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Robert A. Feeler, editorial coordinator

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Continued Limits Recommended on Use of Cellular Telephones in Aircraft

The U.K. Civil Aviation Authority included the recommendation in its report on tests that measured cellular telephone interference with avionics. Other reports from the United States and Australia cite more than 200 occurrences in which cellular telephones and other personal electronic devices were believed to have interfered with aircraft avionic equipment.

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FSF Editorial Staff

Tests conducted by the U.K. Civil Aviation Authority (U.K. CAA) show that cellular telephone (cell phone) transmissions can cause a variety of measurable adverse effects on aircraft avionic equipment, including erroneous compass readings and reversals of "to/from" indicators on very-high-frequency omnidirectional radios (VORs).[1]

Reports attributing abnormal behavior of avionic equipment to personal electronic devices (PEDs; also called portable electronic devices or passenger electronic devices) — including cell phones (also called mobile phones) — carried aboard by passengers or crewmembers have persisted for years, but specialists have disagreed about whether the electronic devices present risks to flight safety.[2]

A 2003 report by the U.K. CAA said that the authority received 35 reports of aircraft safety-related occurrences between March 1996 and December 2002 that cited cell phone transmission interference as a factor.

The U.K. CAA report said that the interference had the following effects:

- "False warnings of unsafe conditions (e.g., baggage compartment smoke alarms);
- "Distraction of the flight crew from their normal duties." [The report said that distraction is "a factor in altitude busts and runway incursions."];
- "Interrupted communications due to noise in the flight crew headphones;
- "Increased workload for the flight crew and the possibility of invoking emergency drills;
- "Reduced crew confidence in protection systems [that] may then be ignored during a genuine warning; [and,]
- "Malfunctioning of multiple systems essential to safe flight."

The U.K. CAA report cited a 2001 report by the U.S. National Aeronautics and Space Administration (NASA)[3] that analyzed 118 occurrences involving PEDs that were reported to the NASA Aviation Safety Reporting System (ASRS).[4] In 25 of the 118 occurrences, cell phones had "a strong correlation with the event," and 16 occurrences were "associated with a critical anomaly," the report said. The report said that there were no reports in which aircraft systems were found faulty during checks by maintenance personnel after PED anomalies.

The NASA report said that the anomalies affected aircraft navigation systems "86 percent more often than any other system on the aircraft."

"If these events were happening at cruise altitudes where a pilot's workload is lower than for any other flight phase, they might not be cause for concern, but that is not the case," the NASA report said. "The data clearly indicate that not only were some events judged as having had a critical effect on a system, but they also happened during critical stages of flight, specifically landings and takeoffs."

CASA Describes Australian Incidents As "Worrying"

The Australian Civil Aviation Safety Authority (CASA) said in the September–October 2003 issue of its safety magazine that more than 100 reports had been filed during the previous decade with the Australian Transport Safety Bureau (ATSB) about incidents believed to have involved interference from cell phones and other PEDs with aircraft avionic equipment. No accidents were associated with PEDs; nevertheless, CASA said, "many of the incidents were worrying."[5]

Studies have been conducted in three countries to evaluate the extent of cell phone interference with aircraft avionics. Source: Corbis

For example, the CASA report said that in August 2001, as a light aircraft was being taxied for departure from an airport in Western Australia, its global positioning system "failed to lock onto satellites fully. Halfway through the flight, the system turned itself back on and worked normally. On landing, the pilot discovered that a passenger had had a mobile phone on in the first half of the flight in order to check the unit's range."

In late 2002, also in Western Australia, a Boeing 737 autopilot "initiated an uncommanded climb, which was attributed to a passenger's use of a personal computer," the CASA report said. Investigators were unable to replicate the occurrence.

CASA has proposed regulations to prohibit use of cell phones and other electronic transmitters on aircraft "at all times" and to prohibit use of laptop computers, video cameras and electronic games during takeoffs and landings and at the direction of a crewmember. CASA regulations currently allow cabin crewmembers to prohibit the use of an electronic device if they believe aircraft safety is at risk.

The U.K. CAA report said that the total number of reported occurrences involving cell phone interference is "relatively low, considering the number of aircraft flights involved.

"The difficulties experienced in trying to reproduce the events have led many (including pilots) to question whether a genuine problem exists. However, the potential adverse impact on flight safety and the need to keep that risk to tolerable levels have led to restrictions on the use of cell phones in aircraft."

On the Ground, Risks Are Small

The report said that there is likely to be little interference from a cell phone in an aircraft while that aircraft is on the ground and probably relatively near a base station for cell phone transmissions.[6]

"Under these circumstances, the network would set the cell phone output power to a low level, sufficient to maintain the link," the report said. "The interference risk would, as a result, be low. As the aircraft increases its distance from the base station, the output power setting of the cell phone is increased, eventually to its maximum rating. The risk of interference is then at its greatest."

Cell phone transmission also can be affected when the cell phone is inside a metallic aircraft fuselage, where "complex propagation paths arise [because of] reflections from the metallic structure that can lead to signal cancellation or reinforcement at different locations in the aircraft," the report said. "Tests performed by [the U.K.] CAA in February 2000 have shown that the field strength of the interfering cell phone transmission, at maximum power, will exceed by a significant margin the levels used in susceptibility tests for avionic equipment qualified to earlier standards. Similarly, these tests have shown that interference levels would vary by relatively small changes of location of a cell phone and that persons obstructing the transmission path reduce the interference."

In October 2002, the U.K. CAA conducted tests to determine the level of cell phone interference required before aircraft avionic equipment is affected and to determine how those levels relate to cell phone capabilities.

Tests Involved Various Levels of Interference

"The strategy of this second phase [of tests] involved exposing aircraft avionic equipment, installed on a rack assembly inside a screened test chamber, to increasing levels of interference from simulated cell phone transmissions," the report said. "The objectives were to identify any anomalies caused by the equivalent of an intentional cell phone transmission, such as misleading indications, false warnings of unsafe conditions, degraded performance and audio noise, then to note the level of interference causing each observed anomaly."

The tests did not evaluate the effects on avionic equipment of electronic processing within a cell phone in the receive mode — an unintentional transmission. (The report said that, even when cell phones are in the "standby" mode, they continue to "transmit periodically to register and re-register with the cellular network and to maintain contact with a base station.")

The report said that researchers would have preferred to conduct the October 2002 tests using airline equipment but could not because of "practical considerations of equipment availability, its size, power requirements and complexity of the interface system." Therefore, they used digital and analog general aviation avionic equipment — a very-high-frequency (VHF) communication transmitter, a VOR/instrument landing system (ILS) navigation receiver and associated indicators, and a gyro-stabilized remote-reading compass system — that were assembled to create an integrated system. The report described the equipment as "representative of equipment currently in use but designed and qualified to the earlier, less-demanding standards." None of the equipment had a known history of susceptibility to cell phone interference.

The equipment was connected in accordance with the manufacturer's installation instructions, using standard aircraft components and wiring, antenna connections, a 28-volt direct current power supply and heavy-gauge bonding straps to connect the test rack to the test-chamber ground plane. The report said that the assembly, "from an interference-susceptibility standpoint, … was representative of the manner in which the equipment would be installed in an aircraft."

"With the aid of cell phone signal generators, power amplifiers, monitoring equipment and avionic test equipment, signals were injected into each receiver … and the assembly was exposed to interference up to a maximum level of 50 volts per meter," the report said.

"The avionic test equipment was used to provide signals that exercised the aircraft equipment. The aircraft equipment was monitored for performance of intended functions. The tests did not require the VHF transmitter to operate."

The tests used cell phone frequencies of 412 megahertz, 940 megahertz and 1719 megahertz, with maximum strength of 50 volts per meter; simultaneous tests were conducted involving cell phone frequencies of 940 megahertz and 1719 megahertz, with a maximum combined strength of 35 volts per meter. One receiving frequency was tested in each aviation band — VHF communications, VOR navigation, ILS localizer and ILS glideslope.

The report said that researchers monitored effects "at the external interface with the equipment" and that the equipment's other performance characteristics were not monitored.

"The equipment selected for these tests represented a very small sample of avionic equipment in general use," the report said. "[Although] the results provided an indication of the types of problem that can arise, assumptions about their applicability to other equipment should be made with due caution."

Tests Reveal Numerous Problems

The report said that the tests revealed a variety of adverse effects on the performance of avionic equipment — all observed at interference levels of more than 30 volts per meter, a level produced by a cell phone that is operated at maximum power within 30 centimeters (12 inches) from the avionic equipment or its wiring harness; most anomalies were observed at 1719 megahertz. The anomalies included the following:

- "Compass froze or overshot actual magnetic bearing;
- "Instability of indicators;
- "Digital VOR navigation bearing display errors up to five degrees;
- "VOR navigation to/from indicator reversal;
- "VOR and ILS course deviation indicator errors, with and without a failure flag;
- "Reduced sensitivity of the ILS localizer receiver; [and,]
- "Background noise on audio outputs."

The avionic equipment showed "a satisfactory margin above the original certification criteria for interference susceptibility," but that margin was "not sufficient to protect against potential cell phone interference under worst-case conditions," the report said.

Anomalies Could Cause Confusion, Distraction

For flight crewmembers, the consequences of the observed anomalies in the functioning of avionic equipment could include "crew distraction, confusion and loss of confidence in the equipment," the report said. "The degraded navigation precision could result in an inability to meet required navigation performance with potential adverse effects on aircraft separation and terrain clearance."

The report included the following recommendations:

- "For safety reasons and to keep the risks from cell phone interference to tolerable levels, the regulatory authorities should continue to restrict the use of cell phones by passengers in aircraft, as detailed in Leaflet 29 [*Guidance Concerning the Use of Portable Electronic Devices on Board Aircraft*] published by the European Joint Aviation Authorities;[7,8]

- "Aircraft operators should alert their flight crews to the specific risk from active cell phones on the flight deck and [should] introduce procedures to ensure they are switched off. Similarly, the general aviation community should be alerted to the interference risk in small aircraft;

- "The regulatory authorities should request airport operators and airlines to consider additional measures to further minimize the risks from cell phones when passengers inadvertently fail to switch them off, including … seeking confirmation from passengers at check-in that cell phones in luggage have been switched off and displaying reminder notices in airport departure lounges and at aircraft boarding points;

- "EUROCAE [the European Organization for Civil Aircraft Equipment] and RTCA should amend the minimum equipment qualification levels for radio frequency susceptibility, as defined in EUROCAE ED-14D and RTCA DO-160D, Section 20, with the objective of providing an increased margin against potential interference from cell phones and other transmitting devices used [aboard] the aircraft. Particular attention should be given to minimum susceptibility requirements for equipment intended for installation on the flight deck;[9] and,

- "Recognizing that cell phone technology continues to evolve and that other communication devices are becoming available for general use, the regulatory authorities should continue research to ensure the interference risk in aircraft from such devices is properly understood and mitigated."

A similar evaluation of cell phones and other PED technology is being conducted by RTCA at the request of the U.S. Federal Aviation Administration. The first phase of the evaluation — an assessment of PED technologies that currently exist — is scheduled for completion in January 2004. The second phase — an assessment of emerging PED technologies — is scheduled for completion in October 2005.[10]♦

Notes

1. U.K. Civil Aviation Authority (U.K. CAA). *Effects of Interference From Cellular Telephones on Aircraft Avionic*

Equipment, CAA Paper 2003/3. April 30, 2003.

2. FSF Editorial Staff. "Airlines Around the World Are Adding a New Line to Safety Briefings: 'Turn Off and Stow Your Electronic Devices.'" *Cabin Crew Safety* Volume 28 (September–October 1993).

   A 1993 report by McDonnell Douglas Aircraft Co. said that there were 57 reports worldwide from 1983 through 1989 of electromagnetic interference with avionic equipment caused by personal electronic devices (PEDs); from 1990 through 1992, 40 occurrences were reported.

3. Ross, Elden. *Personal Electronic Devices and Their Interference With Aircraft Systems*, NASA/CR-2001-210866. A special report prepared at the request of the U.S. National Aeronautics and Space Administration (NASA). June 2001.

4. The NASA Aviation Safety Reporting System (ASRS) is a confidential incident-reporting system. The ASRS Program Overview said, "Pilots, air traffic controllers, flight attendants, mechanics, ground personnel and others involved in aviation operations submit reports to the ASRS when they are involved in, or observe, an incident or situation in which aviation safety was compromised. … ASRS de-identifies reports before entering them into the incident database. All personal and organizational names are removed. Dates, times, and related information, which could be used to infer an identify, are either generalized or eliminated."

   ASRS acknowledges that its data have certain limitations. ASRS *Directline* (December 1998) said, "Reporters to ASRS may introduce biases that result from a greater tendency to report serious events than minor ones; from organizational and geographic influences; and from many other factors. All of these potential influences reduce the confidence that can be attached to statistical findings based on ASRS data. However, the proportions of consistently reported incidents to ASRS, such as altitude deviations, have been remarkably stable over many years. Therefore, users of ASRS may presume that incident reports drawn from a time interval of several or more years will reflect patterns that are broadly representative of the total universe of aviation-safety incidents of that type."

5. Higgens, Russell. "Switched Off: Research Underlines the Dangers of Using Mobile Phones and Other Portable Electronic Devices in Flight." *Flight Safety Australia* Volume 7 (September–October 2003).

6. Some airlines have eased restrictions to allow passengers to use their cell phones during some periods on the ground after an aircraft has been landed and while it is being taxied to the gate.

7. *Leaflet 29, Guidance Concerning the Use of Portable Electronic Devices on Board Aircraft* says that if an aircraft operator permits passengers to use PEDs, the operator must have procedures in place to regulate their use. The leaflet says, "At a minimum, procedures [must] ensure that cell phones and other transmitting devices are not used and are switched off from the time at the start of the flight when the passengers have boarded and all doors have been closed until the end of the flight when a passenger door has been opened. At the [captain's] discretion, the use of cell phones may be permitted when the aircraft is stationary during prolonged departure delays, provided that sufficient time is

available to check the cabin before the flight proceeds. Similarly, after landing, the commander may authorize cell phone use in the event of a prolonged delay for a parking/gate position."

8. In the United States, Federal Aviation Administration (FAA) Advisory Circular (AC) 91.21-1A, *Use of Portable Electronic Devices Aboard Aircraft,* permits the operation of some PEDs and other devices if the aircraft operator has determined that their operation will not interfere with the safe operation of the aircraft. The AC says that if an operator allows use of PEDs, the operator must establish procedures for informing passengers of limitations involving their use.

   Nevertheless, the AC says that the U.S. Federal Communications Commission (FCC) prohibits the operation of cell phones while an aircraft is airborne. The AC says that FCC's primary concern is that "a cellular telephone, while used airborne, would have a much greater transmitting range than a land mobile unit. This could result in serious interference to transmissions at other cell locations since the system uses the same frequency several times within a market. Since a cellular mobile telephone unit is capable of operating on all assignable cellular frequencies, serious interference may also occur to cellular systems in adjacent markets. The FAA supports this airborne restriction for reasons of potential interference to critical aircraft systems. Currently, the FAA does not prohibit use of cellular telephones in aircraft while on the ground if the operator has determined that they will not interfere with the navigation or communication system of the aircraft on which they are to be used. An example might be their use at the gate or during an extended wait on the ground, while awaiting a gate, when specifically authorized by the captain. A cellular telephone will not be authorized for use while the aircraft is being taxied for departure after leaving the gate."

9. The European Organization for Civil Aviation Equipment (EUROCAE) and RTCA (organized in 1935 as the Radio Technical Commission for Aeronautics), a private corporation that develops recommendations for communications, navigation, surveillance and air traffic management systems, work together to develop avionics standards. EUROCAE ED-14D and RTCA DO-160D discuss standard procedures and environmental test criteria for testing airborne avionic equipment.

10. *SC-202 Portable Electronic Devices.* <www.rtca.org>. Oct. 22, 2003.

Further Reading From FSF Publications

Ginotra, Vijay K. "Electromagnetic Interference to Aircraft Systems: The Sources and Effects." In *Safety: Beginning at the Top: Proceedings of the 12th European Aviation Safety Seminar.* Alexandria, Virginia, U.S.: Flight Safety Foundation, 2000.

Department of Transport and Regional Development, Bureau of Air Safety Investigation, Australia. "Advanced-technology Aircraft Safety Survey Report." *Flight Safety Digest* Volume 18 (June–August 1999).

FSF Editorial Staff. "Loose Connection on Battery Shunt Involved in Boeing 767 Emergency-landing Incident." *Aviation Mechanics Bulletin* Volume 47 (January–February 1999).

FSF Editorial Staff. "Dubrovnik-bound Flight Crew's Improperly Flown Nonprecision Instrument Approach Results in Controlled-flight-into-terrain Accident." *Flight Safety Digest* Volume 15 (July–August 1996).

Inadequate Maintenance Cited in In-flight Separation of APU Doors

The Boeing 767-332ER was in climb to cruise altitude through 15,000 feet and accelerating through 320 knots after takeoff from Hartsfield Atlanta (Georgia, U.S.) International Airport on a passenger flight to Milan, Italy. According to the captain, a loud noise was followed by a severe vibration of the entire airplane. The captain leveled the aircraft and called for an airspeed reduction to 270 knots. Although the cockpit displays indicated no abnormalities, the captain decided as a precaution to return to the airport. The airplane was landed at Atlanta without incident and there were no injuries to the flight crew, cabin crew or 187 passengers aboard. The airplane was substantially damaged in the April 5, 2002, accident.

"The examination of the airframe revealed that both APU [auxiliary power unit] doors were missing from their normally installed positions," said the accident report by the U.S. National Transportation Safety Board. There was a hole measuring 19 inches (48 centimeters) wide by 26 inches (66 centimeters) long in the left inboard elevator. Another hole, on the right inboard elevator, was 14 inches (36 centimeters) wide by 29 inches (74 centimeters) long. The fuselage structure enclosing the APU also was damaged.

"Prior to the flight, the ground personnel had conducted a pre-departure check that included the servicing of the APU," said the report. "This check was performed one hour before the flight."

The report said that the operator's engineering division suggested two possible causes for the loss of the APU doors: latch disengagement or the failure of the receiving pins. The right door was recovered in three pieces, and the left door, to which the receiving pins were attached, was not recovered.

"Failure examination of the right-door structure indicated that a load was applied to the forward-lower corner of the door and it failed in a tearing motion," said the report. "The APU door aft-latch hook had been severed. The other portions of the recovered door [showed] rivet failures and structural failures also suggestive of an overload condition."

The report determined that the probable cause of the accident was "company maintenance [personnel's] inadequate maintenance inspection that resulted in the in-flight separation of the APU inspection doors."

Fumes From Hydraulic-system Coupling Penetrate Cabin

The British Aerospace BAe 146-100 was being taxied for takeoff on a flight from Brisbane, Australia, to Alice Springs when the flight crew noticed a hydraulic-system "LOW QUANTITY" warning light on the instrument panel. About the same time, a cabin crewmember alerted the pilots to the presence of fumes, described by passengers and two off-duty cabin crewmembers as a slowly moving white haze. "The haze was acrid and transparent and caused coughing and breathing difficulties," said the report by the Australian Transport Safety Bureau (ATSB) on the July 22, 2002, incident.

One of the off-duty cabin crewmembers also went to the flight deck to tell the captain that there was smoke on the right side of the cabin. The aircraft was stopped on the taxiway, the engines were shut down and an evacuation was ordered. Despite some initial disorder, the passengers evacuated the cabin with no injuries using slides on the left-forward door and left-rear door. The two off-duty cabin crewmembers exited first and positioned themselves where they could assist passengers.

Cabin crewmembers who had inhaled vapors, or who had helped passengers, reported that later in their tours of duty they suffered extreme tiredness, sore muscles and minor throat problems and chest problems.

"Two independent systems provided hydraulic power to the aircraft flight controls and landing gear," said the report. "The power-generation components were housed in the hydraulic bay, situated immediately forward of the main-landing-gear bay, below the forward rows in the passenger cabin."

The aircraft operator's inspection found a leak in a hydraulic-system coupling. The leak had allowed pressurized hydraulic fluid to escape as vapor into the hydraulic bay, and then to enter the cabin through gaps in the sealing of the bay, the report said.

"The o-ring seal for the coupling was replaced and the leak stopped," said the report. "After a number of flights the coupling leak reoccurred. On closer inspection it was found that the coupling had a crack along its threads. The coupling was replaced."

Subsequent nondestructive testing of the failed coupling showed that the coupling had cracked from overload, which was consistent with the coupling having been over-tightened, the report said. The crack in the coupling threads may have been present at the time of the first hydraulic-fluid vapor leak, but if so, the effects were masked temporarily by the replacement of the o-ring.

The aircraft manufacturer had issued three service bulletins concerning remedial action to improve the insulation between the hydraulic bay and the cabin. "At the time of the occurrence, the operator had incorporated the first two service bulletins and had scheduled, but not commenced, the third," said the report.

Despite praising cabin crewmembers for their assistance that helped ensure a successful evacuation, ATSB noted that they had violated company procedure by opening the flight-deck door when fumes were present.

The report said, "Although crewmembers had conducted an evacuation and some had inhaled fumes, both flight [crew] and cabin crew continued the tour of duty without rest. Following abnormal events, the ability of crewmembers to carry out their safety duties for the care of passengers on subsequent flights may [have been] adversely affected due to the effects of the event."

As a result of its investigation, the report said, the operator took the following actions:

- "Carried out a fleet inspection that did not find evidence of any other coupling failures;
- "Accelerated the scheduled program on its remaining fleet for the implementation of all the manufacturer's service bulletins related to proper sealing of the hydraulic bay;
- "Advised the ATSB that all manufacturer's advised modifications have since been incorporated on the occurrence aircraft; [and,]
- "Recommended company procedural changes, including whenever possible using able-bodied passengers to assist at the base of slide during an evacuation and consideration of stand-down of crews following an emergency."

Impurities Found in Fractured Tail-rotor Blade Spar

On June 12, 2002, an Agusta A119 public-use helicopter was being flown on a training mission with the pilot, a paramedic and a technician aboard. Shortly after takeoff from a hospital helicopter pad in Okeechobee, Florida, U.S., at an altitude of 250 feet, there was a loud noise and the aircraft yawed to the right. The paramedic in the helicopter said that she saw parts of the tail rotor pass to the left of the aircraft. The pilot turned the helicopter 270 degrees to the right and conducted a run-on landing in a pasture. After touchdown, the helicopter skidded and pitched forward. The nose contacted the ground, then the main-rotor blades struck the tail boom and separated the tail boom from the fuselage. None of the occupants was injured.

"The tail-rotor blades and portions of the tail-rotor gearbox were removed from the helicopter and examined at the NTSB [U.S. National Transportation Safety Board] Materials Laboratory," said the NTSB accident report. "According to the NTSB Materials Laboratory factual report, examination of the tail-rotor gearbox revealed that all cracks and fractures in these components were 'typical of overstress separations.'"

Both tail-rotor blades had fractured at about the same location, near the outboard end of the innermost doublers, the accident report said. The blades contained a leading-edge spar and skin, as well as doublers, constructed of grade 301 stainless steel. [Stainless steel is an alloy of steel containing at least 11 percent chromium, which improves the metal's corrosion resistance. Grade 301, containing 16 percent to 18 percent chromium, is defined by standards published by ASTM International, formerly known as the American Society for Testing and Materials.]

Examination of one tail-rotor blade determined that "the spar and skin fractures were mostly on a 45-degree slant plane and were typical of 'overstress separations,'" said the accident report. "[A second tail-rotor blade] contained significant damage inboard of the fracture, but very little damage adjacent to the outboard fracture face, indicating that the inboard damage 'was produced after the fracture.' The paint on the leading edge of this blade was eroded away, and the leading edge was free of evidence of any type of blade strike."

A large portion of the fracture through the spar of the second blade was on a flat plane, which was typical of fatigue cracking, the laboratory report said. Beyond the flat-plane fatigue region was a saw-tooth pattern, and beyond that region the fracture was on a slant plane.

The accident report said, "The fatigue cracking (flat region and saw-tooth region) progressed through about three-fourths of the spar before final fracture. Detailed optical examination of the flat fracture region revealed that most of this region 'did not contain features that would positively indicate crack-propagation directions.' However, several areas of faint crack-arrest positions were found, and the orientation of these arrest positions indicated that the cracking in the flat fatigue region on the camber portion of the spar 'propagated from the trailing edge of the spar toward the leading edge.'

"The blade skin was bonded to the trailing-edge portion of the inside surface of the spar, and the skin fracture was approximately at the same blade station as the spar fracture. The skin fracture adjacent to the spar was on multiple flat planes, 'indicative of fatigue propagation through the thickness of the skin, with minimal extension of the fatigue cracking aft of the spar.'"

The outboard spar-fracture area was removed from the blade and cleaned. The area was subjected to scanning-electron-microscope examination and X-ray energy-dispersive spectroscopy (EDS).

The report said, "The laboratory examination revealed that the fracture of [the second] tail-rotor blade was a result of fatigue cracking in the blade spar. The cracking initiated just under the outboard tip of the innermost doubler on the curved side of the blade. The origin area was near the trailing edge of the spar, and was a region that contained material inconsistent with the specified 301 stainless steel alloy. The origin region was part of a three-dimensional volume of material similarly affected.

"A constituent within the origin region generated [an EDS] spectrum that was very similar to the adhesive primer, indicating that the origin region was partially porous when the primer was applied at the time of construction of the blade. A second constituent identified within the origin area was very rich in chromium and oxygen, indicating the presence of inclusions containing these elements."

Failed Engine Exceeded Service Life By 4,113 Cycles

The Raytheon Learjet LR35A had been ferried to Nürnberg, Germany, for repairs. The following day, the aircraft was being flown to Rome, Italy, where it was needed for a charter flight. The two pilots and the operator's chief technician, who had overseen the repairs, were aboard the Learjet. About three minutes after takeoff from the airport at Nürnberg, at an altitude of 5,900 feet and at an airspeed of 250 knots, the left engine failed without warning. The first officer, who was the pilot not flying, declared an emergency to the control tower and said that the crew needed to return to the airport.

The circling approach was conducted under visual meteorological conditions. While on final approach to Runway 10 at Nürnberg, about one kilometer (0.4 mile) from the approach end of the runway, the airplane appeared to enter unusual maneuvers, according to witnesses.

"The airplane deviated then from the landing direction to the north, and made some reeling movements," said the accident report by the German Federal Bureau of Aircraft Accidents Investigation (BFU). "Afterwards it seemed for a short period that the pilot intended to turn right to reach the runway. Immediately afterwards and near the ground the airplane abruptly stalled to the left, approximately maintaining its height, then [assumed] a bank angle of more than 90 degrees and [struck terrain] nearly upside down … into a forest north of the runway."

All three occupants of the Learjet were killed in the Feb. 8, 2001, accident. The aircraft was destroyed by impact forces and a post-accident fire.

The left engine that had failed in flight was a Honeywell Engine Systems (formerly AlliedSignal Aerospace) TFE731-2-2B turbofan.

The report said, "The fan is driven by the low-pressure spool through a planetary gear system. The low-pressure spool consists of a four-stage axial compressor driven, along with the fan, by a three-stage axial turbine. The high-pressure (HP) spool consists of a single-stage centrifugal compressor driven by a single-stage axial turbine.

"The engine and aircraft accessories are driven by the HP spool through the accessory gearbox mounted at the lower part of the engine. The combustion section of the engine consists of a single annular, reverse-flow combustor, 12 fuel nozzles and two electrical igniters."

The left engine that had failed in flight was found at the impact site, separated from the main wreckage. Investigation determined that the left engine had not been operating at the time of impact, and that the right engine had been operating at 91.4 percent of N_1 (fan speed) and 96.4 percent of N_2 (turbine speed). Both engines were taken to a Honeywell facility at Raunheim, Germany, where representatives of BFU and the U.S. National Transportation Safety Board (NTSB) examined them.

Investigators determined that three mounts, known as tree posts, of the turbine disk — where the turbine-blade roots were attached to the disk — and four blades of the HP turbine were missing in the left engine. The damaged turbine disk was taken to the BFU facility in Braunschweig, Germany, for further investigation.

"All other blades of the turbine were damaged on their leading edges and tips," said the report. "The turbine blades which had separated were found within the turbine section. The shroud housing of the HP turbine was partially damaged. The broken mounts and turbine blades, however, had been contained in the housing."

Intergranular cracking on the turbine disk had led to the loss of the three blade-root mounts, the report said.

"In the cracking area, there were further cracks proceeding from outside, as well as fractured carbides with starting cracks within the material," said the report. "The mounts adjacent to the cracking area also showed starting cracks in both waists. The material resistance (service life) against the combination of cyclical stress [caused] by speeding up and [slowing] down (cycles), creep stress and hot-gas corrosions during the operation obviously had [caused deterioration]."

When the technical documentation of the engine was studied, it was discovered that the engine and its turbine disk had exceeded their service lives.

Investigators found that the 5,200-cycles maximum prescribed for the engine in service bulletin TFE731-72-3001 had been exceeded by 157 cycles.

Investigators discovered that before installation into the accident-aircraft engine, the turbine disk had been installed in another engine. "At that time, the counting of cycles did not comply with the manufacturer's instruction, so that 3,965 cycles had not been registered," said the report. "When it was installed into the [accident-aircraft engine] in February 1998, the HP turbine disk had already accumulated 6,582 cycles. Together with the 2,731 cycles accumulated meanwhile, this resulted in a total of 9,313 cycles at the moment of accident, i.e., 4,113 cycles more than the allowable service life."

The operator and maintenance organizations would not have been able to learn of the error from the life-limit records for the HP turbine disk, the report said.♦

NEWS & TIPS

Paste Indicates Excess Water in Fuel-storage Tanks

SAR-GEL Water-Indicating Paste is designed to be an easy and accurate means of determining the water-contamination level at the bottom of a jet-fuel storage tank. To measure the water level, the user spreads SAR-GEL directly from its tube container onto the end of a dipstick. The dipstick is then inserted into the storage tank for 10 seconds and removed. Where the dipstick has come into contact with water, the paste changes color from white to bright red.

The paste's formulation prevents the red color from running so that the demarcation line for the water is distinct, and the paste is easy to clean from the dipstick, the manufacturer said.

For more information: Sartomer Co., 502 Thomas Jones Way, Exton, PA 19341 U.S. Telephone: (800) 345-8247 (U.S.) or +1 (610) 363-4100.

Kit Contains Emergency-survival Equipment

The Seton 10-Person Industrial Kit is designed to enhance emergency preparedness in the workplace. Each kit contains equipment selected from the U.S. Department of Homeland Security's list of recommended emergency supplies.

The kit includes one first-aid kit (containing supplies for 10 people), 10 hard hats, five rolls of duct tape, one roll of barricade tape, 10 flashlights, 24 industrial "D" batteries, five heavy-duty 32-inch by 40-inch (81-centimeter by 102-centimeter) plastic bags, 10 pairs of safety glasses, 10 personal eyewash systems, 100 disposable gloves, 10 respirators and one "super pliers." The items are packed in a highly visible 30-U.S.-gallon (114-liter) container.

Industrial Emergency Kit

An individual-person version of the kit is also available.

For more information: Seton Identification Products, 20 Thompson Road, Branford, CT 06405 U.S. Telephone: (800) 243-6624 (U.S.) or +1 (203) 488-8059.

Ultrasonic Inspection System Records Sound, Logs Data

A digital ultrasonic-inspection, information-storage and information-retrieval system from UE Systems consists of a hand-held, metered "pistol" sensor unit that records sound and logs data. The product, Ultraprobe 10,000, includes analytical software that can be used with most personal computers to turn the sound data into comprehensive diagnostic functions, including spectral analysis, record keeping, trending and reporting.

Test data can be uploaded to the sensor unit as well as downloaded to a computer. Uploaded data enable inspectors to compare current test results with baseline data on the same screen, the manufacturer said. Spectral analysis software included with the system gives inspectors the ability to view recorded sounds both as spectral images and as time-series images for sound-wave analysis.

Ultrasonic Inspection System

Test data can be entered in English units or metric units. According to the company, 23 modes of operation can be selected to customize the instrument functions and screens to meet specific inspection needs.

For more information: UE Systems, 14 Hayes Street, Elmsford, NY 10523. Telephone: (800) 223-1325 (U.S.) or +1 (914) 592-1220.

Suction Cups Lift Heavy Loads

Developed for lifting steel, plastic and glass-fiber plates weighing as much as 500 pounds (227 kilograms), Anver ETL Series Powered Vacuum Lifters with Powered Tilting are said by the manufacturer to enable one person to handle awkward loads such as radar antennas and large molded parts.

The lifters, which can be attached to the hook of a hoist, feature vacuum suction cups that pivot on an adjustable cross-arm. Models powered by 115-volt alternating current (AC) and models powered by air are available. Suction cups made from a wide variety of materials can be chosen for various applications. The cups are attached instantly to the load and are released instantly from the load, the manufacturer said.

For more information: Anver Corp., 36 Parmenter Road, Hudson, MA 01749 U.S. Telephone: (800) 654-3500 (U.S.) or +1 (978) 568-0221.

Instrument Detects High Voltages

Voltages from 80 volts to 275 kilovolts can be detected without physical contact by the AEMC Instruments Model 275HVD. An eight-position switch is used to select a detection range, and as the lightweight sensor is moved closer to the voltage conductor, the sensor measures the electrical field around the conductor. When the range threshold is reached, a buzzer sounds and a bright red light illuminates to warn the operator of the “live” high-voltage conductor.

High-voltage Detector

The Model 275HVD is powered by three standard alkaline "C" batteries and can be used either indoors or outdoors. A self-test position can be used to ensure that all system functions and that annunciators are working correctly.

For more information: AEMC Instruments, 200 Foxborough Boulevard, Foxborough, MA 02035 U.S. Telephone: (800) 343-1391 (U.S.) or +1 (508) 698-2118.

Lighting Is Explosion-proof or Vapor-proof

Two series of industrial incandescent lighting fixtures that are explosion-proof and vapor-proof, respectively, are offered by LDPI Lighting. Each series includes models designed for ceiling, pendant, box and stanchion mounting, and different reflectors for various applications are available.

The explosion-proof Series 383 is approved for storage areas for hazardous materials, paints and chemicals, the manufacturer said. The Underwriters Laboratories (UL)-listed vapor-proof Series 381 is certified for nonhazardous areas where the lamp, socket and wiring need protection from rain, corrosive fumes, dust and nonexplosive vapors or gases, the manufacturer said.

Series 381 and Series 383 are both constructed of cast aluminum and equipped with a heat-resistant and impact-resistant glass globe inside a die-cast guard. Reflectors are available in versions that cast light downward or an angled version that directs light downward and 30 degrees to the side.

For more information: LDPI Lighting, 800 Wisconsin Street, Eau Claire, WI 54703 U.S. Telephone: (800) 854-0021 (U.S.) or +1 (715) 839-9585.

Cables Compatible With Skydrol Hydraulic Fluid

Chainflex CF9, CF10 and CF11 control and power cables from Igus have been found through testing to be compatible with Skydrol, a widely used fire-resistant aircraft hydraulic fluid, the manufacturer said.

Chainflex cables, which are encased in thermoplastic elastomer (TPE) jackets, were immersed for seven days in Skydrol at a controlled temperature of 158 degrees Fahrenheit (70 degrees Celsius). At the end of the test period, the cables had resisted damage from the hydraulic fluid, the manufacturer said.

Control Cables and Power Cables

Chainflex TPE cables are designed for continuous flexing and tight bending, the manufacturer said. They are designed to be abrasion-resistant, oil-resistant, flame-retardant, ultraviolet wave–resistant and halogen-free.

For more information: Igus Inc., 50 North Broadway, East Providence, RI 02914 U.S. Telephone: (800) 521-2747 (U.S.) or +1 (401) 438-2200.

Mobile Station Puts Computer and Peripherals on Wheels

The Mobile Technology Center (MTC) from Shure Manufacturing Corp. houses a personal computer, monitor, printer and accessories in a wheel-mounted unit that is designed for the needs of a technician on the shop floor.

The MTC features a processor compartment with a built-in fan and filter; a monitor stand with a pull-out keyboard shelf that hides the keyboard when not in use; a door in the back panel for fast access to computer connections; and a solid hardwood maple top that provides a work space.

Models are available in a 36-inch (0.91-meter) width and a 60-inch (1.52-meter) width. The customer may specify a primary color and an accent color.

Mobile Work Station

For more information: Shure Manufacturing Corp., 1901 West Main Street, Washington, MO 63090 U.S. Telephone: (800) 227-4873 (U.S.) or +1 (636) 390-7100.♦