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Robert A. Feeler, editorial coordinator

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Improved Understanding Of Human Factors Could Reduce Foreign Object Damage

A U.S. Federal Aviation Administration report provides guidelines for reducing maintenance-related foreign object damage through the application of human factors best practices.

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FSF Editorial Staff

Foreign object damage (FOD) accidents/incidents have resulted in loss of life and destruction of aircraft, as well as flight delays and additional work for aviation maintenance technicians and others. A U.S. Federal Aviation Administration (FAA) report said that one reason for maintenance-related FOD occurrences is the complexity of the aviation-maintenance environment, in which maintenance personnel apply specialized knowledge and skills to conduct controlled procedures in surroundings that include organizational pressures, environmental pressures and work pressures.

[FOD is defined as damage to any part of an aircraft — frequently an engine or a flight control mechanism — that is caused by any extraneous material; the cost of FOD to the worldwide aerospace industry has been estimated to be US$4 billion annually.][1]

Maintenance personnel may not be able to anticipate many of the problems that result from the complexities of the aviation-maintenance system.

"It is critical, therefore, to have an understanding of the human factors of the system and to address those human factors through both proactive [measures], as well as reactive measures," the report said. "Through a grounded understanding of the human factors involved in FOD, the industry can provide the best guidance to eliminate existing FOD problems and prevent future FOD occurrences."

Many FOD-prevention programs emphasize technical procedures but do not consider human factors related to those procedures. Therefore, the FAA Office of Aerospace Medicine conducted a study to identify methods of reducing maintenance-related FOD occurrences by applying human factors best practices.[2]

The report discussed the four causes of most FOD in the maintenance environment — poor housekeeping, deterioration of facilities, improper maintenance and inadequate operational practices. The report also discussed interaction and support of FOD-prevention efforts by management and employees, FOD awareness, FOD training, FOD audits and FOD inspections.

"These factors, taken together, make up the proactive measures that can be used to eliminate and prevent [FOD] in the aviation-maintenance environment," the report said.

The report said that a FOD-prevention program should include precise policies and procedures that discuss the following items:

- The importance of FOD prevention and how FOD prevention affects safety, quality, costs and customer satisfaction;
- The goals of the FOD-prevention program and the time required to achieve those goals;
- The standards that will be used to assess the progress of the FOD-prevention program and to compare it with similar programs in other organizations;
- The organization of the FOD-prevention program, including how the program will be managed and what support will be available;
- The FOD-prevention program's policies and procedures, including how those procedures will be disseminated and how improvements in the process will be achieved;
- The methods of communicating the successes or failures of the FOD-prevention program to aviation maintenance technicians and aviation maintenance managers; and,

- The methods of investigating FOD incidents and FOD accidents, including how the occurrences will be reported, what data will be collected and how the data will be stored and analyzed.

The report described management support as essential to the success of a FOD-prevention program and said that management support should include adequate funding, appointment of an individual or group with authority to implement the program, support for work to eliminate FOD throughout the aerospace industry and support of a "FOD-prevention culture" throughout the organization.

"The culture of an organization is the collection of beliefs, norms, attitudes, roles, as well as social [practices] and technical practices, that are shared by individuals within an organization," the report said. "A good safety culture focuses on minimizing dangerous and injurious conditions that may affect not only the employees of the organization. A more important result of a good safety culture is improved safety for the public at large. …

"The aircraft maintenance technician's attitudes toward FOD will be a reflection of the values and beliefs that management places on FOD prevention or elimination. … Thus, it is incumbent on management to establish and maintain a FOD-prevention culture within the organization."

The report said that all maintenance personnel should receive training in how to prevent FOD, including information about the organization's FOD-prevention procedures; causes and effects of FOD; safe working practices and individual responsibilities; correct storage, shipping and handling of material, components, equipment, personal items and tools; accountability and control of tools, materials and hardware; vigilance for potential sources of FOD; clean-up techniques; and reporting of FOD incidents.

"In addition to the general FOD training required for all employees, contractors and subcontractors, the maintenance technician should receive additional training focused on the technical aspects of FOD prevention," the report said. The additional training may discuss correct methods of cleaning and maintaining fuel filters and disposing of small pieces of maintenance-related material, such as pieces of safety wire.

FOD-prevention training should be required before maintenance personnel work on an aircraft on or aircraft subassemblies. Recurrent training also should be required, the report said.

To ensure that all employees develop an awareness of FOD occurrences and the FOD-prevention program, FOD announcements and discussions should be included in meetings, incentive programs should be established to reward individuals or departments for their efforts to reduce FOD, and FOD articles should be published regularly in the company newsletter.

The report said that the FOD-prevention program should include easily recognizable and appropriately sized FOD receptacles throughout the maintenance facilities. Outdoor receptacles should be watertight, and all receptacles should be emptied regularly and should not be permitted to overflow.

"There should be regularly scheduled FOD walks of hangar bays, aircraft ramps and aprons," the report said. "Consideration should be given to using specialized brooms, magnets and vacuum-type machines to clear areas." (Brooms and sweepers should not have metal bristles, which increase the risk of FOD.)

The report recommended several clean-up activities for individual maintenance technicians, including:

- Clean the immediate work area when work is completed, when work "cannot continue," at the end of each shift and before inspection;

- Pick up debris that might migrate to an inaccessible location or to a location where the debris would be out of sight. The report said, "If you see debris, don't walk over it; pick it up and dispose of it properly";

- Do not take food or beverages to the work area; and,

- Return cleaning equipment and tools to the proper storage area.

"The fundamental process to prevent [FOD] is to perform all maintenance tasks 'by the book,'" the report said. "This includes all procedures, from removing excess grease from a component to capping all aircraft ports and disconnected lines with approved material."

The guidelines recommended by the report include the following:

- Protect equipment that is sensitive to FOD. For example, cover engine inlets and exhausts during maintenance that does not require access to the engine area;

- Aircraft undergoing maintenance or modification and the areas surrounding the aircraft should be inspected and cleaned throughout the maintenance/modification process;

- If an item is dropped in a "critical airworthiness area," the item should be removed before further work is performed. If the item is not found, the occurrence should be reported to a supervisor. The item should be accounted for before the aircraft is released for return to service;

- Every assembly step should include an inspection for extraneous material, and FOD inspections should be performed before all final closures;
- Only essential hardware should be taken aboard the aircraft. Tools should be carried and stored in tote trays, sacks or boxes. Tool trays should have lids;
- Before an engine is started, a FOD walk should be conducted in front of the intake area and behind the exhaust area of the engine to ensure that the areas are free of objects that could cause damage;
- "Check aircraft tires for foreign objects";
- Report damage to pavement; and,
- Whenever debris is seen, it should be collected and disposed of properly.

The report said that, whenever possible, the packaging of any item used during maintenance should be in a color that contrasts with the background of the maintenance area. Tools sometimes may be in colors that blend into the background; therefore, tool-control procedures should be implemented. The report said that a written tool inventory should be maintained for each tool-storage area, that personnel should be able to identify all tools and trace them to their assigned storage location and that tools should be transferred from one individual to another only with proper documentation.[3]

The person responsible for the FOD-prevention program should ensure that FOD inspections and FOD audits are conducted regularly, using checklists to verify compliance with FOD-prevention procedures.

"FOD audits should provide a review of existing conditions, as well as recommendations for improving … debris control," the report said. "The audit results may be used to develop corrective-actions programs and to provide improvements to FOD-training programs."

When a FOD incident or FOD accident occurs, it must be reported promptly and the circumstances must be reviewed to prevent a similar problem in the future. The report recommended that the individual or group responsible for the FOD program conduct an investigation, analyze the resulting data and develop corrective actions.

"Human factors should be an integral part of any investigation of any incident or accident resulting from FOD," the report said. "Whenever possible, investigators of a FOD incident or accident should conduct an on-site examination. This would include walks through the area of concern and interviews with personnel involved and [with] other stakeholders."

The report said that several human factors investigative models have been developed for assessing accidents and incidents in aviation maintenance, including the following:

- Maintenance Error Decision Aid (MEDA), developed by Boeing Commercial Airplanes, is designed to investigate maintenance errors and to reduce or eliminate the errors by redesigning procedures. MEDA is based on three principles: "Mechanics don't intend to make mistakes"; "errors result from a variety of workplace factors, such as unclearly written manuals, poor communication between workers or improperly labeled parts"; and "management can fix the factors that contribute to errors";[4]
- Dirty Dozen, developed by Gordon Dupont in his work with Transport Canada, includes a checklist of aviation human factors issues that can be used for training and situational awareness. The checklist cites 12 errors in aviation maintenance that can affect safety, including lack of communication, complacency, lack of knowledge, distraction, lack of teamwork, fatigue, lack of resources, pressure, lack of assertiveness, stress, lack of awareness and "norms" (adopting the behavior of others in the group, even when that behavior is not correct);[5]
- SHEL Model, developed by Elwyn Edwards and modified by Frank Hawkins, describes how the human interacts with the system; SHEL is an acronym for software, hardware, environment and liveware (humans). The SHEL model explains how the liveware interacts with the other three elements, as well as with other human colleagues;[6]
- PEAR Model, developed by Michael Maddox specifically for use in aviation maintenance environments, emphasizes the relationship between individuals and the other elements of the system; PEAR is an acronym for people, environment, actions and resources. The "people" factors include mental capability, physical capability, attitude, training, age and adaptability. "Environment" factors include working conditions such as temperature, noise level and organizational environment. "Actions" factors include the actions that must be taken to complete tasks. "Resources" factors include the tools, computers, information, other people and time that are required for people to perform actions; and,

- Human Factors Analysis and Classification System Maintenance Extension (HFACS-ME), developed by the U.S. Naval Safety Center, is designed to identify human error that contributed to aviation maintenance occurrences and to use the information in the development of strategies to prevent such errors. HFACS-ME classifies human error into four categories — supervisory conditions, maintainer conditions, working conditions and maintainer acts — to study the relationships among latent failures and active failures.

The report said that each organization should have a form to be used in FOD investigations and to help organize data for entry into a FOD database. The form should be designed to collect data to be used in analyzing the cause of the FOD problem, including a description of the occurrence, a description of damage, a report on immediate action taken and recommendations or corrective actions.

By compiling and reviewing the data, the organization can work to identify and to understand the situation that resulted in a FOD occurrence and to implement best practices that will prevent FOD occurrences, the report said.

"Once the problem has been defined and the [investigating] team has an understanding of the system, then they can begin to analyze the information and data in order to identify the root cause of the FOD incident or accident," the report said. "It is possible that an individual — who intentionally deviated from the safe operating procedures, recommended practices or rules — may have caused the problem. More than likely, however, the investigating team may find weaknesses in equipment design or availability, incorrect or out-of-date operational procedures, or lack of awareness and training deficiencies. They may even find that the root cause goes as far back as the culture of the organization or the lack of management support for FOD prevention."

A corrective-action plan should be developed by the individual or group responsible for FOD prevention to establish procedures to ensure that the root causes of a FOD incident or FOD accident are identified and are corrected promptly.

A corrective-action plan may include such items as documentation of the processes included in the investigation of the FOD incident or FOD accident; results of the investigation and the root-cause analysis; identification of human factors causes and human factors intervention strategies; evaluation of alternative solutions; and assessments of the economic impact of the solution, of the solution's regulatory compliance and the potential for conflict with other groups or procedures.

If the analysis reveals more than one root cause of the FOD occurrence, separate corrective-action plans should be developed for each cause.

The report cited other analyses of human error in aviation maintenance that have found that errors originate from individual factors or from organizational factors.

The individual factors consisted of the following: physical health, fatigue, time constraints, management pressure, complacency, body size/strength, personal event/stress, workplace distractions, lack of awareness, lack of knowledge, lack of communication skills, and lack of assertiveness.[7]

The organizational factors consisted of the following:

- Hardware/equipment/tools/lack of resources/inadequate staff;
- Design/configuration/parts;
- Maintenance management/leadership/supervision/company policy;
- Work processes/procedures/information;
- Error-enforcing conditions/norms/peer pressure;
- Housekeeping;
- Incompatible goals;
- Communication processes;
- Organizational structures/corporate change/union action;
- Training/technical knowledge/skills;
- Defenses;
- Environment/facility; and,
- Lack of teamwork.[8]

"Not all FOD errors are due to the individual, nor are all FOD incidents or [FOD] accidents attributable to organizational causes," the report said. "In the past, the focus of a FOD investigation was on the problem point or the individual where the active failure occurred. More recently, however, there has been a … shift in FOD investigations to examine the relevant facts related to the event and to the background causes or latent failures. Employing a structured and systematic approach to the investigation and root-cause analysis will minimize any potential bias toward the individual in the corrective-action plan."

After the FOD error has been categorized, a corrective-action plan can be developed, including human factors intervention strategies. After the plan has been implemented, it should be evaluated to determine whether modifying or eliminating the root cause of the FOD has eliminated the immediate cause of the FOD and whether implementation of the plan prevented similar recurrences of FOD.

The report recommended the following guidelines for conducting the evaluation:

- Incorporate the evaluation into other routine proactive FOD-prevention procedures rather than establishing a separate group to evaluate the process;
- Seek opinions from groups rather than individuals. The report said that groups often provide "more valid and creative feedback";
- Computerize all aspects of the evaluation; and,
- Ensure that data-collection procedures are well organized and that the database is designed to allow information to be extracted for analysis.

"The elimination of FOD is a continuous improvement process," the report said. "Lessons learned can help guide and tune future implementation processes, as well as help in developing a business case to expand the [corrective action plan] to other parts of the organization. Finally, the evaluation measures can aid in the development of benchmarks for future comparisons."♦

[FSF editorial note: This article, except where specifically noted, is based on *Guidelines for the Prevention and Elimination of Foreign Object Damage/Debris (FOD) in the Aviation-Maintenance Environment Through Improved Human Performance.* The report was written by David C. Kraus of Galaxy Scientific and Jean Watson of the Aircraft Maintenance Division of the U.S. Federal Aviation Administration Flight Standards Service. The 34-page report contains figures, tables and appendixes.]

Notes

1. "FOD Defined." *FOD News.* <www.fodnews.com/fod-defined.html>. June 17, 2002. The estimate of the cost of foreign object damage (FOD) was made by U.S. National Aerospace FOD Prevention Inc. (NAPFI), a nonprofit education organization established in 1985 to work to eliminate FOD.
2. The guidelines relate only to maintenance operations and do not discuss other causes of foreign object damage (FOD), such as bird strikes, animal ingestion, weather-related events, damage from ground-support equipment and airport operational practices. They also do not discuss aircraft tire maintenance.
3. Eri, Eulaine. "Sample Tool-control Ten-point Baseline."

National Aerospace FOD Prevention Newsletter. May 1998.

4. Boeing Maintenance Error Decision Aid — MEDA. Boeing Commercial Airplane Group. 1994.

5. Dupont, Gordon. "The Dirty Dozen Errors in Maintenance." *Human Factors Issues in Aircraft Maintenance and Inspection, Meeting 11 Proceedings.* Washington, D.C., U.S.: U.S. Federal Aviation Administration, 1997.

6. Hawkins, F.H. *Human Factors in Flight*. Aldershot, Hampshire, England: Gower Technical Press, 1987.

7. Pakantar, Manoj S.; Taylor, James C. "Analyses of Organizational and Individual Factors Leading to Maintenance Errors," Paper no. 2001-01-3005. Society of Automotive Engineers.

8. Ibid.

Further Reading From FSF Publications

FSF Editorial Staff. "Foreign-object Damage Cripples Concorde on Takeoff From Paris." *Accident Prevention* Volume 59 (April 2002).

O'Neill, John F. Jr. "Foreign Object Damage: Elimination Should Be a Priority to Reduce Risks to Personnel and Equipment." *Aviation Mechanics Bulletin* Volume 21 (March–April 1993).

MAINTENANCE ALERTS

FAA Orders Limits on Fokker F.28 APU Operations

The U.S. Federal Aviation Administration (FAA) has issued an airworthiness directive (AD) to prohibit operation of auxiliary power units (APUs) during deicing operations of all Fokker F.28 series airplanes.

FAA said that AD 2002-07-03, effective April 19, 2002, is intended to "prevent ingestion of deicing fluid into the APU, which could cause uncontained failure of the turbine wheel of the APU and [could] result in failed-and-uncontained parts penetrating the aft-cabin pressure bulkhead, and consequent possible injury to the cabin crew or passengers."

The FAA action followed a March 29, 2002, recommendation by the U.S. National Transportation Safety Board (NTSB), which cited the uncontained rupture of the turbine wheel in the

AlliedSignal (now Honeywell) APU (model GTCP36-150RR) of a Fokker F.100 (an F.28 Mark 100 is known as an F.100) while the airplane was being deiced at Dallas–Fort Worth (Texas, U.S.) International Airport on March 2, 2002. Fragments of the turbine wheel damaged the interior of the airplane's tail cone, and one fragment penetrated the aft pressure bulkhead and was embedded in a first aid kit under the flight attendant's aft jump seat. None of the 34 people in the airplane was injured.

The APU normally operates at 100 percent of its rated revolutions per minute (rpm); NTSB said that, "under some circumstances, it can quickly accelerate beyond this value, resulting in a hazardous situation." An electronic control unit (ECU) shuts down the APU by stopping its fuel supply if the ECU senses that the APU rotor is operating at a speed faster than 107 percent.

Examination of the ECU's nonvolatile memory after the incident revealed that an overspeed occurred. There was no sign of fatigue, but fragments of the turbine wheel were scheduled for further examination to determine whether fatigue was a factor.

NTSB said that a similar event involving another F.100 operated by the same company occurred at the same airport on March 6, 2001. In that incident, the ECU sensed an overspeed and stopped the flow of fuel to the APU, but the rotor continued to accelerate and the turbine wheel burst.

In February 2001, the company issued a bulletin warning that deicing fluids and anti-icing fluids should not enter the APU inlet. The F.100 maintenance manual contains a similar warning.

The NTSB recommendation said that the deicing fluid used on the company's airplanes is "an ethylene glycol solution that is combustible when compressed."

"If deicing fluid enters the APU inlet, it will augment the combustion process," NTSB said. "If the APU ingests enough deicing fluid, it will sustain combustion even if the ECU senses an overspeed and cuts off the fuel to the APU. Because the ECU no longer has command of the rotor speed, the APU will continue to accelerate unabated until the turbine wheel bursts."

NTSB said that an AD was required to prevent similar incidents that could result in injury to passengers and/or crewmembers.

NTSB member John Goglia, in a dissenting statement, said that the NTSB recommendation "misses the mark" by failing to discuss the importance of "effective training in deicing and anti-icing applications." He also said that prohibiting use of the APU during deicing "may have significant unintended consequences."

Electrical-discharge Damage Results in Engine Failure

A Short Brothers SD-360 was in cruise flight from Bundaberg, Australia, to Brisbane, Australia, on Aug. 13, 2000, when the crew heard a loud noise. The right propeller automatically feathered, and the crew shut down the right engine, declared "pan-pan" (an urgency condition) and continued to the destination airport.

The accident report by the Australian Transport Safety Bureau said that an investigation revealed that the right engine (Pratt & Whitney Canada [P&WC] PT6A) would not rotate and that the no. 1 bearing had failed. Surfaces of the bearing were blackened in a manner associated with "extreme overheating," the report said.

"The bearing balls and inner race [the surface on which the bearing balls roll] showed heavy localized wear and metal flow associated with the sliding contact of the balls against the inner race," the report said. "There was also evidence of electrical arcing damage on the inner race, [which] was traced back through the accessory gearbox components to the starter-generator input shaft. Four equally spaced groups of two [teeth] or three teeth on the starter-generator drive gear were pitted. The electric current required to cause the pitting was an alternating [frequency] or pulsed frequency equal to four times the rotational speed of the starter gear. The coupling gear that mated with the starter-generator drive gear showed continuous pitting over the whole contact surface."

Tests conducted by the operator on a starter-generator of the same model that was used in the failed engine revealed "pulsed electric-current discharges from the starter-generator output shaft," the report said. After brush dust from the armature (the rotating element), was blown from the housing of the starter-generator, the measured voltage of the pulsed discharge decreased.

The operator had experienced four previous engine failures — all involving failure of the no. 1 bearing — in Shorts 360 airplanes. The report said that in three of the four previous occurrences, "there was evidence to suggest than an electric current from the starter-generator gear shaft passed through the accessory gearbox gear train and the compressor hub splined coupling" and that the electric current "initiated spalling damage [cracking and flaking of the surface] to the bearing." The reason for the electric discharge was not determined. All four engine failures occurred between

60 hours and 640 hours after a replacement starter-generator was installed in the airplane; the report said that there were "indications that in some occurrences, a previously installed starter-generator may have initiated damage to the no. 1 bearing."

The report said that the engine manufacturer has said that 17 engine failures have occurred in PT6A engines worldwide on Shorts 360 and on Raytheon Beech 1900 and King Air 350 airplanes. The engine failures involved PT6A-60A, PT6A-65B, PT6A-65R, PT6A-67D and PT6A-67R series engines with Lucas Aerospace (TRW Aeronautical systems) 23078 and 23085 starter-generators.

"The most likely source of the electrical-discharge damage [in the Aug. 13, 2000, occurrence] was the starter-generator unit, which couples directly to the starter-generator gear," the report said.

As a result of the occurrence, the Australian Civil Aviation Safety Authority (CASA) told Australian operators of aircraft equipped with PT6A engines that are used in commercial passenger operations to conduct the following maintenance actions:

- "Periodic in-service [starter-generator] field cleaning and resistance checks to be performed in accordance with the procedures detailed in TRW Lucas Maintenance Manual No. 23700, revision 9, at intervals not to exceed 300 hours [starter-generator] time in service; and,

- "Oil-system monitoring of engines in service from which [a starter-generator] was removed to rectify a reported engine-starting [defect] or electrical-generation defect that was confirmed to be caused by the [starter-generator]."

CASA also notified all certificate-of-registration-holders of PT6A-60 series engines of the investigation's findings and recommended that they review their maintenance procedures.

The operator, working with CASA and the aircraft manufacturer, conducted bonding checks to ensure that "an appropriate electrical-discharge path was available from the starter-generator" and tested starter-generators that were removed from service after 600 hours to determine whether there was any source of electrical leakage. The operator also:

- Installed a supplemental chip-detector system on engine accessory gearboxes and told flight crews to use the chip-detector before and after each flight "to determine that no metal has bridged the chip-detector probes"; and,

- Reduced to 1,000 operating hours (from 1,500 operating hours) the starter-generator overhaul period.

At 250-hour inspections and 750-hour inspections, the starter-generator is to be cleaned and brushes are to be inspected. At the 500-hour inspection, brushes are to be replaced, the starter-generator is to be cleaned and an armature-resistance check is to be conducted to determine whether voltage could leak from the starter-generator.

The aircraft manufacturer (Bombardier Aerospace, Short Brothers) issued the following service documentation to operators:

- Service bulletin (SB)360-24-24, describing installation of a new grounding point between the engine firewall and the starter-generator to provide additional electrical bonding for the starter-generator;
- Service information letter (SIL) SD360-IL-207, describing starter-generator removal instructions and installation instructions, and "advising that operators ensure the integrity of the engine starter-generator electrical bonding"; and,
- SB360-72-01, recommending |that operators comply with P&WC SB PT6A-72-13348 and PT6A-72-14304 within 25 flight hours of the failure or unscheduled removal of a starter-generator.

The aircraft manufacturer agreed with proposed TRW Lucas modifications to "electrically isolate the starter-generator output shaft from the engine-starter gear," the report said.

The report also said that P&WC issued three SBs — PT6A-72-14304, PT6A-72-13348 and PT6A-72-14318, recommending engine-oil-filter patch inspections within 25 flight hours to detect debris in the oil system that originates from the no. 1 bearing area.

'Lack of Bond' Defect Blamed for Fan-blade Failure

A Boeing 747-400 was being flown at Flight Level 330 (approximately 33,000 feet) en route from Sydney, Australia, to Bangkok, Thailand, on Jan. 3, 2002, when the flight crew felt vibration and observed an "ENG 3 REVERSER" indication on the engine-indication and crew-alerting system (EICAS).

The crew shut down the no. 3 engine and returned the airplane to Sydney.

A preliminary report by the Australian Transport Safety Bureau said that an investigation revealed that an engine fan blade had failed and that debris had punctured the engine cowling, the right-wing leading-edge flaps, the right-wing trailing-edge flaps and the fuselage.

"The inspection found fractured fasteners and other components beneath the fan cowls and damage to the structure associated with the thrust-reverser assembly," the report said. "Debris from the no. 3 engine fan was also found embedded within the nose cowl of the adjacent no. 4 engine."

The report said that the fracture surface on the fan blade "showed features typical of a progressive fatigue-cracking mechanism, with the crack origin located adjacent to the blade centerline, approximately 50 millimeters [two inches] back from the leading edge." Visible cracking covered about half of the fracture area, and the remainder was "typical of tensile overload," the report said.

An investigation revealed that the fatigue-crack initiation occurred from a previous planar defect at the blade centerline. The defect was described as a "lack of bond" defect that developed during the manufacturing process.

When the failure occurred, the fan blade had accumulated 9,444 cycles since new and 1,299 cycles since the most recent re-work.

On March, 12, 2002, after the initial inspection of the failed fan blade, Rolls-Royce issued alert service bulletin RB.211-72-AE001, which instructed operators to remove from service blades that were "considered to be at risk of cracking from bonded areas." The affected engines are on B-747 and B-767 airplanes.

Improper Installation Cited in In-flight Separation of Elevator Trim Tab

A Cessna 421 was being flown in cruise flight during a personal flight in the United States, en route from Springdale, Arkansas, to Destin, Florida, on May 29, 2001, when the pilot experienced flight control problems.

The incident report by the U.S. National Transportation Safety Board said that the pilot heard a loud popping sound while flying the airplane at Flight Level 190 (approximately 19,000 feet) about 45 minutes after departure. The control yoke shook, and the pilot disengaged the autopilot, observing that the airplane had begun to descend. He told air traffic control about the problem and was given vectors to the nearest airport, Mid Delta Regional Airport in Greenville, Mississippi.

"The airplane was flying in a nose-down attitude with a descent rate of 1,200 [feet per minute] to 1,500 feet per minute," the report said. "The pilot utilized full-aft elevator and increased power to bring the airplane's nose to a more controlled attitude."

The pilot used power and full-aft elevator to flare the airplane during landing. The pilot and seven passengers were not injured.

An inspection revealed that the inboard half of the right-elevator trim tab was not connected to the right elevator, that the push-pull rod was not connected to the trim-tab horn and that the bolt and hardware that connect the push-pull rod to the right-elevator trim-tab horn were missing. The trim-actuator rod was bent.

Maintenance records revealed that the flight controls had been removed for painting and were signed off by maintenance personnel at the painting company on May 11, 2001. The records also revealed that the elevator trim was adjusted and signed off by maintenance personnel on May 22, 2001.

The report said that the probable cause of the incident was the "improper installation by maintenance personnel of the push-pull rod assembly on the right-elevator trim-tab horn, [which] resulted in an in-flight separation of the right-elevator trim tab."

Failed Rivets Lead to Landing-gear Collapse

A Cessna 310R was being taxied to the runway for takeoff from Jersey Airport in England on Nov. 7, 2001, when the right-main landing gear collapsed and the right wing and right propeller struck the ground. The pilot of the cargo flight, who was the only person in the airplane, was not injured.

The U.K. Air Accidents Investigation Branch said in the final report on the accident that an inspection of the airplane revealed the failure of the rivets that attached the landing-gear torque-tube support-bracket assembly (part no. 5027002-5) to the right wing.

"This had allowed the aft end of the torque tube to become displaced, allowing the landing-gear side brace to move out of lock and causing the [right-main] landing gear to collapse," the report said.

The report said that the airplane had been involved in an accident five months before this occurrence in which the right-main landing gear failed to retract and later collapsed during landing.

"It is believed that the rivets holding the … support bracket for the torque tube had been overstressed in this accident but that this damage had not been evident during subsequent external inspections of the landing gear," the report said.♦

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For more information: Vitta Corp., 7 Trowbridge Drive, Bethel, CT 06801 U.S. Telephone: +1 (203) 790-8155.

Lamps Provide Up to 10,000 Hours Of Lighting

The lifetimes of Welch Allyn HPX halogen aircraft/transportation lamps have been increased by as much as 150 percent to up to 10,000 hours, the manufacturer said.

The increases resulted from improvements in components, the manufacturing process, product testing and the

Halogen Lamps

gas chemistry used in the lamps, the manufacturer said. The lamps are available in six-volt, 12-volt and 28-volt versions at wattages from 10 watts to 15.4 watts and are designed to withstand electrical power spikes. HPX aircraft lamps are used as reading lamps, cockpit lamps and galley lamps.

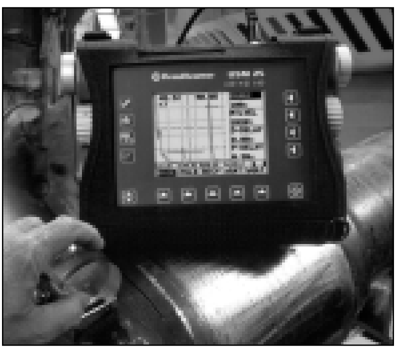
For more information: Welch Allyn Lighting Products Division, P.O. Box 187, Skaneateles Falls, NY 13153-0187 U.S. Telephone: +1 (315) 685-4347.

Portable Flaw Detectors Have Lower Minimum Range

Krautkramer USM 25 series portable flaw detectors have a minimum range of 0.02 inch (0.51 millimeter) for optimum thin-range use and evaluation of echo dynamics, said the manufacturer, Agfa NDT.

Curvature correction has been added to compensate in calculations performed on piping and tubular goods, and two independent monitor gates provide more versatility, the manufacturer said.

For more information: Agfa NDT, Krautkramer Ultrasonic Systems, 50 Industrial Park Road, Lewistown, PA 17044 U.S. Telephone: +1 (717) 242-0327.



Portable Flaw Detector

Sockets Prevent Damage to Hardware

Protective Sockets have a fiberglass composite lining surrounded by a steel sleeve to prevent marring, flaking and stripping of coated bolt heads and nuts, the manufacturer said.

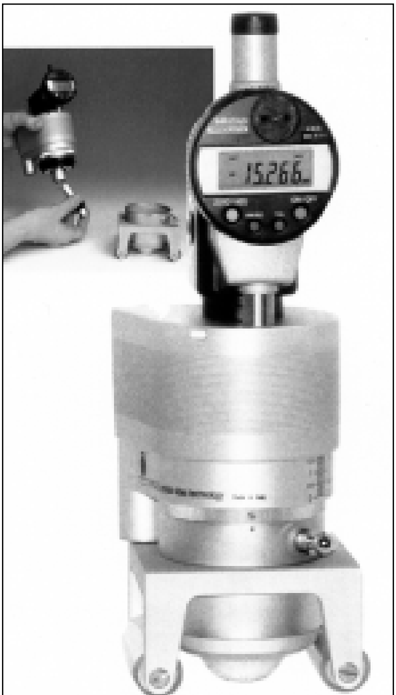
Protective Sockets were designed for aerospace applications and are available in fractional sizes and metric sizes. They can be custom-ordered in any size and in several materials: non-magnetic, titanium, nickel-plated, chrome-plated and black-oxided.

For more information: Protective Sockets, 6 Dusthouse Road, Enfield, CT 06082 U.S. Telephone: +1 (860) 749-1862.

Portable Microscope Aids in Measuring Aircraft Skin Cracks

A compact, portable microscope from AEI Optics Unlimited provides real-time, flat-field images for a variety of applications, including observing and measuring surface finishes and aircraft skin cracks, the manufacturer said.

The Video-Check Roll and the Video-Check Roll-Z produce images at magnifications from 25 times actual size to 2,350 times actual size for observation and long-term storage, the manufacturer said. The focusing barrels of both microscopes contain programmable rings to vary illumination effects, and the housing allows operators to easily change fixed-magnification objectives. Plastic-covered, non-conductive, silicone-free rollers protect targets against damage and unwanted deposits.



Portable Microscope

For more information: AEI Optics Unlimited, 2521 Cherry Valley Turnpike, Marcellus, NY 13108 U.S. Telephone: +1 (315) 673-4151.

Adapters Feature Corrosion-resisting-steel Band

Raychem CRES-Lock Adapters have a corrosion-resisting-steel (CRES) band that can be installed around screen braid cable to establish an electrical connection between the braid and the adapter, said the manufacturer, Tyco Electronics.

Raychem CRES-Lock Adapters can be tightened and secured with a buckle design that allows the band to remain under tension during the cut-and-lock-in-place operation. The terminated cable is sealed by a heat-shrinkable covering that increases the strain relief. Raychem CRES-Lock Adapters are available with straight

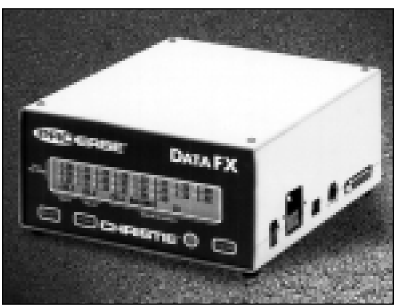
CRES bands or pre-coiled CRES bands and with a variety of options.

For more information: Tyco Electronics, P.O. Box 3608 MS 38-41, Harrisburg, PA 17105-3608 U.S. Telephone: +1 (650) 361-4470.

Battery Monitor Features Large-screen Display

The DataFX monitors aircraft batteries and battery cells with a large-screen display for viewing as many as 22 cell voltages simultaneously, said the manufacturer, the Christie division of Marathon Power Technologies.

The DataFX works with any aircraft battery charger/analyzer used in servicing large, vented NiCad batteries and lead acid batteries. After the DataFX is connected to the aircraft battery charger/analyzer, it scans a battery's cells during charge and discharge to measure cell voltages at various intervals and displays the result on a panel screen. The information can be transferred to paper with an optional serial printer.



Battery Monitor

For more information: Marathon Power Technologies Co., 8301 Imperial Drive, Waco, TX 76712 U.S. Telephone: +1 (254) 776-0650.

Assembly-process Monitor Detects Fastener-related Errors

The TS II Qualifier assembly-process monitor can be used with electric-powered drivers or air-powered drivers to detect fastener-related assembly errors, said the manufacturer, the ASG Division of Jergens.

The assembly-process monitor can determine whether each screw in an assembly has been inserted, torqued to its designated value, cross-threaded or stripped. The assembly-process monitor also can be programmed to stop the assembly process if a pre-set parameter is not achieved, can monitor the assembly process to determine whether washers or gaskets have been omitted from a fastener and can be programmed for use with automatic feeders.

For more information: ASG, 15700 S. Waterloo Road, Cleveland, OH 44110 U.S. Telephone: +1 (216) 486-6163.♦

Call for Nominations

Air BP Ramp Safety Award

Established by Air BP and first presented in 1996, this award recognizes outstanding or significant improvement in the ramp environment through innovation and implementation of a ramp safety program. Recipients have been honored for their efforts in such areas as prevention of ground-damage accidents, improvement of aircraft rescue and fire fighting services and reduction of injuries among baggage handlers.

The award includes travel to the Flight Safety Foundation International Air Safety Seminar (IASS) for the award presentation and a handsome, wood-framed, hand-lettered citation. The award is administered by the Foundation.

The nominating deadline is Aug. 30, 2002.

Flight Safety Foundation

Submit your nomination(s) via our Internet site.
Go to http://www.flightsafety.org/ramp_safety.html

For more information, contact Kim Granados, membership manager,
by e-mail: granados@flightsafety.org or by telephone: +1 (703) 739-6700, ext. 126.