assembly to and disassembly from the FCU, was deformed significantly.

1.5.17 The P_X air bleed restrictor is a finely calibrated component and the orifice should be circular and at a set diameter and edge radius. Any enlargement or deformation of the orifice could affect the air flow through it. The orifice can be "stoned[3]" to meet a required limit only by using a special bleed stoning tool and technique. The inlet edge was the only edge that could be reworked and the radius should be no greater than 0.002 inches (0.0508 mm).

1.5.18 The bellows nut was found to be incorrectly tensioned, with the bellows end screw hard up against the side of the housing.

1.5.19 A small hole was found in the fuel strainer canister. The broken pieces were not found.

1.5.20 The 2 drive bearings were not the latest type. One was notchy.

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[3] A process of shaping the orifice by precision grinding.

1.5.21 The flyweights were re-examined. One flyweight was stiff and notchy in operation; the other was free in movement. There were marks on the back of the flyweights where they had been striking the inside of the clip weight stops.

1.5.22 The P_X air bleed restrictor was further examined under a scanning electron microscope, and compared with another used P_X air bleed. The orifice was not circular but had been enlarged on one end. Close examination revealed a round object had enlarged the orifice. Debris consisting of oil and dirt was present adjacent to the enlarged end of the orifice. A “V” shaped groove ran in a radial direction from the enlarged end of the orifice and was aligned with the centre of the enlarged orifice. Two score marks defined the edges of the “V”. There were no cracks. At the enlarged end of the orifice, the side of the orifice was not perpendicular to the axis of the P_X air bleed restrictor, but at an angle to the axis. Marks present on the face of the enlarged end of the orifice showed a round object had probably been pushed into the orifice at an angle to the axis. Two separate indents were present, showing the round object had probably been pushed into the orifice on more than one occasion. Numerous grinding or polishing marks were present on the face around the orifice (see Figure 3).

1.5.23 The P_X air bleed restrictor and drive body assembly were sent to the manufacturer for air flow tests across the P_X air bleed restrictor orifice. The manufacturer completed 3 dynamic flow performance tests on the P_X air bleed, and graphed the results. As a result of the tests the manufacturer stated it did not believe the P_X bleed would have caused any major anomalies with the functioning of the FCU, because the graphs showed a smooth and linear progression of the pressure drop across the restrictor orifice. The 3 tests produced identical results and the graphs represented a normal functioning restrictor. The manufacturer said, based on the flow performance of the P_X air bleed, it considered the bleed serviceable. However, the manufacturer considered the bleed was in an unserviceable state because of its physical condition.

1.5.24 With regard to the flyweights’ clip, the manufacturer reviewed the independent Australian component overhaul facility test and examination report. Several test points were out of limits with the most significant being test paragraph 9 (maximum governor spring setting). The manufacturer said it believed the incorrectly set flyweights’ clip caused a shallow slope at test points 9. Simply, this meant that as N_1 increased P_Y bleed off did not increase, and consequently the fuel flow would not decrease at the prescribed rate.

1.5.25 Prior to disassembly for examination, the FCU external security lock wiring had been observed by the independent component overhaul facility to be uniform, and consistent with an overhaul facility using 0.015-inch stainless steel lock wire. The maintenance manual only allowed approved overhaul facilities to complete internal work on the FCU. TRW’s FCU records noted that examination of the FCU prior to its repair disclosed the external lock wire in the vicinity of the P_X restrictor had been altered since the overhaul. There was no evidence or record showing the FCU had been subject to any internal adjustments or removal since the repair.

PTG and fuel pump

1.5.26 The PTG and fuel pump were both tested in accordance with their overhaul manuals and found satisfactory. There was no evidence they contributed to the engine flameout. The fuel pump capacity was satisfactory and no leaks were detected. The PTG was outside overhaul limits, but within service limits for a unit with a time since overhaul of more than 200 hours.

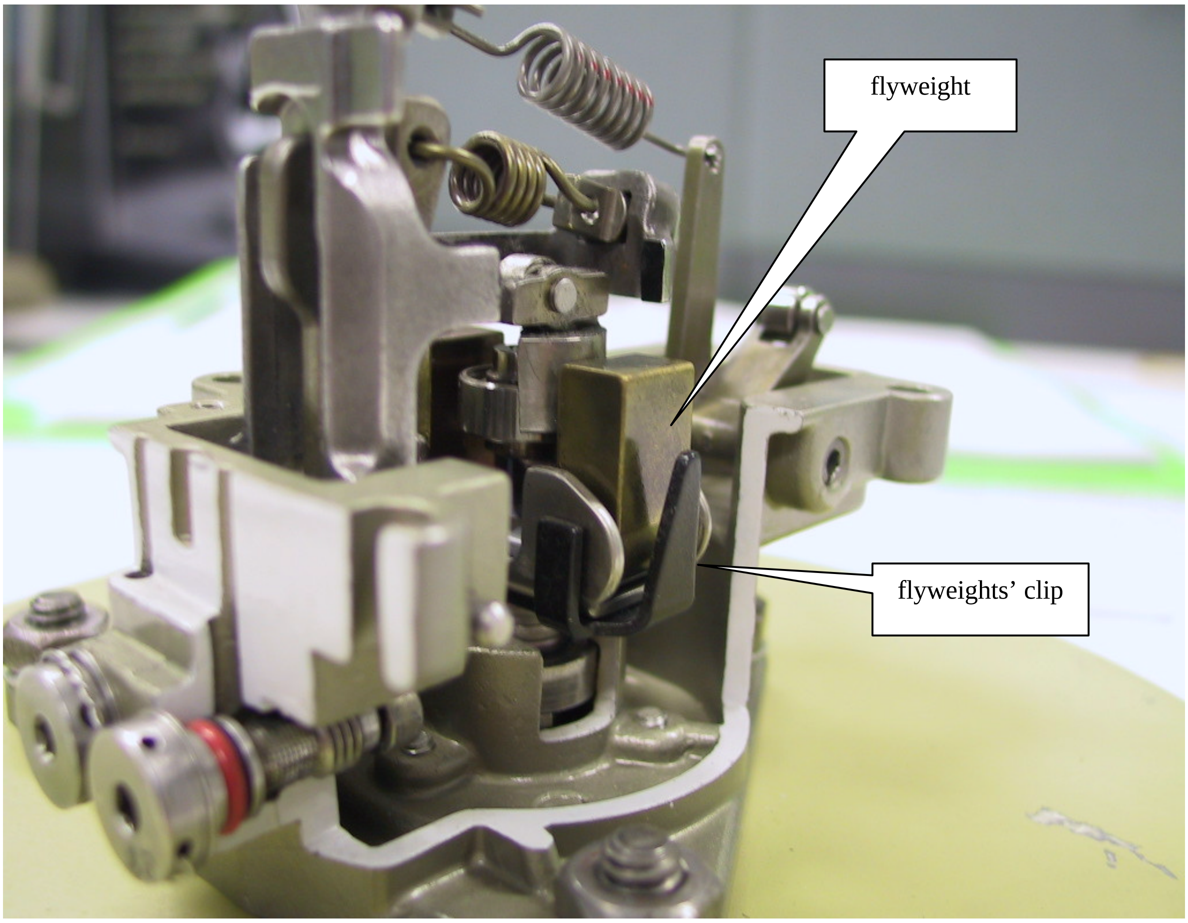

Figure 1
Cut-away view of a model FCU drive body

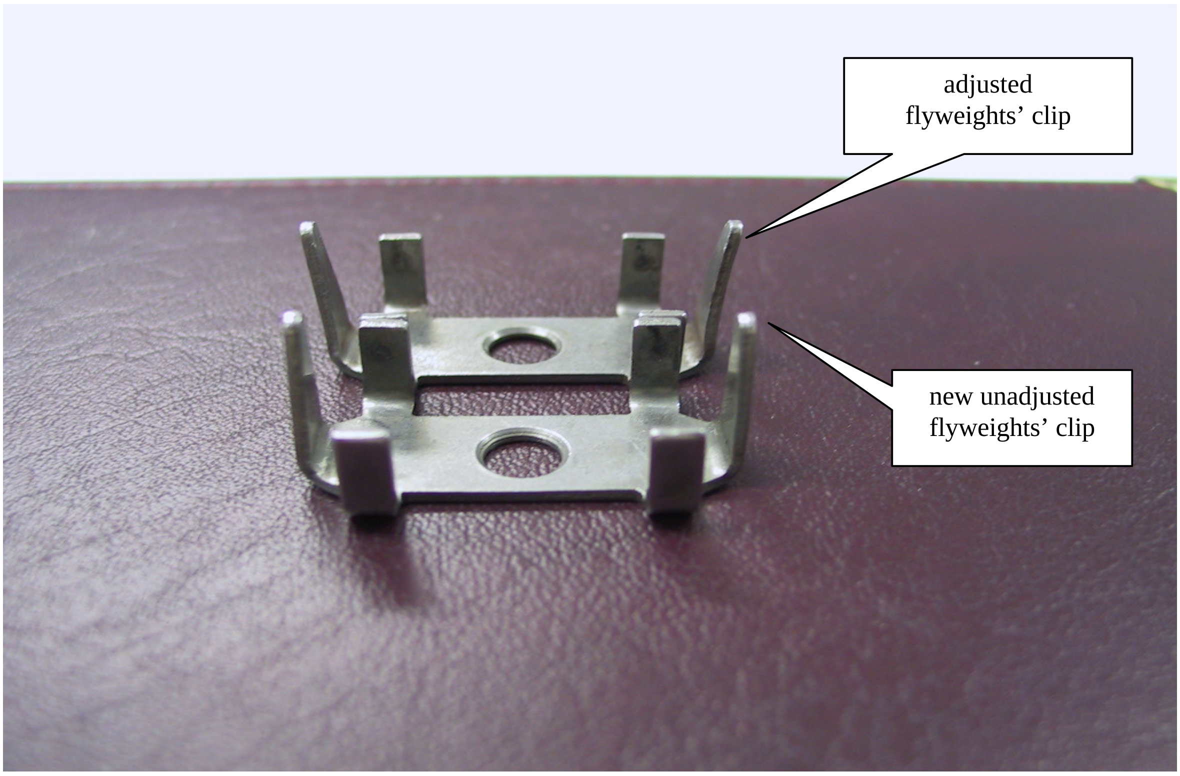

Figure 2
FCU flyweights’ clips

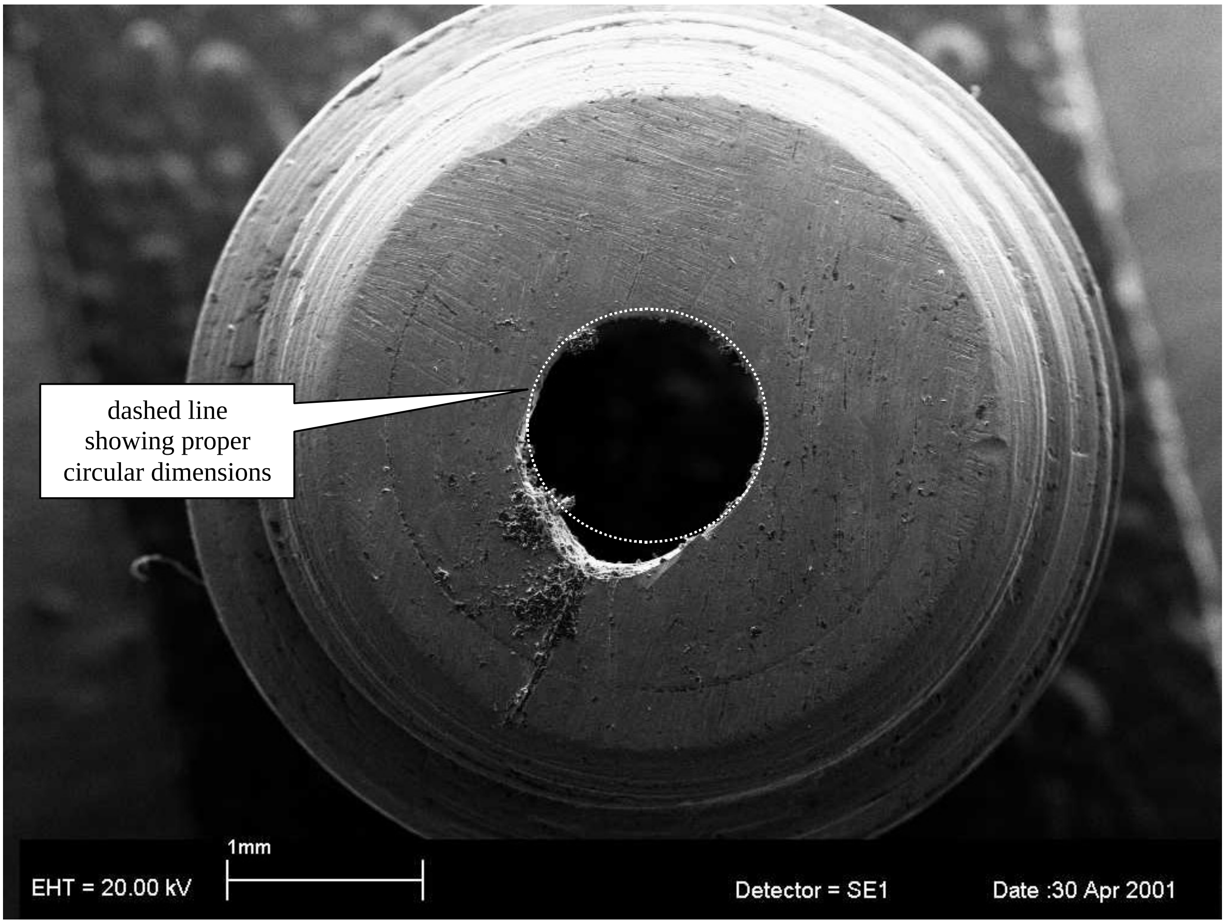

Figure 3
P_X air bleed restrictor orifice

1.6 Organisational and management information

1.6.1 The Australian Civil Aviation Safety Authority (CASA) approved TRW to conduct various aircraft component overhauls and repairs, including Honeywell Bendix FCUs and PTGs fitted to the Rolls-Royce Allison 250-C20B engines. As well, Honeywell Bendix, the FCU and PTG manufacturer, authorised TRW to carry out overhauls and repairs of these components. The FAA also approved TRW to repair and overhaul various components fitted to United States registered aircraft. The New Zealand CAA accepted the CASA approval of the facility for repair and overhaul of components fitted to New Zealand registered aircraft.

1.6.2 TRW was subject to ongoing audits by various organisations, including CASA and the component manufacturer. The component manufacturer audited TRW every 2 years and the next audit was due in December 2001.

1.6.3 Examination of TRW's records showed all the accident FCU overhaul and repair test records were completed, including the entering and recording of specifications and test point data. The recorded data was within the required limits. This included the data entered under test points 9 (maximum governor spring setting).

1.6.4 One technician completed the FCU overhaul, and the work was inspected and accepted by a fitter who was approved to sign off the work. The unit was set to standard datum settings before being passed to another technician for test bench testing and any necessary adjustments. The test bench technician could adjust the FCU governor springs tension to bring the unit to the required performance specifications, if necessary. Any adjustment would require the test bench technician to remove the governor drive body. Following testing the unit was returned to the fitter for security lock wiring and release.

1.6.5 TRW routinely checked the calibration of its testing equipment. TRW records showed the dial test indicator used to check the FCU flyweights' travel was in service from 1993 to 1999. The indicator was replaced in 1999 because of excessive errors. The calibration checks performed during 1996 to 1998 (the FCU overhaul and repair period) showed the indicator was serviceable and within calibration limits.

1.6.6 The FCU manufacturer routinely checked TRW's FCU test benches, which included consistency checks against other test benches. The last check was completed satisfactorily in April 2000.

1.6.7 When the FCU from ZK-HMN was returned for repair, the fitter who had signed off the overhaul carried out the repair work himself. He approved his own repair work and passed the unit to the test bench technician for testing. The fitter had been working for the facility for some 30 years.

1.6.8 Allowing a single authorised and qualified person to complete and sign off their own work was an approved practice, and one that was followed by other overhaul companies. After a rebuild or repair the units were subject to separate test bench checking.

1.6.9 On 3 June 1999, the year following the FCU repair, the test bench technician who had tested the FCU at repair left TRW for other employment.

1.6.10 In June 1999 TRW carried out an internal audit on 6 randomly selected, recently completed work job folders involving 11 personnel. The folders were checked for content and certification. The audit results raised a total of 35 major, 31 minor and 4 question issues. TRW documented a range of proposed and required resulting actions on the audit sheets.

1.6.11 After the accident on 23 March 2001 Flightline returned a FCU and a PTG from another Rolls-Royce Allison 250-C20B engine fitted to a different Hughes 369D helicopter, to the independent Australian component overhaul facility for examination and repair. The units were returned because of "N_2 fluctuations at 103%". Because the defect was still present after the FCU was initially examined, the overhaul facility requested the PTG for examination along with the FCU.

1.6.12 Flightline sent the Commission the PTG deficiency examination report. The FCU was reported as being serviceable. The PTG had been overhauled on 2 July 1999 by TRW. The TRW fitter who had completed the accident FCU repair work completed the PTG overhaul. A different test bench technician tested the unit.

1.6.13 The PTG had run 780 hours, time-in-service since overhaul. The maximum time allowed between overhauls was 2000 hours. The PTG was recorded as being unserviceable and a number of deficiencies were noted. The deficiencies included:

- the drive spline assembly was incorrectly epoxy bonded, making it a fixed drive spline. CEB 1130 and 1170 both indicate this can cause N_2 droop and fluctuations. This also transmits vibration through the unit and accelerates wear
- the drive bearings very noisy and rough – unserviceable. CEB 1347 new type drive bearings to be incorporated
- eccentric shaft and lever both badly worn – unserviceable
- spool bearing base badly worn by flyweight feet – unserviceable
- throttle shaft grooved and oval – unserviceable
- throttle bushing oversize – unserviceable
- $P_R – P_G$ bleed has been damaged during calibration – unserviceable.

The deficiency report also noted that CEB 1347 (incorporating new drive bearings, part number 2543734) should already be incorporated. However, part number 2520501 bearings (old type bearings) were fitted to the unit.

1.6.14 TRW's Authorised Release Certificate for the overhauled PTG, dated 2 July 1999 and signed by the fitter, stated that CEB 1347 had been incorporated. TRW explained that since CEBs were not mandatory it was acceptable to use old bearing stock first, if the customer did not wish to purchase new bearings. This was an accepted practice approved by the PTG manufacturer. TRW could not explain why the release certificate stated that CEB 1347 had been incorporated, indicating that new type drive bearings were fitted.

1.6.15 Because of the involvement of an Australian component overhaul facility, the Australian Transport Safety Bureau (ATSB) joined the investigation to examine TRW's performance and any other Australian related safety issues. The Bureau will report on these issues separately.

1.7 Additional information

1.7.1 Because other incorrectly overhauled or repaired FCUs or PTGs could potentially have been released to service by TRW, the Commission conducted a survey of the main New Zealand Rolls-Royce Allison 250 engine maintenance organisations. The aim of the survey was to determine if there were other instances of ongoing engine governing or overspeeding concerns and, if so, which company carried out the previous FCU or PTG overhaul or repair. TRW was not referred to during the survey.

1.7.2 Apart from the 2 instances discussed in this report, the survey did not reveal any similar cases. Other component overhaul facilities were used by most of the New Zealand maintenance organisations.

1.7.3 A review of CAA records showed there were no similar instances recorded by CAA on its records.

2. Analysis

2.1 The 2 helicopter occupants were fortunate to have escaped the accident without injury, given the inhospitable surrounding terrain. If the helicopter had been in a different location when the engine flameout occurred, the situation could have been more serious. Equally, the helicopter could have been carrying fare-paying passengers on an air transport operation and their safety could also have been jeopardised.

2.2 A defective FCU fitted to the helicopter engine several years earlier ultimately caused the engine to flameout during flight. Prior to the flameout the pilot reduced power and descended the helicopter by lowering the collective lever. This action put the engine power into the hunting range observed with the engine on the test stand. Consequently, the engine would have been hunting in a manner similar to that seen on the test stand. When the pilot raised the collective lever normally to arrest the descent, he demanded a significant increase in power and fuel flow. Because of the hunting, the demand for a significant increase in fuel flow will have occurred simultaneously with the FCU cycle that was rapidly reducing the fuel flow. Sudden engine deceleration and flameout resulted.

2.3 Two main problems were found in the FCU. One was the condition of the P_X (P_C to P_X) air bleed restrictor orifice, which was deformed and enlarged. The other was the incorrect setting of the flyweights' clip, which restricted the flyweights' travel to less than half the required distance.

2.4 When the damage to the P_X air bleed restrictor orifice occurred could not be established. A circular object pushed through the P_X bleed orifice probably domed the base of the P_X bleed around the orifice. The "V" shaped groove in the base of the P_X air bleed was probably formed as a result of restraightening the base after it was domed. Although the manufacturer's tests showed the orifice's condition would not have caused any major anomalies, the manufacturer said it should not have been installed in the FCU in that condition.

2.5 TRW said the orifice should have been inspected at overhaul and the P_X bleed discarded if found in the condition observed. There was no record of the P_X bleed being replaced at overhaul, and the records of the 2 FCU test bench tests did not disclose any anomalies. Someone outside of TRW could have tampered with the P_X bleed and replaced the lock wire, which would explain the repair documentation stating the lock wire near the access to the P_X bleed had been disturbed. Prior to 1996 the manufacturer allowed the field removal of the P_X bleed for cleaning, but since then the manufacturer amended the maintenance manual instructions to no longer allow that practice. There was no reason why the P_X bleed should have been removed after overhaul, and there was no record indicating it had been. Alternatively, the TRW technician who overhauled the unit may have overlooked inspecting or replacing the P_X bleed, but this could not be established.

2.6 The FCU flow body assembly was not dismantled, or required to be, during the repair. However, it is reasonable to expect an overhaul facility, having observed inconsistent security lock wiring and being concerned about potential internal tampering, to have carried out an examination of this area internally.

2.7 Because the FCU flyweights' clip restricted the flyweights' travel to less than half the required distance, the FCU could not adequately control any tendency for engine N_1 overspeeding. Any N_1 increase would cause the N_2 to increase. N_2 was controlled by the PTG, which was effective from 98% N_1. The PTG, therefore, had limited effect and was not able to fully govern N_2 and adequately control rotor speed.

2.8 The maladjustment, or non-adjustment, of the FCU flyweights' clip will have occurred either when the unit was overhauled or, more probably, when it was subsequently repaired by TRW. There was no evidence the FCU unit had been tampered with internally since the repair, and it remained on the helicopter until after the accident. The FCU lock wiring was uniform, and it was consistent with the type of wire used by overhaul facilities. The security tabs were in place. Specialist knowledge was required to disassemble the FCU drive body, remove the flyweights and readjust their clip. This would require a major field adjustment, and it was not an operation that was authorised or expected to take place away from an approved overhaul facility. There was no evidence the outside of the clip weight stops had either struck or been struck by an object, causing them to bend inwards. Had this occurred, it would be extremely unlikely for them to have moved coincidently to within 0.002 inches (0.051 mm) of each other, and to a setting consistent with a new unadjusted clip. In addition, soon after the repaired FCU was fitted to the helicopter engine the operator recalls, and the records record, overspeeding difficulties. A defective PTG, not the FCU, was suspected as being the cause of the overspeeding. The PTG had been removed and refitted several times.

2.9 Because the flyweights' clip setting caused the "out of limits" results found under test points 9, and the tests on the P_X bleed showed no anomalies, the restriction to the FCU flyweights' travel will have ultimately caused the engine hunting. The hunting probably occurred shortly after the repaired FCU was fitted to the engine, but the right mix of parameters to cause a flameout may not have come together until the day of the accident. What is likely is the FCU's performance progressively worsened with normal use and wear, until the situation became critical on the day of the accident. In addition, the fitment of a new engine compressor 66 hours before the flameout would have increased compressor discharge efficiency and engine performance. This could have further degraded the ability of the defective FCU to function adequately.

2.10 The operator was not aware of any engine hunting during flight, other than repeated N_2 and rotor overspeeding concerns. Only in the morning prior to the accident did the pilot notice some unusual, and previously unobserved, helicopter flight characteristics. This should have alerted the pilot to a potential problem, and it would have been prudent for him to return to Milford Sound.

2.11 The FCU overhaul and repair records did not show that the flyweights' clip had been replaced. However, the clip was probably replaced with a new item during the repair and not adjusted and recorded. The clip weight stops were near perpendicular, similar to an unadjusted new item. Both the overhaul and repair records' data entries recorded the clip weight stop adjustments as being appropriate. Since the dial test indicator was correctly calibrated, this suggests either the data was entered on the repair documents without the appropriate measurement check being completed, or the check was inadequate.

2.12 The bench test technician could remove the FCU drive body and adjust the tension of the governor springs above the flyweights, if necessary, after the fitter completed his work. This, however, would not require any adjustment of the flyweights' clip. Governor spring tension adjustment by the test bench technician was not usually required. Accidental adjustment of the flyweights' clip to the condition found is almost impossible, and there was no evidence of any rotational contact with the outside of the clip weight stops.

2.13 Proper FCU test bench testing following the repair should have disclosed the flyweights' clip setting deficiency, and test points 9 should not have been achieved. However, the data under test points 9 was correctly entered on the test specification sheet. The test bench was reportedly within calibration. This suggests the data may have been entered without the test being carried out, or the test was completed incorrectly.

2.14 The TRW fitter involved in the FCU overhaul and repair also carried out the overhaul of the faulty PTG, which was fitted to the same engine type in another New Zealand registered Hughes 369D. Examination of that PTG indicated it had been overhauled incorrectly, which led to its failure. In addition, a CEB relating to the PTG was signed off as having been completed, when it had not.

2.15 TRW had been subject to ongoing surveillance by various agencies including the FCU manufacturer and CASA. On 7 June 2001 following the accident, CASA conducted a routine audit of the overhaul facility. This included inspection of: facilities; quality assurance; personnel; tooling and equipment; spare parts; technical publications; and maintenance records. No discrepancies were identified.

2.16 Despite the ongoing surveillance of TRW, this investigation disclosed a number of discrepancies and inconsistencies with 2 components that were repaired and overhauled by the facility between 1998 and 1999. One led to this accident, which had the potential to be fatal. The facility's anomalies may be restricted to the 1998 – 1999 period, and restricted to a few technicians only, but given the potential consequences of an in-flight engine failure a special investigation is warranted to determine the extent of any problems.

2.17 Although other similarly deficient components could potentially have been released to service by TRW, results of a New Zealand survey and a review of CAA records suggested this was not the case.

2.18 Given the operator's repeated concerns about engine overspeeds, including the 3 times the PTG had been removed and refitted with no real improvement, it is somewhat surprising the various maintenance personnel did not consider looking beyond the PTG. After the second change of the PTG, comprehensive fault diagnosis with reference to the trouble-shooting section in the maintenance manual could have been carried out and may have pointed to the FCU. The engine was also observed to hunt to some extent during a ground run following the 300-hour check when the PTG was last refitted, which could have prompted a deeper examination of the engine systems. A flight test, however, was performed satisfactorily and the pilot said he was satisfied with the helicopter performance.

2.19 Fault diagnosis was not always straightforward because maintenance personnel were generally frustrated by the performance of some FCUs following modifications over several years. Some units new from overhaul could be troublesome, especially during engine starting. This made trouble-shooting somewhat confusing.

2.20 The concerns maintenance personnel also held generally about the PTGs probably sidetracked them away from the real problem. PTGs were known to be sticky following overhaul, until they had operated for several hours. In addition, the replacement PTG fitted to the engine was perhaps more compatible with the defective FCU and may have masked some of the earlier symptoms. As well, the maintenance personnel did not always get consistent and accurate information about the performance of the helicopter to make informed fault assessments.

2.21 Although the FCU did not have the latest springs modification called for by the Alert CEB the springs did not cause the failure. Even though the operator's operations manual stated the engine was to be maintained in accordance with service bulletins, routine implementation of all bulletins was not in accordance with usual aviation practice. When writing the operations manual requirements, the operator's intention was not to require the routine implementation of all service bulletins. Bulletin implementation was not normally a mandatory requirement. The CEB, however, had not been studied by the chief engineer and discussed with the operator, in accordance with the operator's operations manual. This indicated improper CEB control and monitoring by Flightline, which should be rectified. Paradoxically, if the CEB had been implemented the incorrect flyweights' travel could potentially have been discovered and rectified by the overhaul facility completing the work.

3. Findings

Findings and safety recommendations are listed in order of development and not in order of priority.

3.1 The pilot was appropriately licensed and fit to conduct the flight.

3.2 The helicopter had a valid airworthiness certificate and was suitable for the operation.

3.3 The weather was suitable for the flight.

3.4 The helicopter engine flamed out in flight during normal application of power, because of a defective fuel control unit that induced engine hunting while at reduced power.

3.5 The fuel control unit had been repaired incorrectly by an approved Australian component overhaul facility and released to service, after which it was refitted to the engine.

3.6 Repeated engine overspeeding symptoms resulted after refitment of the repaired fuel control unit, over a period of 2 years and 8 months before the accident, but these were misdiagnosed as being power turbine governor related.

3.7 Comprehensive trouble-shooting should have been carried out after the power turbine governor had been changed several times, which could have isolated the engine overspeeding problem to the fuel control unit and averted the accident.

3.8 The performance of the deficient fuel control unit may have deteriorated further over time, until it ultimately brought about the flameout.

3.9 Improper monitoring and control of commercial engine bulletins resulted in the fuel control unit not being modified to the latest specification. This did not contribute to the flameout.

3.10 This investigation indicated a quality assurance problem had existed within the Australian component overhaul facility at some time. Because of the potential for safety-critical components to affect the safety of flight, a more in-depth investigation into the overhaul facility's performance is required.

4. Safety Actions

4.1 On 31 July 2001 the Australian Transport Safety Bureau advised that as a result of this investigation, on 12 July 2001, it identified a possible safety deficiency with TRW and initiated a systemic investigation of the facility. The Bureau will publish the results of this investigation separately.

5. Safety Recommendations

5.1 On 17 October 2001 the Commission recommended to the managing director of Flightline Aviation Limited that he:

5.1.1 establish a system to ensure proper monitoring and control of service bulletins (050/01)

5.1.2 review Flightline's Rolls-Royce Allison 250-C20B engine trouble-shooting procedures, and ensure comprehensive fault diagnosis is carried out when a repeated component change does not rectify a known problem. (051/01)

5.2 On 6 November 2001 the managing director of Flightline Aviation Limited replied:

5.2.1 Safety recommendation 050/01

There is no formal requirement to establish a system to ensure proper monitoring and control of service bulletins. Service Bulletins are produced by the manufacturer and after advice from the Civil Aviation Authority of New Zealand (NZCAA), there is no mandatory requirement to satisfy overseas manufacturer's Service Bulletins for General Aviation aircraft unless they are reproduced as Airworthiness Directives.

Flightline Aviation does however - as a reputable and professional organisation obtain, view and generally advise customers of the existence of manufacturer's Service Bulletins. Service Bulletins are received and assessed for applicability so that the customer has the option of accepting or rejecting their intent.

The issue has raised the point that there is general confusion within the aviation industry of whether, for example, a manufacturer's Service Bulletin is actually mandatory within NZ and must be satisfied. Reference A relates to a conversation with the NZCAA and confirmation was obtained regarding the General Aviation requirements relating to Service Bulletins. In short, there is no requirement for NZ maintenance organisations to abide by manufacturer's Service Bulletins (mandatory or otherwise) unless directed via a NZ Airworthiness Directive.

Reference B is the only direction that identifies aircraft types that have foreign source mandatory airworthiness requirements to be followed. The Rolls-Royce Allison 250-C20B engine is not included in this list.

5.2.2 Safety recommendation 051/01

As stated within our submission to the report, all the relevant trouble-shooting procedures (and more) were carried out in accordance with the maintenance manual pertaining to the defect information supplied at the time.

Flightline Aviation's engineering staff are qualified and well experienced concerning this engine type. All documented trouble-shooting procedures were followed in accordance with the maintenance manual and it is only in hindsight with a complete set of facts that anyone could conclude that repeated component changes in this instance might not have been the best course of action. During the maintenance process the defect information changed regularly, and based on past experience, Flightline staff acted reasonably in light of the information on hand.

The intent of the safety recommendation refers specifically to this one engine type. “Trouble-shooting procedures and comprehensive fault diagnosis for repeated component changes’ relates not to only this one task but all trouble-shooting tasks. It is a generic requirement and Flightline cannot implement additional processes concerning one task over any other. As such we believe there is no necessity to implement this safety recommendation in addition to our current practices.

5.2.3 Please note that Flightline Aviation Ltd supports and promotes a rigorous safety culture and associated work practices. The intention here is not to whole-heartedly disagree with TAIC safety recommendations but more importantly to ensure that any recommendations are based upon factually supported data and that requirements are necessary, able to be effectively implemented, and measurable. This is especially so for matters published within the public arena.

Approved for publication 31 October 2001

Hon. W P Jeffries
Chief Commissioner