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Robert A. Feeler, editorial coordinator

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Fatigue Evaluation Indicates Most Aviation Maintenance Personnel Obtain Insufficient Sleep

An FAA evaluation of the effects of fatigue and workplace environmental factors on 500 maintenance personnel revealed that most slept less than the 7.5–8 hours a day recommended by specialists and that 50 percent sometimes felt tired at work. Thirty percent said that fatigue had a negative effect on their work performance.

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FSF Editorial Staff

Because aviation maintenance personnel often work in conditions that can contribute to fatigue, researchers evaluated workplace environmental conditions and the amount of sleep obtained by aviation maintenance personnel.

The evaluation is part of the U.S. Federal Aviation Administration (FAA) Human Factors Issues in Aircraft Maintenance and Inspection Research Program and part of a comprehensive ongoing research program to determine the effects of fatigue and workplace conditions on workplace errors.

The evaluation was designed to collect "a large amount of diverse data."

One phase of the project involved collection of "hot-weather data" from maintenance personnel who worked for U.S. airlines in the southeastern United States and the southwestern United States during the warmest months of the year — July through September, said the report on the evaluation.

Hot-weather data were collected from two groups:

- One hundred aviation maintenance personnel whose jobs were "in the environment, including line maintenance … and heavy maintenance in large hangars," the report said. (Data were not collected from maintenance personnel who worked in small-component repair shops or climate-controlled repair shops.) The personnel who participated in this phase of the data collection worked for three large air carriers. They wore two types of equipment — one to monitor the temperature, lighting and sound levels in their work environments and the second to monitor the duration of their sleep — for two weeks; and,

- The same 100 personnel and 399 other aviation maintenance personnel who worked in the three air carriers' maintenance organizations and who volunteered to respond to a 41-question survey about fatigue and work conditions. The report said that the survey was intended to help researchers understand "selected data associated with personal life, [such as] exercise, eating, sleeping, perceived job satisfaction and other such factors."

Most aviation maintenance personnel are men, and more than 97 percent of the participants in the evaluation were men. Ages of the participants ranged from 25 years to 65 years; the average age was 39 years. Most participants were line personnel and hangar personnel. (The researchers had discouraged participation by maintenance personnel whose work was primarily supervisory or managerial.)

Monitoring Equipment Shows Daily Sleep Periods Averaged Five Hours

The sleep evaluation determined periods of the participants' actual sleep and "assumed sleep." Actual sleep was calculated by software in a watchlike device worn on the wrist that measured each wearer's activity and plotted the activity levels on a chart; assumed sleep was derived by researchers who examined each chart to determine when inactivity began (when the wearer went to bed) and when activity resumed (when the wearer arose). The period of assumed sleep typically was about 50 minutes longer than the period of actual sleep.

Evaluation of the sleep data showed that the average daily sleep period for the 100 participating maintenance personnel was about five hours.

A different device — about the size of a pack of cigarettes and worn in the front pocket during work hours — collected data on temperatures, sound levels and light levels. The device recorded an average reading every two minutes. Results included the following:

- The average workplace temperature was 86 degrees Fahrenheit ([F]; 30 degrees Celsius [C]) in large hangars and 84 degrees F (29 degrees C) for line maintenance. (Humidity levels were not included in calculations of temperature.) Average temperatures during the day shift (typically beginning around daybreak) were 87 degrees F (31 degrees C); during the afternoon shift (typically beginning at midafternoon), temperatures averaged 86 degrees F; and during the night shift (typically beginning about midnight), temperatures averaged 84 degrees F. The highest temperature recorded during the study was 130 degrees F (54 degrees C). The report said that the 130-degree temperature was "not surprising" because the U.S. National Weather Service had reported outdoor temperatures in the area of more than 110 degrees F (43 degrees C);

- The average sound level was 67.7 decibels. [A decibel is a measurement of loudness. Each decibel is equal approximately to the smallest degree of difference of loudness ordinarily detectable by the human ear, the range of which includes about 130 decibels on a scale beginning with 1 decibel for the faintest audible sound.[1] The U.S. National Institute of Occupational Safety and Health has said that normal conversation is measured at about 60 decibels; a jet engine during takeoff measures about 140 decibels. People who are exposed — without hearing protection — to noises louder than about 85 decibels for long periods of time may experience permanent hearing loss.[2]] Noise levels experienced by maintenance line personnel and personnel working in large hangars were similar. The average sound level on the night shift was lower than at other times — 59 decibels; for the day shift, the average sound level was 67.7 decibels, and for the afternoon shift, the average sound level was 73.2 decibels; and,

- Light levels were measured in lumens per square meter.[3] [A lumen is a measurement of light energy in the air. For example, a 60-watt incandescent light bulb provides about 850 lumens of light.[4]] Light levels ranged from an average of 172 lumens per square meter on the night shift to an average of 1,182 lumens per square meter on the afternoon shift; the overall light measurement was an average of 692 lumens per square meter. The average light measurement for maintenance personnel working in large hangars was 578 lumens per square meter; the average for line maintenance personnel was 979 lumens per square meter.

Survey Responses Conflict With Sleep Data From Monitoring Equipment

The 499 respondents to the 41-question survey comprised maintenance personnel at four airports in the southern United States.

Forty-six percent of the maintenance personnel responding to the survey worked in airframe maintenance; the remainder worked in 10 other maintenance-area categories, including avionics, machine shop, component, power plant, structure/bond, modification line, interiors, quality assurance/inspection and apprentice.

Nearly 42 percent of respondents were from age 36 to age 45, about 30 percent of respondents were from age 26 to age 35, and about 20 percent of respondents were from age 46 to age 55. Less than 10 percent of respondents were from age 56 to age 65, less than 3 percent of respondents were age 25 years or younger, and less than 1 percent were age 66 years or older.

Nearly 90 percent of all respondents had more than five years experience in aviation maintenance, including nearly 38 percent with from 10 years to 14 years of experience, about 20 percent with from 15 years to 19 years of experience and about 20 percent with 20 years or more of experience.

Most respondents (43 percent) worked the day shift at the time of the survey. About 30 percent worked the night shift, and about 25 percent worked the afternoon shift.

Survey questions about sleep, fatigue and alertness on the job yielded the following responses:

- More than 50 percent of the respondents said that they felt most alert at the beginning of their work shifts;
- More than 50 percent of respondents said that they "sometimes"

felt fatigued at work, but only about 30 percent of respondents said that fatigue had a negative effect on their job performance;

- More than 30 percent of respondents said that they had slept between six hours and seven hours the night before they answered the survey questions; about 25 percent said that they had slept between five hours and six hours; about 20 percent said that they had slept between seven hours and eight hours; about 15 percent said that they had slept less than five hours; and less than 10 percent said that they had slept more than eight hours. The report said that responses to this question apparently were "unaligned with the actual sleep data collected" with monitoring equipment.

  "[The response to the question] shows that over 60 percent of the respondents reported that they [had] slept over six hours the previous night," the report said. "However, the [monitoring equipment] data show accurately that the average sleep was about five hours. The [monitoring equipment] data also indicate that about 67 percent of the [respondents] slept, on average, between 4.2 [hours] and six hours. This difference in data … may be attributable to numerous factors. First, the respondents may be over-reporting their sleep slightly. Secondly, the [monitoring equipment] is very accurate and does not count the initial 'tossing and turning' as sleep. Thus, there is a likely difference between the time in bed vs. the actual sleep time."

  The difference between the data gathered by the monitoring equipment and the data collected by the survey and an earlier fatigue survey[5] "strongly suggests that maintenance personnel are not fully aware of their sleep duration and the possible fatigue that may result," the report said; and,

- Most respondents said that they did not observe changes in their alertness from the beginning of a work shift to the end of a work shift.

"The collective set of these data and figures suggests that the airline maintenance workers do not perceive fatigue as a major problem," the report said.

Nevertheless, the responses indicated differences between the shift worked and the perception of fatigue, the report said. Day-shift respondents "may take a little longer to 'wake up' than the afternoon-[shift] and evening-shift [respondents]," the report said. About 45 percent of day-shift respondents said that they felt alert at the beginning of a shift, compared with about 60 percent of afternoon-shift respondents and night-shift respondents.

A higher percentage of night-shift respondents (35 percent) said that they are "frequently," "very frequently" or "always" fatigued at work, compared with day-shift respondents (23.9 percent) and afternoon-shift respondents (16.6 percent).

"[These] data suggest that shift work is related to fatigue, such that night-shift [respondents] are more likely to report being fatigued on the job," the report said.

Almost 30 percent of respondents said that fatigue had a negative effect on their job performance, including more than 40 percent of night-shift respondents, 25 percent of day-shift respondents and 19 percent of afternoon-shift respondents.

"Night-shift [respondents] have a different perspective about fatigue in comparison to the day[-shift respondents] and afternoon-shift [respondents]," the report said. "This indicates that fatigue is perceived to be more of a problem by night-shift [respondents]."

When asked to assess their level of alertness throughout their work shifts, day-shift respondents and afternoon-shift respondents said that their alertness levels were about the same. Night-shift respondents, however, said that their alertness levels decreased from the beginning of the shift to the end of the shift.

The responses provided "more evidence that [respondent] perceptions of alertness vary as a function of the shift worked by the [respondent]," the report said.

"While other factors, such as environmental factors, may have an impact on fatigue and alertness, these data present evidence that working the night shift is linked with higher levels of fatigue, lower levels of alertness and reduced levels of perceived job performance."

Survey questions about workplace environment resulted in the following responses:

- More respondents said that they were bothered more by high temperatures than by problems with sound levels or light levels. Sixty-nine percent of respondents said that heat affected their job performance. Ninety-seven percent of respondents said that water was readily accessible while they worked; 80 percent said that they drank water at least three times a day, and 39 percent said that they drank at least five glasses of water a day;

- Forty-five percent of respondents said that they "frequently" worked in inadequately lighted facilities, and more than 40 percent of respondents said that inadequate lighting had a negative effect on their job performance. (The phrasing of the survey question did not elicit information about the specific ways in which inadequate lighting affected performance); and,
- Fifty-eight percent of respondents said that "noise" had a negative effect on their job performance.

Report Recommends Education on Importance of Sleep

Most sleep researchers recommend that people sleep between 7 1/2 hours and eight hours a day,[6] and none would consider adequate the approximately five hours of sleep (or the six hours of "assumed sleep") achieved by aviation maintenance personnel, the report said.

"The sleep experts would argue that the population of maintenance personnel is acquiring a daily 'sleep debt' of at least two hours," the report said. "Since the [monitoring equipment] was worn seven days a week for the two-week data-collection period, it does not appear that maintenance personnel are repaying the sleep debt. … [T]he questionnaire data … does not reflect a population that perceives chronic fatigue or tiredness. The data collected from the [monitoring equipment] strongly suggest that the population of aviation maintenance workers has a sleep deficiency problem and has not yet acknowledged that potential problem."

The report said that aviation maintenance personnel probably are unaware of how little they sleep in comparison with the amount of sleep recommended by specialists.

The report recommended the following actions to help maintenance personnel improve their sleeping habits:

- Airlines could provide monitoring equipment to maintenance personnel to help them understand their sleeping habits and to improve them, if necessary. "The productivity return on investment would quickly justify the cost of the equipment, administration personnel and training," the report said;
- An educational campaign could be organized to show that adequate sleep — along with avoiding abuse of alcohol or drugs — is an essential element of a maintenance employee's fitness for duty; and,

- Information could be provided to inform maintenance personnel of the symptoms of fatigue and to provide recommendations to eliminate or lessen the problem. "If personnel can recognize fatigue, they can help one another to avoid the inevitable performance degradation and potential error," the report said. The report said that the Air Transport Association of America included such recommendations in its *Alertness Management Guide,* published in 2000. The recommendations called for minimizing sleep loss; altering habits to acquire the necessary amount of sleep; creating an acceptable environment for sleep; and understanding the effects on sleep of age, alcohol, diet and exercise.[7]

The report also recommended the following actions involving workplace temperatures, light levels and sound levels:

- The effects of working in conditions that combine high ambient temperatures, a hot ramp, hot aircraft and hot ground equipment can be lessened with "adequate staffing, reasonable scheduling of activity, proper pacing in high-temperature conditions, plenty of water and adequate rest throughout the work shift," the report said.

  The average 86-degree F temperature experienced by the maintenance personnel who wore monitoring equipment exceeded the maximum temperatures recommended by FAA's *The Human Factors Guide for Aviation Maintenance and Inspection*. The recommended temperatures vary from about 66 degrees F (19 degrees C) to 79 degrees F (26 degrees C), depending on a variety of factors, including temperature, humidity, air velocity, the type of work being performed and the type of clothing worn by the worker.[8]

  Nevertheless, the report said that the companies participating in the study complied with most recommended practices for hot-weather work: Drinking water was readily available, and fans and portable air-conditioning systems were in place;

- High sound levels are "an unavoidable byproduct of turbine engines and industrial repair equipment," the report said. The report recommended hearing protection (earplugs and/or headphones) for workers exposed to sound levels that exceed standards set by the U.S. Occupational Safety and Health Administration (OSHA). The sound levels recorded by the monitoring equipment worn by maintenance personnel were within OSHA limits. Because maintenance personnel wore the monitoring equipment without supervision, there was no indication of when they wore hearing protection. Nevertheless, researchers observed maintenance personnel — especially ramp personnel — wearing hearing protection when required; and,

- The report recommended adequate lighting in the workplace. The average light level of 692 lumens per square meter recorded by the monitoring equipment worn by maintenance personnel was less than the range of 750 lumens per square meter to 1,000 lumens per square meter recommended by *The Human Factors Guide for Aviation Maintenance and Inspection.*

The evaluation described in the report was one element of an ongoing study of the effects of the workplace environment and fatigue on work performance. Additional research was planned to gather data to be used in developing models to predict when a combination of fatigue and environmental factors in the workplace would be likely to result in human error. The report said that the data also will be used to develop guidelines to help maintenance personnel prevent or reduce their fatigue and correct problems in the workplace environment that are within their control.♦

Notes

1. FSF Editorial Staff. "Heredity, Disease, Aging Present Crewmembers With Increased Risk of Hearing Loss." *Human Factors & Aviation Medicine* Volume 47 (July–August 2000): 3.

2. U.S. National Institute of Occupational Safety and Health. *NIOSH Sound Meter*. www.cdc.gov/niosh/hp140.html.

3. The report said that the light measurement might be misleading in some situations, including situations involving reduced light, situations in which a flashlight is used and situations involving maintenance procedures that require personnel to look inside a cowling. The report also said that the sensor measured the amount of light on the person wearing the monitoring equipment rather than the amount of light on the work being performed by that person; nevertheless, the report said that in most situations, those measurements would be similar.

4. Brautigam, Jack. *Compact Fluorescent Lamps*. Washington State University Cooperative Extension. cru.cahe.wsu.edu/CEPublications/eb1845e/eb1845e.html. Nov. 12, 2001.

5. Sian, B.; Watson, J. *Study of Fatigue Factors Affecting Human*

Performance in Aviation Maintenance. Washington, D.C., U.S.: U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine, 1999.

6. Battelle Memorial Institute; JIL Information Systems. *An Overview of the Scientific Literature Concerning Fatigue, Sleep, and the Circadian Cycle*. Washington, D.C. U.S.: FAA Office of the Chief Scientific and Technical Advisor for Human Factors, 1998.

7. Air Transport Association of America (ATA); Alertness Solutions. *Alertness Management Guide*. Washington, D.C., U.S.: ATA, 2000.

8. FAA. *The Human Factors Guide for Aviation Mainte-nance and Inspection*. Edited by Maddox, M. Washington, D.C., U.S., 1998.

[FSF editorial note: This article, except where specifically noted, is based on *Evaluation of Aviation Maintenance Working Environments, Fatigue and Human Performance*, a product of the U.S. Federal Aviation Administration (FAA) Human Factors Issues in Aircraft Maintenance and Inspection Research Program. The report was written by William B. Johnson and Felisha Mason of Galaxy Scientific, Steven Hall of Embry-Riddle Aeronautical University and Jean Watson of FAA. The 44-page report contains figures, tables and appendixes.]

Further Reading From FSF Publications

Hobbs, Alan; Williamson, Ann. "Survey Assesses Safety Attitudes of Aviation Maintenance Personnel in Australia." *Aviation Mechanics Bulletin* Volume 48 (November–December 2000).

Caldwell, J. Lynn. "Managing Sleep for Night Shifts Requires Personal Strategies." *Human Factors & Aviation Medicine* Volume 46 (March–April 1999).

FSF Editorial Staff. "Overcoming Effects of Stress Offers Greatest Opportunity to Sleep Well." *Human Factors & Aviation Maintenance* Volume 45 (July–August 1998).

Flight Safety Foundation Fatigue Countermeasures Task Force. "Principles and Guidelines for Duty and Rest Scheduling in Corporate and Business Aviation. *Flight Safety Digest* Volume 16 (February 1997).

NTSB Recommends Changes in Lubrication of Horizontal Stabilizer Trim System on DC-9, MD-80/90, Boeing 717

The U.S. National Transportation Safety Board (NTSB), citing a Jan. 31, 2000, accident in which an Alaska Airlines McDonnell Douglas MD-83 struck the Pacific Ocean, has recommended changes in the lubrication procedure and the end-play check procedure for the horizontal stabilizer trim system of Douglas DC-9, MD-80/90 and Boeing 717 series airplanes.

The MD-83, which was being flown from Puerto Vallarta, Mexico, to Seattle, Washington, U.S., was destroyed in the accident, and all 88 people in the airplane were killed. The investigation of the accident was continuing when NTSB issued the recommendations.

The horizontal stabilizer on MD-80/90, DC-9 and B-717 series airplanes is at the top of the vertical stabilizer and is hinged near the trailing edge to allow the leading edge to move up and down to provide pitch trim. The horizontal stabilizer's actuating mechanism is an "acme screw" — a threaded shaft that is attached to the horizontal stabilizer and that rotates through a stationary acme nut attached to the vertical stabilizer. The acme screw is rotated by an electric motor activated by the autopilot or by a control-wheel trim switch.

NTSB said, "Performance data based on the accident airplane's flight data recorder indicate that the leading edge of the horizontal stabilizer rotated upward well beyond its design limit. Examination of the acme screw and [acme] nut … revealed that approximately 90 percent of the acme nut threads had worn away before the remainder of the acme nut threads stripped out. Those remnants were found wrapped around the acme screw. The stripping of these threads would have allowed the acme screw to slip upward through the acme nut until the lower stop impacted the bottom of the acme nut."

NTSB said that its review of design-and-certification data revealed that "no contingency for stripped acme nut threads was incorporated into the design for the horizontal stabilizer trim system on these airplanes. Thus, the possibility of the acme screw disengaging from the acme nut was not formally considered during the certification process."

Maintenance manuals for DC-9, MD-80/90 and B-717 series airplanes say that grease should be applied periodically to acme nut fittings, that a light coat of grease should be brushed onto the acme screw thread and that the grease should be distributed over the length of the acme screw by operating the system through its full range of travel. Improper lubrication of acme screw and acme nut assemblies can result in excessive acme nut thread wear rates, NTSB said.

NTSB said that its investigators observed differences in the methods used by maintenance personnel to lubricate acme screw and acme nut assemblies and that some methods did not apply grease to the entire length of the acme screw.

"As a result, [NTSB] is concerned that the current lubrication procedure may not be adequate to ensure consistent and thorough lubrications of the acme screw and [acme] nut assembly by all operators," NTSB said.

Seven months after the accident, on Aug. 23, 2000, NTSB issued airworthiness directive (AD) 2000 15-15 outlining the required procedure to be used in monitoring wear of the acme nut thread. NTSB said that, since then, its investigators have observed maintenance personnel performing the procedure, called an end-play check, and have reviewed data indicating that the end-play check may not be "adequate to ensure consistent, accurate and reliable measurements of acme screw and [acme] nut wear."

NTSB said that during the accident investigation, some inspectors and managers from the U.S. Federal Aviation Administration (FAA) said that the monitoring of airline lubrication practices might not be adequate to ensure that only compatible mixtures of grease are used on the acme screw and acme nut assemblies. (When incompatible mixtures of grease are used, their physical properties or their performance may be affected adversely.)

In a letter to FAA, NTSB said that FAA should:

- Require Boeing Commercial Airplanes to revise the lubrication procedure for the horizontal stabilizer trim system on DC-9, MD-80/90 and B-717 series airplanes "to minimize the probability of inadequate lubrication";
- Require Boeing to revise the end-play check procedure "to minimize the probability of measurement error" and to conduct a study to "validate the revised procedure against an appropriate physical standard of actual acme screw and acme nut wear";
- Require specialized training for maintenance personnel who

lubricate the horizontal stabilizer trim system on DC-9, MD-80/90 and B-717 series airplanes;

- Require specialized training for maintenance personnel who inspect the horizontal stabilizer trim systems on DC-9, MD-80/90 and B-717 series airplanes. The training should include familiarization with the end-play check;

- Require operators that propose changes in lubrication applications to first provide FAA with technical data to show that the proposed changes "will not present any potential hazards" and to obtain FAA approval of the proposed changes;

- Provide guidance to principal maintenance inspectors "to notify all operators about the potential hazards of using inappropriate grease types and mixing incompatible grease types";

- Survey operators to determine whether lubrication processes are being used that deviate from manufacturer specifications. If any of the deviations involve use of inappropriate grease types or incompatible grease mixtures, eliminate those processes; and,

- Convene an industrywide forum to discuss lubrication of aircraft components, "including the qualification, selection, application methods, performance, inspection, testing, and incompatibility of grease types used on aircraft components."

ATSB Recommends Review of Lubrication in Landing-gear Components

The Australian Transport Safety Bureau (ATSB), citing landing gear failures on two Boeing 737s, has recommended that the lubrication of pin/lug joints in main-landing-gear structures be reviewed "to ensure that movement between pins and lugs is effectively lubricated."

ATSB said that components of the main landing gear on two B-737s failed when the landing gear were being extended. Both incidents occurred during landings in Melbourne, Australia; the first incident occurred March 12, 1999, and the second incident occurred April 4, 1999.

"On both occasions, the landing gear extended and locked normally," ATSB said in a technical analysis report on the incidents. "However, while landing was completed without incident, the uncontrolled movement of fractured landing-gear components has the potential to damage other components and interfere with flight controls."

In one incident, an aileron bus cable was damaged during the landing-gear extension.

In a similar incident in 1987, an actuator-beam arm-lug fitting on a B-737 broke and the released components interfered with the movement of aileron cables, resulting in an uncommanded maneuver, the report said. [The report did not say where the incident occurred.] After that incident, modifications were imposed in lug bushes and the methods used to install them.

"The [Australian] occurrences … indicate a continuing deficiency in the safety system that addresses the structural integrity of landing gear," the report said.

The report said that the fractures of the landing-gear-component lugs were a result of stress corrosion cracking, which occurred because "components manufactured from specific alloys [were] exposed to a particular environment while being subjected to a sustained tensile stress state.

"The high-strength steel alloys required for the manufacture of landing-gear components are known to be susceptible to stress corrosion cracking when exposed to the normal operating environment of landing gear (moisture, [especially] salt-laden moisture)," the report said. "Landing-gear components are always subjected to sustained tensile stresses through the residual stresses that are created by the manufacturing processes (e.g., forging, heat treatment)."

Cadmium plating and paint films typically are used to avoid stress corrosion cracking by providing a physical barrier between the steel alloy and the environment. Nevertheless, the contact stresses and relative movements of contacting surfaces in the pin-lug joints preclude the use of cadmium plating and paint films. Instead, replaceable bushings are fitted to the lugs to isolate the lug surface from the operating environment.

"The failure of lugs in landing-gear pin/lug joints by stress corrosion cracking indicates that the designed defense against stress corrosion cracking has been defeated," the report said. "The failure of the lugs should be attributed to the failure of the environmental isolation system."

Inspection of the pin/lug joints in the incident airplanes revealed that a gap had been created between the bushing and the lug and that stress corrosion cracking initiated at the surface of the lugs. The inspection showed that galling (which ATSB described as "adhesive wear [that] occurs when welding and subsequent fracture occurs between the surface asperities of two surfaces subjected to high contact pressure and limited sliding movement") had occurred between the wearing surfaces of the pins and bushings when the landing gear was being operated.

Lubrication of the area to ensure separation of sliding surfaces is essential in preventing galling.

ATSB said that "consideration should be given to verifying the adequacy of grease paths to allow grease to lubricate all contact surfaces within a joint. In particular, the conditions under which grease can flow to all surfaces should be established. Greasing while components are under load may exclude grease from regions of contact. Localized grease exclusions may be significant in joints that experience a limited range of movement."

Engine Failure Prompts Emergency Landing of Twin-engine Islander

The pilot of a Pilatus Britten-Norman BN-2B-26 Islander said that he had leveled the airplane at 3,000 feet after a night departure from Glasgow, Scotland, when he heard a noise that sounded like "hailstones striking the windscreen." The right engine (a Lycoming O-540-E4C5 piston engine) lost power, and the pilot declared an emergency, flew the airplane back to the departure airport and conducted a single-engine landing.

Inspection of the right engine revealed that although the engine was not turning, the propeller could be rotated, that there was a hole in the lower forward face of the crankcase and that the crankshaft had failed in the area of the no. 1 journal bearing. Inspection also showed that the no. 4 inlet valve pushrod tube was bent, that there was a hole in the no. 4 cylinder rocker cover and that the no. 1 piston connecting-rod end cap and debris from the crankcase were in the lower cowling.

The U.K. Air Accidents Investigation Branch (AAIB) said that after the rocker covers were removed, a fracture was observed across the diameter of the no. 4 inlet valve spring upper seat. The fracture caused the valve to enter the cylinder. A similar fracture occurred in the valve spring upper seat of the no. 6 cylinder, but half of the seat remained in position, as did the valve stem.

The engine had accumulated 8,564 hours since new and 1,453 hours since the last overhaul, about 2 1/2 years before the accident.

A metallurgical examination revealed that the crankshaft had failed "as a result of long-term high-cycle tension fatigue" at the no. 1 connecting-rod crank pin and that a fatigue crack had progressed through about 75 percent of the crank-pin cross section. The report said that the fracture progressed through the lubrication supply hole and that, as the fracture widened, oil pressure decreased.

The report said, "Measurement of all the crankshaft journals (i.e., mains and crank pins) showed that they had been ground 0.006 inch [0.152 millimeter] undersize. Microhardness tests were conducted on a sample of material that included the bearing radius in which the crankshaft fracture had initiated. The hardness was found to be low for a nitrided surface, indicating that it had not been renitrided after being ground undersize."

(The renitriding requirements were specified in Textron Lycoming Service Bulletin [SB] 222D, dated Nov. 8, 1999. The SB said that all reground crankshafts should be renitrided but that polishing to 0.006 inch undersize was permitted. The report said that the company considers SB 222D mandatory but that neither the U.S. Federal Aviation Administration (FAA) nor the U.K. Civil Aviation Authority (CAA) requires compliance. Nevertheless, the report said that the renitriding requirements in the SB were the same as those included in the engine overhaul manual, which was last amended in 1971.)

"Although the reason for the fatigue initiation was not fully established, the reduced surface hardness in the failure region of the crank pin radius, coupled with the engine manufacturer's view on the importance of maintaining the hardened nitrided layer, implied that the apparent failure to renitride the crankshaft after grinding could have been a factor," the report said.

Maintenance records showed that the engine was overhauled in 1988 by the manufacturer and that Lycoming had said that the engine had a "reworked crankshaft, serial number B2379, part number LW-17622." Subsequent overhauls were performed in 1992 and 1997; in both instances, there was no record of the crankshaft serial number or part number. (Joint Aviation Requirements [JARs] do not require that the numbers be recorded.)

AAIB was unable to obtain records containing details of the work performed during the 1988 overhaul because FAA requires such records to be kept for only two years and, as a result, the records had been destroyed. JARs Part 145.55 includes a similar two-year requirement.

As a result of the investigation, AAIB recommended that CAA "promote amendment of JARs 145.55 to increase the minimum period for the retention of maintenance records from two [years] to five years."♦

Conference on Quality in Commercial Aviation To Be Held in September 2002

The U.S. Federal Aviation Administration and the Aviation/Space and Defense Division of the American Society for Quality have scheduled their 13th Conference on Quality in Commercial Aviation (CQCA) for Sept. 22–25, 2002, in Dallas, Texas, U.S.

The conference, which is held every 18 months, will include international representatives from airlines, suppliers to the aviation industry, manufacturers of aircraft and aircraft engines, FAA and other civil aviation authorities. Presentations will discuss safety, quality and maintenance issues.

The International Aerospace Quality Group (IAQG), which supports the CQCA, will hold its Supplier General Assembly meeting in Dallas beginning Sept. 25, immediately after the CQCA.

For more information: Lester G. Lemay, CQCA, 5400 Bosque Blvd., Suite 680, Waco TX 76710 U.S. Telephone: +1 (254) 776-3550.

Brushless Torque-controlled Screwdriver Eliminates Carbon Dust

A torque-controlled screwdriver with a brushless motor has been designed to eliminate carbon dust and to last longer, said the manufacturer, ASG.

The screwdriver is rated for continuous use with minimal heat buildup, the manufacturer said. The screwdriver is designed for medium-torque assembly applications to light-torque assembly applications and stops

Torque-controlled Screwdriver

automatically when a preset torque is achieved. The 7.95-inch (20-centimeter), 12.7-ounce (360-gram) screwdriver can be converted from a lever-start screwdriver to a push-to-start screwdriver.

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

Lightweight Solid-wall Swaged Inserts Designed for Use in Aircraft Engines

A variety of lightweight solid-wall swaged inserts have been designed for use in aircraft engines and other aerospace applications, said the manufacturer, SPS Technologies.

The inserts are available in various alloy-steel materials with various finishes, are intended to improve thread life and thread performance, and include a locking knurl design to aid in installation.

Solid-wall Swaged Inserts

For more information: SPS Technologies, 301 Highland Ave., Jenkintown, PA 19046-2692 U.S. Telephone: +1 (215) 572-3718.

Stripping Agents Remove Silicon, Polysulfide From Aircraft

Two aircraft grades of GenSolve high-performance stripping agent allow removal of silicone and polysulfide sealants and coatings from aircraft metal, glass, ceramic and plastic components, said the manufacturer, General Chemical Corp.

The GenSolve stripping agents break down sealants so that they can be rinsed away without damage to aircraft components. The stripping agents can be sprayed on, wiped on or used in immersion cleaning systems. They do not react with copper, iron, aluminum, zinc or titanium.

For more information: Fine Chemicals Group, General Chemical Corp., 90 East Halsey Road, Parsippany, NJ 07054 U.S. Telephone: (800) 631-8050 (U.S.) or +1 (973) 515-0900.

Leak-detection Technology Tests Deicing Fluid, Fuels

Vista Research's non-invasive leak-detection technology is being used to test aircraft deicing fluid and aircraft fueling systems, said the manufacturer.

The Vista system calculates the expected change in fluid volume as air conditions and ground conditions cause the temperature of pipeline contents to change. If changes in fluid volume do not conform to the expected changes, the discrepancy indicates that a leak exists. The leak can be located by sensors attached to the pipe.

For more information: Vista Research, 755 North Mary Ave., Sunnyvale, CA 94085 U.S. Telephone: +1 (408) 830-3300.

Inspection Camera Fits Through Narrow Openings

The PTZ-Cam 2.75 robotic inspection video camera fits through narrow openings to evaluate the structural condition of a vessel, said the manufacturer, iShot Imaging.

The camera has a total zoom capability of 40-to-1, and the camera's head assembly pans 360 degrees and tilts plus or minus 110 degrees. The camera is equipped with twin spot lamps and twin flood lamps for even illumination without shadows, and a remote control console for many camera functions.

For more information: iShot Imaging, 27 Ironia Road, Flanders, NJ 07836 U.S. Telephone: +1 (973) 927-2900.

Instrument Measures Tension Ultrasonically

The StressTel BoltMike III ultrasonically measures the tension and clamp load of threaded fasteners in the tightening of critical bolted joints in aircraft engines and the verification of tension on bolts on clamping wheel assemblies, said the manufacturer.

The instrument weighs 2.5 pounds (1.14 kilograms), operates for as long as 40 hours on standard double-A

Ultrasonic Tension Meter

batteries and has rapid calibration and setup, the manufacturer said.

For more information: StressTel, 2790 West College Ave., State College, PA 16801-2605, U.S. Telephone: +1 (814) 861-6300.

Electrostatic Oil-cleaning Systems Remove Contaminants

KLEENTEK electrostatic oil-cleaning systems remove insoluble contaminants, including tars and varnishes, from hydraulic oil systems, said the manufacturer.

Tar, varnish and sludge on component surfaces can cause a loss of control stability, requiring repeated valve adjustments, increased downtime and reduced machine performance. The oil-cleaning systems draw contaminants out of the oil and trap them on the surface of the collector, the manufacturer said.

For more information: Kleentek, 4440 Creek Road, Cincinnati, Ohio 45242 U.S. Telephone: (888) 281-4888 (U.S.) or +1 (513) 891-0400.

Tapes Protect Aircraft Surfaces

Colored self-adhering tapes have been introduced to replace top-coat paints on aircraft surfaces, said the manufacturer, 3M Engineered Adhesives Division.

The tapes are easy to apply, provide protection for interior surfaces and exterior surfaces, and resist accumulation of surface contaminants. The tapes require little maintenance and resist degradation or discoloration caused by exposure to ultraviolet light.

Paint Replacement Tape

For more information: 3M Engineered Adhesives Division, 3M Center, Building 220-8E-05, St. Paul, MN 55144-1000 U.S. Telephone: (800) 364-3577 (U.S.) or +1 (651) 733-1110.♦