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Faulty Repair of Fuel-control Unit Cited in Engine Flameout

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Robert A. Feeler, editorial coordinator

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On the cover: Accident investigators compared a new unadjusted fuel-control-unit flyweights' clip with one that was properly adjusted. The accident report said that the flyweights' clip probably had never been adjusted in a Hughes 369D that was substantially damaged during a landing in a wooded area after an engine flameout. (Photo: New Zealand Transport Accident Investigation Commission)

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Faulty Repair of Fuel-control Unit Cited in Engine Flameout

A report by the New Zealand Transport Accident Investigation Commission said that symptoms of engine overspeeding in the Hughes 369D helicopter were improperly diagnosed for more than 2 1/2 years before the accident.

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FSF Editorial Staff

At 0705 local time March 23, 2001, the pilot of a Hughes 369D helicopter being flown on a deer-hunting flight in southwestern New Zealand experienced an engine flameout as he applied collective control to stop the helicopter's descent. He landed the helicopter in trees on a mountainside at 3,000 feet, about 12 kilometers [7.5 statute miles] northwest of Milford Sound. The helicopter received substantial damage; neither the pilot nor the helicopter's owner, who was working as a crewmember, was injured.

The New Zealand Transport Accident Investigation Commission (TAIC) said, in the final report on the accident, that the engine "flamed out in flight during normal application of power because of a defective fuel-control unit [FCU] that induced engine hunting [oscillating: alternately running too fast or too slow] while at reduced power."

Other findings included the following:

- "Repeated engine overspeeding symptoms resulted after [reinstallation] of the repaired fuel-control unit, over a period of two years and eight months before the accident, but these were misdiagnosed as being power turbine governor [PTG]–related;

- "Comprehensive troubleshooting 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;
- "The performance of the deficient fuel-control unit may have deteriorated further over time, until it ultimately brought about the flameout;
- "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; [and,]
- "This investigation indicated [that] 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."

The pilot of the accident helicopter was 29 years old and held a commercial pilot license (helicopter) and a class 1 medical certificate. He had accumulated 3,000 flight hours, including about 850 flight hours in Hughes 369 helicopters.

The accident helicopter, which usually was flown for air tours and other commercial transport operations, was manufactured in the United States in 1977. When the accident occurred, the airframe had accumulated 7,278.55 hours of operation, and the Rolls-Royce Allison 250-C20B engine had accumulated 8,073.31 hours of operation. The last inspection was performed Feb. 22, 2001, at 7,212.2 airframe hours; during that inspection, a new compressor was installed in the engine.

The morning of the accident, the pilot conducted a takeoff from Milford Sound Aerodrome at 0645. The helicopter, which was operated by Milford Helicopters, had fuel for about two hours of flight. The pilot said that samples of fuel taken before the flight from the helicopter's belly drain and the airframe fuel filter revealed no contamination.

Weather for the flight was clear, with good visibility and calm winds.

The report said that, about 10 minutes after departure, the pilot observed "an unusual response from the helicopter, as though it had flown through its own turbulence." Simultaneously, the amber engine re-ignition light illuminated.

The pilot observed no other cockpit indications of abnormalities.

"About five minutes later, when the helicopter was approaching a 3,500-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,'" the report said. "There were no cockpit indications of any abnormalities.

"About a minute after leaving the knoll, the crew saw two deer running down the side of a hill. The pilot said he lowered the collective lever and reduced engine power to about 15 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 [cockpit warnings] and visual cockpit warnings that the helicopter engine had lost power. The pilot also noticed the engine gas producer turbine speed (N_1) decaying."

The pilot moved the collective lever to determine whether the engine would respond. There was no response, so he conducted an autorotation in a wooded area on a mountain slope. The helicopter rolled onto its left side, and the two occupants exited without injury. They used a radio to request assistance, and the crew of another helicopter rescued them.

Examination of the wreckage revealed that the engine was not rotating when the accident occurred. The fuel was not contaminated, and there were no deficiencies in the helicopter fuel system.

The report said that, during tests on the ground, the engine "started normally … 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. At 30 psi, the hunting became pronounced, with the torque rapidly fluctuating some 15 psi either side. The fuel flow fluctuated rapidly between about 78 pounds [35 kilograms] per hour and 160 pounds [73 kilograms] per hour. Minimum normal engine fuel flow at idle is around 79 pounds [36 kilograms] per hour.

"Engine torque was increased slowly, and the hunting subsided as power was increased above about 50 percent. At maximum power, the engine parameters were within specifications. As power was reduced below about 50 percent, the hunting recommenced, with the same results."

The report said that because of the oscillations in engine speed, rapid acceleration and deceleration tests were not performed.

Adjustments were not made during the tests of the FCU, the main component of the engine fuel-control system. Later, the PTG was replaced with a different unit; in subsequent ground runs, the oscillations continued. Then, the FCU was replaced with an overhauled FCU, and the engine started normally and accelerated normally throughout its power range and there were no oscillations in engine speed. Rapid acceleration and deceleration tests revealed that the engine was operating within specifications with no overspeeding. At the maximum power setting, the engine delivered 6 percent more than rated power.

The FCU in the accident helicopter was a Honeywell Bendix FCU (part no. 2524644-29) that last had been overhauled in December 1996 by an Australian component-overhaul facility, Lucas Aerospace (now TRW Aeronautical Systems). The FCU was installed — with zero hours since overhaul — in the accident helicopter by a maintenance technician in New Zealand in March 1997.

Overspeeding Reported in 1997

In December 1997, at 237 hours since overhaul, the FCU was removed "because it ran constantly at 110 percent power turbine speed (N_2)," the report said. "The FCU was returned to TRW for repair. Records showed the FCU had two 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 [that] the governor housing had been crack-checked at overhaul and that no cracks were detected. The repair records stated [that] the flow body assembly was not dismantled. … The operator believed the cracking occurred during service because the starter-generator developed vibrations."

The repair was completed June 24, 1998, and the FCU was tested and reinstalled in the accident helicopter July 31, 1998.

The report said that on March 15, 1999, Rolls-Royce Allison issued alert commercial engine bulletin (CEB) A-1361, revision 1, calling for replacement of the FCU's internal springs. (The CEB was first issued Oct. 5, 1998.) The spring-replacement was to be performed within 150 hours of receipt of the CEB, or no later than Oct. 31, 1999. The spring-replacement had not been performed on the accident helicopter, and the internal springs had not failed. The report said that failure of the springs would have resulted in immediate engine deceleration.[1]

"The operator did not receive service bulletins and said he was not aware of CEB A-1361," the report said. "Flightline [Flightline Aviation, the approved maintenance organization] received service bulletins but did not pass them on to the operator. Flightline's chief engineer [maintenance technician] 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."

The report said that the engine in the accident helicopter was equipped with a Honeywell Bendix PTG (part no. 2524769-14), which was examined several times during the two years before the accident because of the operator's concern that the engine was "overspeeding when power was reduced and [was] not holding its revs [revolutions per minute]."

The operator said that the problem was most noticeable in turbulence and that, "if the collective lever was lowered fully, the engine would overspeed, and the collective had to be raised to prevent it."

Maintenance personnel checked the PTG rigging in April 1999, before Flightline became the helicopter's approved maintenance organization.

On Aug. 6, 1999, Flightline maintenance personnel removed the PTG (at 1,316 hours time in service since its last overhaul) for overhaul. Another PTG was installed as a temporary replacement, and the operator said that, "although there seemed to be some improvement with the [replacement] PTG, the engine speed control was still not right."

The overhauled PTG was reinstalled on April 5, 2000. On June 26, 2000, Flightline requested that a different maintenance organization remove the PTG (at 67 hours time in service since the overhaul) because of engine overspeeding and reinstall the temporary replacement PTG.

"The PTG was returned to TRW for examination and testing," the report said. "Flightline requested the investigation report, which stated [that] the unit was governing slightly early (0.8 percent) at normal governing range but was governing slightly late at overspeed conditions."

The PTG was recalibrated to overhaul limits and on Oct. 24, 2000, was reinstalled in the engine by the maintenance organization that had removed it.

On Jan. 16, 2001, Flightline again asked the other maintenance organization to remove the PTG because of engine overspeeding and to reinstall the temporary replacement PTG, which had been operated for 146 hours since its last examination. The accident helicopter's PTG was again returned to TRW for examination and tests.

Flightline reinstalled the PTG in the accident helicopter on Feb. 22, 2001, during the 300-hour maintenance check.

"After the maintenance, the helicopter was run several times to track the rotor blades," the report said. "During the first ground run, [maintenance] engineers noticed the engine hunting (about 3 percent). 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 [ground] run. The hunting did not occur on subsequent [ground] runs. A test flight was carried out, and the pilot and engineers were satisfied with the helicopter's performance. … A few days later, the chief [maintenance] 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."

Flightline maintenance personnel said that PTGs sometimes were "sticky" during the first few hours of operation after an overhaul and that fluctuations in engine speed could occur as a result.

Operator Wanted Additional Maintenance

The operator said that the engine speed-control problem continued and that he had decided — although he had not told maintenance personnel — that he again would have the PTG removed.

The report said that the maintenance manual and the manufacturer's operation and service manual for the FCU and PTG said that a probable cause of overspeed incidents could be a defective FCU or a defective PTG. The manuals said that if the idle speed was normal during a ground run conducted under specific conditions, the PTG was probably the cause of the problem; if the idle speed was high, the FCU was the likely cause.

"Flightline advised [that] because the engine problems had not specifically been reported as overspeeding incidents, the part [FCU] was not followed," the report said. "The [reported] concern was more about unstable or erratic engine operation."

The operator and the pilot said that until the morning of the accident, they had not observed the problems that preceded the accident.

Further tests revealed that the PTG and the fuel pump had not contributed to the engine flameout.

Further tests of the FCU, however, revealed that the flyweights' clip was adjusted improperly, and as a result, the flyweights' movement was restricted to less than half of the required distance.

The FCU is designed so that its two flyweights rotate at a speed proportional to engine N_1. As N_1 increases, centrifugal force pushes the flyweights' path outward. The report said that 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."

"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," the report said.

The report also said that the flyweights' clip probably had been replaced during the 1998 repair and not adjusted. The clip weight stops resembled those of an "unadjusted new item," the report said. Maintenance records did not show that the flyweights' clip had been replaced, and entries in the records for the FCU overhaul and FCU repair both showed that the clip weight stop adjustments were appropriate.

"This suggests either [that] the data [were] entered on the repair documents without the appropriate measurement check being completed, or the check was inadequate," the report said.

The engine oscillating probably occurred soon after the repaired FCU was installed in the engine, but "the right mix of parameters to cause a flameout may not have come together until the day of the accident," the report said. "What is likely is [that] 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 [installation] of a new engine compressor 66 [flight] hours before the accident would have increased compressor discharge efficiency and engine performance. This could have further degraded the ability of the defective FCU to function adequately."

The FCU tests also revealed that the acceleration bellows pressure (P_X) air bleed restrictor orifice was enlarged at one end and that the surface around that end was scratched. At the opposite end of the restrictor, a screwdriver slot was deformed. The manufacturer said that the condition of the orifice probably caused no serious anomalies with the functioning of the FCU. Nevertheless, the manufacturer said that the air bleed "was in an unserviceable state because of its physical condition."

TRW said that the orifice should have been inspected during overhaul and that the P_X air bleed would have been removed and discarded if it had been in poor condition. Overhaul records did not show that the P_X bleed had been replaced. The report said, "Someone outside of TRW could have tampered with the P_X bleed and replaced the lock wire, which would explain the repair documentation stating [that] the lock wire near the access to the P_X bleed had been disturbed. … 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."

During the subsequent repair, the FCU flow body assembly was not dismantled, and such action was not required. Nevertheless, the report said, "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."

TRW had been approved by the Australian Civil Aviation Safety Authority (CASA) to perform overhauls and repairs of various aircraft components, including Honeywell Bendix FCUs and PTGs on Rolls-Royce Allison 250-C20B engines. Honeywell Bendix also authorized TRW to perform the work. The New Zealand Civil Aviation Authority accepted CASA approval of TRW for repairs and overhauls of components on aircraft registered in New Zealand.

TRW records showed that the FCU overhaul was performed by one maintenance technician, and the work was inspected and approved by "a fitter, who [had authority] to sign off the work," the report said. Another maintenance technician performed bench tests and made required adjustments.

When the FCU was returned for repairs, the same fitter performed and approved his own work. Another maintenance technician performed bench tests.

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

The report said that in a June 1999 internal audit, TRW checked the work folders for six recently completed jobs and found "a total of 35 major [issues], 31 minor [issues] and four question issues." The report did not say whether records about the accident helicopter's FCU were included in the audit.

After the accident, Flightline sent the FCU and the PTG from another Rolls-Royce Allison 250-C20B engine for examination by another independent Australian component overhaul facility. The PTG had been overhauled by the TRW fitter who had completed the repairs on the accident helicopter's FCU. The report said that examination of the PTG, which had accumulated 780 hours since the overhaul, revealed a number of deficiencies that rendered the PTG unserviceable. The report said that in addition, the authorized release certificate for the overhauled PTG — signed by the fitter — said that CEB 1327, incorporating new drive bearings, had been incorporated; nevertheless, older bearings were in the unit.

As a result of the investigation, TAIC issued the following two recommendations to the managing director of Flightline Aviation:

- The managing director should establish a system for "proper monitoring and control of service bulletins."

  In response, the managing director said, "There is no formal requirement to establish a system to ensure proper monitoring and control of service bulletins. …

  "Flightline Aviation does, however, as a reputable and professional organization, 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"; and,

- The managing director should review the organization's engine troubleshooting procedures to "ensure comprehensive fault diagnosis is carried out when a repeated component change does not rectify a known problem."

  In response, the managing director said, "All relevant troubleshooting 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 [is] well-qualified and well-experienced concerning this engine type. All documented troubleshooting 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. …

  "The intent of the safety recommendation refers specifically to

> this one engine type. 'Troubleshooting procedures and comprehensive fault diagnosis for repeated component changes' relates not only to this one task but all troubleshooting 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."

The managing director also said, "Flightline Aviation supports and promotes a rigorous safety culture and associated work practices. The intention here is not to wholeheartedly 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."

Also as a result of the TAIC investigation, the Australian Transport Safety Bureau (ATSB) conducted an investigation of the TRW facility, not identified by name in the ATSB report. The ATSB report said that CASA had audited the maintenance facility in February 1996 and had issued three noncompliance notices "outlining discrepancies." A December 1997 audit resulted in two noncompliance notices (NCNs), a June 1998 audit resulted in one documentation discrepancy, a September 1998 audit resulted in issuance of "one documentation-related NCN," and in April 1999, one noncompliance notice was issued "citing no corrective action following an internal audit." The ATSB report did not discuss other details of the noncompliance notices.

The ATSB report also said that the U.S. Federal Aviation Administration (FAA), which monitored the facility because of its work on components that were used in U.S.-registered aircraft, had revoked in 1997 the facility's FAA air agency certificate "because the facility did not conform to FAA regulations." FAA reinstated the certificate in December 2000.

CASA's records did not include documentation of the FAA actions, and CASA said that "there was no formal mechanism through which CASA would be advised of the results of any surveillance action taken by a foreign airworthiness agency on an Australian certificate-of-approval holder."

As a result of its investigation, ATSB recommended that CASA "consider formalizing a method to obtain and review the results of any foreign airworthiness authority audit of Australian certificate-of-approval holders." [CASA said, in a Feb. 4, 2003, response to the recommendation that its representatives would "consult with the relevant foreign airworthiness authorities" to develop formal procedures for obtaining results of foreign audits of Australian certificate-of-approval holders.]♦

[FSF editorial note: This article, except where specifically noted, is based on New Zealand Transport Accident Investigation Commission Aviation Occurrence Report 01-003 *Hughes 369D ZK-HMN, in-flight engine flameout, 12.5 kilometers northwest of Milford Sound* (17 pages with photographs) and Australian Transport Safety Bureau *Air Safety Recommendation R20020134* (three pages).]

Note

1. Implementation of service bulletins is not mandatory unless required by an airworthiness directive (AD). Neither the U.S. Federal Aviation Administration, the authority for the engine's country of origin, nor the New Zealand Civil Aviation Authority had issued an AD to require implementation of alert commercial engine bulletin A-1361. Normal aviation practice does not require that all service bulletins be implemented automatically. The operator's operations manual said that ADs or service bulletins that affected the accident helicopter were to be reviewed by the operator and the approved maintenance organization to determine what action was required.

MAINTENANCE ALERTS

Error Leads to Installation of Defective Landing Gear Parts

The right main landing gear of a Grumman G-73, a twin-engine amphibious aircraft being operated as a scheduled passenger flight, collapsed while the aircraft was being taxied to the parking ramp. There were no injuries to the two pilots or the 17 passengers.

According to the report by the U.S. National Transportation Safety Board (NTSB), the U.S. Federal Aviation Administration (FAA) found two pre-existing cracks and corrosion in the area where the landing gear had collapsed.

"Review of paperwork by company maintenance personnel revealed that components had been sent to a laboratory for examination," said the report. At the laboratory, the landing gear parts had undergone magnetic-particle inspection and X-ray inspection.

"Upon return of the components, the paperwork indicated that two components had been rejected due to cracks," said the report. "A red tag was also attached to the [laboratory] report."

The landing gear containing the rejected parts nevertheless was prepared, painted and installed on the accident airplane. Following the accident and investigation, the airline's director of maintenance said, "At this time, I realized that I had tagged an unserviceable part [as] serviceable by mistake," the report said.

NTSB said that the probable cause of the accident was "the improper review of component records by company maintenance personnel of returned landing-gear components from a laboratory for [magnetic-particle] and X-ray [inspection]."

Airworthiness Directive Calls for DC-9 Circuit-breaker Inspections

U.S. Federal Aviation Administration (FAA) Airworthiness Directive (AD) 2002-25-04 has been issued "to prevent internal overheating and arcing of circuit breakers and airplane wiring due to long-term use and breakdown of internal components of the circuit breakers, which could result in smoke and fire in the flight compartment and main cabin" of McDonnell Douglas DC-9-10, DC-9-20, DC-9-30, DC-9-40 and DC-9-50 series airplanes, and the C-9 military version of the DC-9. (The McDonnell Douglas Corp. merged with The Boeing Co. in 1997 and is now Boeing, Douglas Products Division.)

Within 18 months of the effective date (Jan. 17, 2003) of the AD, operators of the affected aircraft are required to perform a one-time general visual inspection of circuit breakers to determine the manufacturer of the circuit breakers, in accordance with McDonnell Douglas Alert Service Bulletin DC9-24A171, Revision 01, dated Sept. 21, 1999, excluding Evaluation Form. If any Wood Electric Corp. or Wood Electric Division of Potter Brumfield Corp. circuit breaker is found, that circuit breaker must be replaced with a new circuit breaker in accordance with the service bulletin. No circuit breaker having a part number listed in paragraph 1.A.2 of the service bulletin may be installed on any affected airplane, the AD said.

About 830 DC-9s in the affected series are in service worldwide, FAA said. An estimated 580 airplanes of U.S. registry will be affected.

Earlier ADs required similar inspection of other aircraft types. AD 2001-08-16, issued on April 17, 2001, applies to certain McDonnell Douglas Model DC-8 series airplanes and requires a one-time inspection to determine the manufacturer of the circuit breakers, and corrective action, if necessary. AD 2000-09-07, issued on May 3, 2000, applies to certain McDonnell Douglas DC-10-10, DC-10-15, DC-10-30, DC-10-30F and DC-10-40 series airplanes, and KC-10A (military) airplanes.

Deferred Maintenance Item Unrecorded, Overlooked

A Bell JetRanger 206B II helicopter was being used to apply agricultural chemicals northeast of Cromwell, New Zealand, on Sept. 11, 2001. An instructor pilot and a trainee pilot were on board, and the trainee pilot was the pilot flying. During the climb on the aircraft's 10th flight of the day, at 40 feet to 50 feet above ground level (AGL) and about 50 knots indicated airspeed, the trainee pilot lowered the collective lever and reduced power from about 100 percent torque to about 90 percent torque. The instructor pilot, who had been looking out the windshield, sensed the power reduction and turned his attention to the power-turbine-speed (N_2) indicator, which showed the power-turbine speed steadily decreasing and approaching 80 percent.

"Believing the engine was losing power, as though the throttle was being smoothly rotated to the closed position, [the instructor pilot] immediately took control of the helicopter and put his hand on the throttle and confirmed [that] it was fully open," said the accident report by the New Zealand Transport Accident Investigation Commission. "He lowered the collective lever and activated the rotor speed (N_R) selector switch to ensure [that] it was fully 'beeped' to maximum N_R." [The "beeper" is a thumb-activated switch by which the pilot makes small adjustments to N_R.]

The helicopter was landed heavily but it maintained some forward speed and became airborne again, reaching an altitude of about 40 feet AGL. After rotating about 270 degrees, the helicopter descended to the ground and came to rest upright with the throttle fully open and the engine turning. The pilots shut down the engine by moving the fuel selector to the off position. The pilots were not injured.

Maintenance records showed that on March 17, 2001, the company that maintained the helicopter had assigned an engineer to conduct field maintenance, and that the engineer had replaced the N_2 tachometer generator because there had been no N_2 indication on the dual gauge that indicated both N_R and N_2.

The engineer said that he had determined that the N_2 tachometer generator-drive-shaft receptacle was worn but serviceable. To replace the receptacle, which formed part of a gear in the accessory gearbox, the engine would have to be removed from the helicopter and the accessory gearbox opened. Because the work was too complex to be carried out in the field, the engineer planned to replace the generator-drive-shaft receptacle at the next scheduled maintenance time, and meanwhile inserted red RTV (a sealant) into the receptacle to prevent further wear or slippage.

The report said, "The engineer recorded the maintenance action on a company work record sheet for the helicopter, which formed part of the helicopter logbook records, but he did not record the need to subsequently replace the drive-shaft receptacle. The engineer said he overlooked transferring the requirement to replace the receptacle to the Additional Maintenance Due section on the maintenance advice form, and consequently he did not remember to complete the action.

"There was no loose-leaf [entry] or direct entry made in the helicopter logbook concerning the N_2 tachometer-generator replacement. Neither the pilot at the time, nor the engineer, made any entry in the aircraft technical [log] or daily flight log carried in the helicopter, and the operator was only verbally made aware of the need to replace the receptacle."

No erroneous N_2 gauge indications were reported subsequently, and the replacement of the N_2 generator-drive-shaft receptacle was overlooked at the next scheduled maintenance on March 27, 2001, and during later maintenance.

"Consequently, the RTV deteriorated over time and failed to prevent further wear, or failed to continue to assist in maintaining a positive drive, between the N_2 tachometer generator-drive-shaft and its receptacle, until slippage between them occurred," said the report. "On the accident flight, the drive failed, causing the N_2 gauge indication to decrease."

The report found that "the maintenance company and [the] operator did not have a suitable system in place to make certain that any additional maintenance action required following field maintenance was recorded correctly and completed at the next available aircraft servicing." The quality manager for the maintenance company subsequently advised the commission that corrective action had been taken, and a system established to ensure that required follow-up action would be recorded and performed at the appropriate time.

Uncontained Engine Failure Follows Ingestion of Bellmouth

The flight crew of a McDonnell Douglas DC-10-30F, engaged in cargo operations, began the takeoff from Amsterdam (Netherlands) Schiphol

Airport on a scheduled flight to London (England) Gatwick Airport. The pilots advanced all throttle levers to 50 percent N_1 (low-pressure fan speed) and engaged the autothrottle system. The selected power setting for takeoff was 103.4 percent N_1 derated. At about 75 percent N_1, the flight crew noted heavy vibration, and the captain, who was the pilot flying, observed an indication that the exhaust gas temperature (EGT) for the tail-mounted no. 2 engine was higher than the EGT for the other two engines. The Schiphol tower air traffic controller (ATC) reported that the no. 2 engine was on fire, although no warnings were given by the engine-fire-warning system in the cockpit.

The takeoff was rejected, and because of the high EGT indication and the ATC warning, the crew performed the "Engine Fire or Severe Damage" checklist. Nevertheless, when the aircraft rescue and fire fighting personnel arrived, there were no indications of a fire in the no. 2 engine, a General Electric CF6-50C2. None of the four crewmembers was injured in the accident.

"The left fan-reverser [cowling] and tailpipe cone from the [no. 2 engine], as well as numerous small debris, were found on and near the runway," said the accident report by the Dutch Transport Safety Board. "Fan blade parts had penetrated the fan cowlings. On the underside of the right inboard elevator, some damage was visible on the skin."

Investigators could find no evidence of damage to the accident engine prior to its failure.

"According to the [no. 2 engine] instrument read-outs registered during previous takeoff and cruise, the engine operated within [prescribed] limits," said the report. "The parameters showed average values, without any deviations. Also, the [no. 2 engine] trend-monitoring parameters presented normal values. The laboratory examination of the fan blades did not reveal pre-existing cracks or anomalies in the fan-blade materials. … Overall, it can be assumed that prior to the serious incident [the no. 2 engine] was in good condition."

During the investigation, a borescope inspection of the no. 2 engine indicated that a substantial quantity of debris had been ingested.

Investigators considered the possibility that the engine had ingested ice during the flight into Amsterdam, which had concluded about four hours and 35 minutes before the beginning of the takeoff roll for the accident flight. Investigators determined that under the conditions of the previous flight, ice ingestion could not be eliminated as a possibility but was "very unlikely," the report said. A bird strike was considered impossible because visual examination and a black-light inspection of the fan blades, spinner cone and associated parts showed none of the bird remains that would have been found after such an event.

"Between [the no. 2 engine] and the rigid inlet duct of the pylon [to which the engine is attached], the tail-engine inlet adapter is installed to provide a flexible coupling that compensates for engine movement caused by flexing of the pylon structure," said the report. "The inlet adapter consists of a bellmouth attached to the front flange of the engine and an adapter ring attached to the lower vertical-stabilizer rear-spar fireseal. The forward portion of the bellmouth fits inside the ring to permit a sliding action between the two parts."

The most probable cause of the engine failure, according to the report, was ingestion of parts of the bellmouth into the engine.

The bellmouth assembly is supported by 13 attachment brackets. On the accident engine, "nine brackets were intact, from which six did not exhibit distortion or other damage," said the report. "From the remaining three intact brackets, one suffered distortion, one showed a crack and the last one was gouged."

The report said that the aircraft manufacturer had reported six events directly related to bellmouth failures or adapter-ring failures, and in response the manufacturer had issued service bulletins SB 71-73, SB 71-75 and SB 71-76. In addition, the U.S. Federal Aviation Administration published a related airworthiness directive, AD 75-12-03.

The report said, "According to the manufacturer, it is known that conditions that may cause bellmouth [failures] and adapter-ring failures are:

- "Improper repair of the bellmouth/inlet-adapter-ring assembly;
- "Engine no. 2 inlet ice ingestion due to accumulation of snow and ice during wintertime, FOD [foreign object damage] and bird strikes;
- "Bellmouth and inlet-adapter ring not properly installed and rigged; [and,]
- "Nonrepaired excessive bellmouth/inlet-adapter-ring delamination."

No previous event involving bellmouth failure had led to complete ingestion in the engine or an uncontained engine failure, but ingestion of the bellmouth appeared to have occurred in this accident, the report said.

The report said, "It is evident that the bellmouth failed at the joints between the brackets and honeycomb material, which seems to be similar to earlier events associated with bellmouth failures where bellmouth failure mode was affected by an irregularity in the installation condition. …

"It is believed that the bracket at the four o'clock position [forward looking aft] itself stayed intact, but the joint between the bracket and the honeycomb material of the bellmouth probably had been weakened by influence of (normal) engine vibrations, movements due to throttle (power) transients and landings. It is likely that the joint of this particular bracket eventually broke and caused the bellmouth to become unsupported in that position, thereby imposing more load on the adjacent brackets and perpetuating the failure mode. Finally, after 2,599 [flight] hours (about seven months since [the] last overhaul of the aircraft and 10 months since the last 2C inspection of the bellmouth and the adapter ring) the bellmouth panels were ripped off from the brackets and were ingested into the engine. …

"The loose and distorted bracket found during the investigation supports the thesis that improper installation was the initiating factor in this particular incident."

The report did not prescribe any remedial action on the grounds that proper installation and rigging of the bellmouth assembly were presented adequately in existing service bulletins, airworthiness directives and maintenance procedures.♦

NEWS & TIPS

Digital Video Recorder Stores Inspection Video on Hard Disk

The DV Sidekick from iShot Imaging is a lightweight, compact digital video recorder that can record up to 6.5 hours of inspection video at broadcast-quality resolution, or more than 33 hours at maximum video-data compression, on the highest-capacity model. The recorder can be used with video probes, camera crawlers, pole cameras and other video-based inspection equipment, the manufacturer said.

Video images in the DV Sidekick are stored on a hard disk, available in 120-gigabyte (GB), 100-GB, 80-GB, 60-GB and 40-GB models. Recording time is determined by hard-disk capacity, frame rate and the compression ratio, which is selectable between 4-to-1 and 20-to-1. Besides the standard television rate of 30 frames per second (fps), rates as low as 2 fps can be chosen for long-term monitoring.

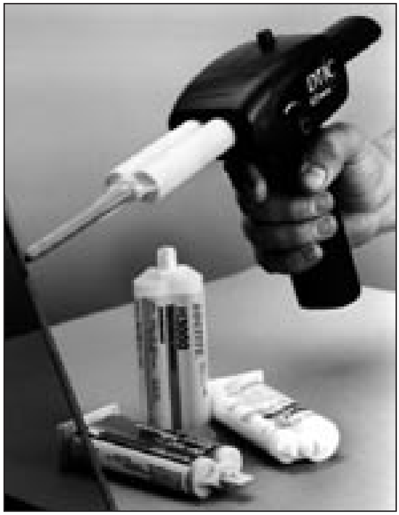
The DV Sidekick can be clipped to an operator's belt, worn on a neck strap, mounted on other equipment or set up to be freestanding. Controls are located on a keypad that is integral with the recorder, which supports both the NTSC and PAL formats. S-video inputs and outputs, as well as composite inputs and outputs, are available.

For more information: InterTest (the parent company of iShot Imaging), 303 Route 94, Columbia, NJ 07832 U.S. Telephone: +1 (908) 496-8008.

Hand-held Adhesive Dispenser Reduces Leakage

The EZ-mix HI Dispenser is a cordless electric hand-held adhesive dispenser that accommodates standard 50-milliliter (17-ounce) two-component cartridges. The dispenser is designed to significantly reduce leakage from the mix tip after the light-touch trigger is released, said the manufacturer, DTIC Dispensing Technologies.

The dispenser features variable-speed control of its direct-current (DC) motor that allows the user to adjust the speed to the viscosity of the material dispensed and the requirements of the application. The power supply is a six-volt nickel-metal-hydride (NiMH) battery pack. The motor can produce a maximum 200 pounds (91 kilograms) force. The contents of as many as 50 cartridges, depending on the material's viscosity, can be dispensed before the battery needs recharging, the manufacturer said.



Cordless Electric Hand-held Adhesive Dispenser

For more information: DTIC Dispensing Technologies, 835 Sterling Road, South Lancaster, MA 01561 U.S. Telephone: (877) 367-3842 (U.S.) or +1 (978) 365-1884.

Drill Uses Tangential Blades

The KUB Duon drill from Komet has exchangeable cutting blades that are capable of drilling holes with a length-to-diameter ratio of as much as 5-to-1.

Tangential positioning of the blades results in a high degree of stability during use, the manufacturer said.

Cutting-blade diameters are available in both English and metric measurements, ranging from 0.828 inch to 1.156 inch (21.0 millimeters to 29.5 millimeters). Cutting-blade inserts are secured with clamping screws, which are designed for easy and fast exchange of blades. Applications include cutting cast steel, cast iron, low-alloy steel, high-alloy steel and nonferrous metals.

For more information: Komet of America, 2050 Mitchell Blvd., Schaumburg, IL 60193 U.S. Telephone: +1 (847) 923-8400.

Kit Tests for Aviation-fuel Fungus

Horoconis resinae, a microscopic fungus, thrives in aviation fuel and can damage the linings of fuel tanks. Contamination of fuel by the fungus is particularly prevalent in tropical environments or when aircraft spend an extended time in hangars. The FUELSTAT *resinae* diagnostic kit from Conidia Bioscience offers a fast and convenient method to test for the presence of the fungus in kerosene fuel samples, the manufacturer said.

Results are classified as negative (there is little or no contamination and no action is required); low positive (there is enough contamination to warrant the application of biocide to fuel to kill the fungus); or high positive (there is serious contamination that requires application of biocide and removal of the microbial contamination from inside the fuel tank).

For more information: Conidia Bioscience, Bakeham Lane, Egham, Surrey TW20 9TY England. Telephone: +44 (0)1491 829012.

Fiber-optic System Bends Light

Aviation maintenance technicians work in structural areas, fuel tanks and installations that are sometimes difficult to illuminate because of obstructions or narrow openings. One tool designed to make viewing of confined spaces easier is the 3M High Intensity Fiber Optic Flashlight System.

The system consists of a flashlight base to which is fitted the wide end of a cone, lined with reflective material to concentrate the light. Attached to the narrow end of the cone is a flexible fiber-optic tube, available in seven-inch or 12-inch (18-centimeter or 30-centimeter) lengths. When the flashlight is powered, the fiber-optic tube is illuminated along its entire surface, with a high-intensity spot at the tip.

The flashlight, which uses AA-size batteries, meets Underwriters Laboratories (UL) specifications for use where flammable gases, vapors or liquids exist, the manufacturer said.

For more information: 3M Aerospace, 3M Center, Building 220-8E-05, St. Paul, MN 55144 U.S. Telephone: (888) 364-3577 (U.S.) or +1 (651) 737-7117.

High Intensity Fiber Optic Flashlight System

Parts Cleaner Uses Water-based Solution

PB10 and PB20 Parts Blasters from Peterson Machine Tool use a heated cleaning solution sprayed at 600 pounds per square inch (42 kilograms per square centimeter) to strip away grease and grime. The water-based solution has environmental-safety advantages and equal cleaning effectiveness compared with solvents, the manufacturer said.

The cleaning machines have seven-day timers for energy conservation and temperature-controlling thermostats. Either a dual-fan or a "pencil" spray pattern can be selected to direct the spray. The cleaning solution is filtered so that the Parts Blaster can be used for final cleaning before assembly, the manufacturer said. Optional casters enable the units to be moved to different locations within the work area.

For more information: Peterson Machine Tool, 5425 Antioch Drive, Merriam, KS 66202 U.S. Telephone: (800) 255-6308 (U.S.) or +1 (913) 432-8970.♦

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