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Robert A. Feeler, editorial coordinator

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On the cover: Aircraft fueling

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Safety Specialists Recommend Precautions for Work In Aircraft Fuel Tanks

Risks of explosion and life-threatening health problems can be minimized by following proper procedures and monitoring the work area to guard against unsafe levels of toxic substances and to ensure adequate levels of oxygen.

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FSF Editorial Staff

The fuel tanks of large airplanes are inherently hazardous places to work, full of toxic vapors from jet fuel and associated chemicals that present risks of explosion and chronic illness or death.

To minimize the risks, specialists in fuel-tank entry procedures recommend an extensive series of precautions, emphasizing continuous monitoring of the atmosphere inside the tanks to ensure that the level of oxygen is adequate for breathing and that volatile and toxic concentrations of fuel, cleaning solvents and other substances taken into the tanks by maintenance technicians do not exceed legally allowable levels.

In some instances, the maintenance technicians who work in airplane fuel tanks are not fully aware of the long-term risks of their jobs, said David DeClue, a Canadian Airlines senior instructor who teaches classes on fuel-tank entry procedures. A common misconception, even among many of the maintenance technicians who regularly work on fuel tanks, is that the greatest hazard is the risk of explosion, said DeClue, whose classes stress the hazards posed by long-term exposure to jet fuel in liquid and vapor forms.

Studies since 1976 have explored links between long-term exposure to jet fuel and health problems, including ailments that affect the central nervous system and the lungs.

Effects on workers vary, depending on the type of fuel. Jet A and Jet A-1, generally used in commercial aviation, and JP-5 and JP-8, which are used in land-based military aircraft, are primarily kerosene, with a small percentage of additives. Jet B and JP-4, fuels that no longer are widely used, are blends of kerosene and gasoline that also contain benzene, a carcinogen associated with leukemia (bone-marrow cancer) and other ailments, including aplastic anemia (a deficiency of red blood cells or hemoglobin caused by defective functioning of blood-producing organs, such as bone marrow).

Many older workers who attend the classes taught by DeClue and his colleagues are skeptical of warnings about possible health hazards posed by their jobs, and they frequently cite their own apparent good health as evidence that exposure to jet fuel poses no problems.

But medical researchers have said that in the short-term, a worker exposed to a concentrated level of JP-4 fuel vapor can experience slurred speech, blurred vision, headaches, drowsiness and dizziness.

Russell B. Rayman, M.D., of the Aerospace Medical Association, said that "dangerous exposures can result from the inhalation of fumes … . The major effect is on the nervous system, causing CNS [central nervous system] dysfunction, headache, drowsiness, dizziness and possible coma and death."[1]

A study published in 1979 found that workers with long-term exposure to jet fuel vapor experienced a higher incidence of fatigue, anxiety, mood disturbances, memory dysfunction and psychosomatic symptoms than members of a control group not exposed to jet fuel vapor.[2]

A study by the U.S. Navy and U.S. Air Force found that laboratory animals exposed to JP-4 fuel vapor showed no significant blood or bone marrow changes.[3] Nevertheless, Rayman has questioned those results.

"The follow-up period may have been too short since the latency period may be 20 years or more," Rayman said.

More recent studies by researchers at the University of Arizona found the beginnings of pulmonary fibrosis, a stiffening of the lungs, in rats that were exposed to JP-8 vapor.[4] The studies also found that the rats' "attentional mechanisms" may have been affected by their exposure to the substance.[5]

DeClue said that another misconception among some of the fuel-tank maintenance technicians in his classes is that their working conditions are safe, as long as the atmospheric monitors that often are used to alert them to danger are not registering an alarm. But some alarms are triggered only when vapors reach levels that are considered explosion hazards — not when they are present at lower levels that put unprotected workers at risk for health problems caused by long-term exposure to toxic substances, he said.

For example, DeClue said, if an oxygen/lower-explosive-limit (LEL)[6] atmospheric monitor detected 20.4 percent oxygen and 5 percent LEL in a fuel tank, those readings would indicate that a technician could enter the tank and expect to be safe from an explosion. According to occupational safety regulations in many countries, the monitor must indicate no more than 10 percent LEL before a maintenance technician may enter. The LEL for Jet A fuel is 0.7 percent of the atmosphere. Ten percent of 0.7 is 700 parts per million (ppm). But since the generally accepted time-weighted average exposure limit (calculated for eight hours a day, five days a week) is 49 ppm, then the reading of 5 percent LEL (or 350 ppm) would mean that a technician exposed to that level over a long period of time would be overexposed to the toxic effects of the fuel.

DeClue and Canadian Airlines colleague Larry Remin, a technical instructor and developer, recommend steps that maintenance technicians should take to protect themselves while performing maintenance in airplane fuel tanks.

The first step is to defuel and to determine what type of fuel was in the tank, a difficult task because more often than not, repeated fuelings leave a combination of Jet A and Jet A-1 — or in aircraft used by the military, a combination of military fuels — in the tank.

The next step is to use an atmospheric monitor to measure the oxygen level in the fuel tank and the LEL of the fuel vapor in the tank.

Before workers enter a tank, the oxygen level must be between 19.5 percent and 23.5 percent (a higher level presents the risk of explosion; a lower level is considered insufficient for human needs), and the LEL must be less than 10 percent, according to the U.S. Occupational Safety and Health Administration (29 Code of Federal Regulations 1910.146) and regulatory agencies in a number of other countries.

Workers then decide what type of ventilation to use in the fuel tank. One effective type is extraction, which positions electric blowers to draw fuel vapor into a safe area, generally outdoors. In some places, local laws require an additional decontamination process that releases the exhaust into the air only after it passes through a toxic-filtration system.

Then begins a check for toxic levels of kerosene, the base ingredient of both Jet A and Jet A-1 (and sometimes for the presence of other toxic substances). Among the airlines that Remin considers "progressive" in their attitudes on worker exposure to jet fuel, an acceptable level of Jet A is 49 ppm or 50 ppm; other airlines tolerate levels as high as 300 ppm. (In some countries, including the United States, government regulations control some aspects of work in confined spaces such as aircraft fuel tanks. But U.S. regulations do not set exposure limits; instead, U.S. industries rely on recommendations from the American Congress of Industrial Hygienists and from material safety data sheets provided by chemical manufacturers.)

Monitoring should continue throughout fuel-tank maintenance procedures to ensure that adequate oxygen levels are maintained and that vapors (fuel vapor or vapors from cleaning fluids or any other substances taken into the tank) remain well below explosive and toxic concentrations.

Often, extraction is enough to reduce toxicity levels to acceptable limits. But in some situations, especially on warm days, a worker may need to enter the tank to use a mop or an explosion-proof vacuum system to remove lingering traces of fuel. In those instances, the worker should wear full personal-protective equipment — chemically resistant clothing and an air-supplied respirator.

Airline procedures differ on when workers are required to wear protective gear, but Remin said that "by the time we've finished training our guys, they wear their personal-protective gear all the time."

Even if monitors indicate that the tank holds a safe level of oxygen and acceptably low levels of fuel vapor, the situation can change — if the worker uses a solvent, for example, or opens a valve that releases fuel. In the confined space of a fuel tank, the addition of even a small amount of a new substance can dramatically change the atmosphere.

The area within a radius of 25 feet (7.5 meters) of the fuel-tank opening should be clear of work that might cause additional hazards, including any activity involving electrical equipment, paint or sanding. No power source should be used in any aircraft within this safety zone, and use of radio-transmitting and radar equipment should be limited even outside the zone. If the atmosphere in the fuel tank is considered explosive, the radius of the safety zone should be expanded to 50 feet (15 meters).

The aircraft should be statically grounded and located in an area that will allow for adequate ventilation and easy access by emergency equipment and personnel.

After monitoring equipment indicates that toxicity levels are within acceptable limits, a worker can enter the tank, but only after personal precautions are taken. Among those precautions:

- The worker should wear flame-resistant or 100 percent cotton coveralls and cotton underwear. (During a fire, some synthetic fibers can melt on the skin, causing severe burns.) Coverall pockets should be sewn shut so that nothing can be carried in a pocket into the tank;
- Street clothes should not be worn into a tank, because cloth absorbs fuel vapors. The worker should change clothes before entering the tank, then shower before putting street clothes on again;
- Jewelry, steel-toed boots, battery-powered hearing aids and other battery-powered electronic devices should not be worn in fuel tanks. Flashlights and work lights used inside a fuel tank must be designed to operate safely in volatile atmospheres; and,
- Contact lenses should not be worn if the worker is using a respirator, because the respirator can dry the eyes.

The area near the aircraft's fuel tanks should be secured according to an elaborate lock-out/tag-out procedure in which every person working in the area installs a padlock on every power source and every valve that could do damage if it were opened. When the required locks are in place, the work is authorized to begin. Atmospheric monitoring should continue throughout the procedure. When every person who installed a lock on a power source or valve has completed work, his or her locks are removed; as long as a single lock remains, the device cannot be operated.

Remin said that, after all precautions have been taken, "you've eliminated 99 percent of the hazards." Among the remaining 1 percent are unexpected developments, such as a fire near the work site, and health issues involving the individuals who enter the tank.

"If they haven't had a medical [examination] and you're sending them into a fuel tank, you're increasing the [hazards]," Remin said.

Health issues also include the sudden onset of claustrophobia or an incapacitating illness.

The rescue of anyone working inside a fuel tank is difficult, often impossible, because of the time-consuming process of crawling through the confined spaces of the fuel tank.

Many aircraft operators lack the personnel and equipment needed for fuel tank rescue operations, and they give the responsibility to a local fire department. If aircraft operators take the responsibility themselves, the rescue staff needs training in first aid and special techniques for extracting a victim from a tank, as well as regular practice to maintain proficiency.♦

References and Notes

1. Ribak, Joseph; Rayman, Russell B.; Froom, Paul. *Occupational Health in Aviation: Maintenance and Support Personnel*. San Diego, California, U.S.: Academic Press, 1995.

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3. Macnaughton, M.G.; Uddin, D.E. "Toxicology of Mixed Distillate and High Energy Synthetic Fuels." In *Proceedings of the Workshop on the Kidney Effects of Hydrocarbons.* Washington, D.C., U.S.: American Petroleum Institute, 1983. Cited by Ribak et al.

4. Mark L. Witten, Ph.D., University of Arizona. Personal correspondence with Werfelman, Linda. Alexandria, Virginia, U.S., Sept. 13, 1999. Flight Safety Foundation, Alexandria, U.S.

5. Carol M. Baldwin, R.N., Ph.D., University of Arizona. Personal correspondence with Werfelman, Linda. Alexandria, Virginia, U.S., Sept. 16, 1999. Flight Safety Foundation, Alexandria, U.S.

6. The lower explosive limit (LEL) is the leanest mixture of a combustible gas and air that could result in an explosion if an ignition source is present.

Further Reading From FSF Publications

FSF Editorial Staff. "Knowledge of Hazardous Chemicals in the Aviation Workplace Can Help Prevent Work-related Illness and Injury." *Aviation Mechanics Bulletin* Volume 45 (July–August 1997).

Feeler, R.A. "One Cure for Workplace Safety Complacency: Safety Checklists." *Aviation Mechanics Bulletin* Volume 43 (September–October 1995).

Feeler, R.A. "Correct Selection and Use of Respirators Is Vital in Contaminated-air Environments." *Aviation Mechanics Bulletin* Volume 42 (November–December 1994).

In-flight Engine Failure Traced to Disintegrated Second-stage Turbine Wheel

The Australian Bureau of Air Safety Investigation (BASI), citing an in-flight engine failure, has recommended that the manufacturer, AlliedSignal, review elements of the process used to produce second-stage turbine wheels for TPE331 engines.

The engine failure involved the right engine of a Fairchild Metro II as the airplane was descending to land at Launceston airport in Tasmania, Australia. The crew conducted a single-engine landing, and a subsequent inspection revealed that the engine failure was a result of the disintegration of the second-stage turbine wheel. Segments of the wheel penetrated the engine nacelle, and one fragment was found in the cabin lining.

The engine, an AlliedSignal TPE331-3U-304G, had been flown 6,017 hours. The second-stage turbine wheel had been in service for 2,973 hours.

The report said that the second-stage turbine wheel failed because of "the progressive reduction of the wheel cross-section, during operation, near the transition from the hub to web." An analysis found that no pre-existing cracks and no material anomalies contributed to the separation of the wheel segments. The reduction in the wheel cross-section was attributed to the effects of sliding contact with parts of the wheel's knife-edged seal.

The investigation found that the seal fractured because of fatigue-crack growth from the radii at the corners of slots in the seal's forward edge. When the fractured seal was compared with the seal from another second-stage turbine wheel assembly, a significant variation was observed in the radii of the slot corners, and the only intact slot corner in the fractured seal was sharper than the corners of other seals. The report said that a decrease in the radius of a slot corner would increase stress concentration and increase chances of a fatigue crack.

BASI issued the following interim recommendations:

- AlliedSignal should audit the manufacturing process for TPE331 turbine wheel knife-edged seals to determine what might lead to excessive variations in slot-corner radii;
- AlliedSignal should determine how sensitive turbine wheel seals

are to “the initiation of fatigue cracks from slot corners, as a function of slot-corner radii;”

- AlliedSignal should “consider, during engine design and the formulation of continuing airworthiness instructions, the possibility that turbine-wheel seal-fatigue failure may result in hazardous modes of engine failure;”

- The Australian Civil Aviation Safety Authority should review parts of the aviation system that deal with the operational histories of life-limited components to determine why the operational history of the second-stage turbine wheel could not be determined; and,

- The U.S. Federal Aviation Administration should note the deficiency and take whatever action it considers necessary.

Emergency Directive Grounds Eurocopter BK117s

The German Luftfahrt-Bundesamt (LBA) and the U.S. Federal Aviation Administration (FAA) issued emergency airworthiness directives (ADs) that grounded MBB-BK 117 Eurocopters after a fatal accident caused by separation of a main-rotor blade during a flight in the United States. Three people were killed in the accident in Texas, and the aircraft was destroyed.

“The cause of the blade separation was a tension-torsion (TT) strap rupture in the main-rotor head,” LBA said.

The TT strap is a wound-wire cable that binds the rotor blade to the rotor head.

Both agencies’ ADs ground the helicopters until the operators determine the age of the TT strap and the number of flights that have been made with the strap in place. The ADs also require inspection and replacement of the straps.

“This condition, if not corrected, could result in failure of a TT strap, loss of a blade and subsequent loss of control of the helicopter,” FAA said.

The ADs said that TT straps that have exceeded 15 years service time or that have completed 25,000 flights must be replaced immediately. For TT straps that are between 10 years old and 15 years old, the maximum of 25,000 allowable flights is reduced by 3,000 flights for each year exceeding 10. TT straps that have been in place for more than the calculated number of allowable flights must be replaced immediately. If no defect is found, the straps may be used for a maximum of 500 additional flights before they are replaced.

If the time in service for the TT strap or the TT strap's age and number of flights cannot be determined, the TT strap must be removed from service.

After the initial replacement, TT straps must be replaced every 10 years or every 25,000 flights, whichever comes first.

Inspections Recommended For Beech Aircraft Oxygen Masks

The Australian Civil Aviation Safety Authority (CASA) has called for inspections or tests of oxygen masks on all pressurized Beech aircraft to ensure that the masks were installed properly.

The recommendation followed an incident involving the emergency oxygen system on a Beech 200 King Air. During the maintenance investigation that followed the incident, technicians discovered that some of the covers over the passenger mask headliner compartments were installed incorrectly. If the emergency oxygen system had been activated, the covers would not have released the oxygen masks for use.

Subsequent inspections of other Beech 200 aircraft determined that a number of other oxygen mask covers also had been installed in a way that would not allow them to be used properly.

The covers are designed to be pushed open by a plunger that is operated by pressure in the oxygen line. But if the cover is rotated 180 degrees before installation, the plunger is not in the proper position to open the covers, the report said. The Beech 200 maintenance manual recommends caution in installing the cover, but if the cover is installed improperly, there is no obvious visible indication of the error.

CASA recommended inspections to ensure that the striker block in the cover is located below the plunger. Recommendations call for any incorrectly installed covers to be refitted and for the technician to notify CASA.

In-flight Engine Failure Prompts Investigation Of Bearing

The no. 1 engine of an Airbus A320-211 failed while the aircraft was cruising at flight level 390. The pilots advised air traffic control (ATC) of the problem, and ATC issued a descent clearance. The pilots executed a normal landing at Sydney, Australia.

A subsequent inspection of the CFM-56 engine revealed that the high-pressure rotating assembly and the low-pressure rotating assembly seized and that there was light metal contamination on the chip detector, according to a report by the Australian Bureau of Air Safety Investigation (BASI). When inspectors dismantled the engine, they determined that the no. 4 bearing had failed. The bearing had been in service for 21,004 hours since new and 10,128 hours since it had last been inspected. The chip detector had been clean at its last inspection, about 25 hours before the bearing failure.

Two similar bearing failures have been reported in Australia, and the engine manufacturer, CFM International, said that an improved bearing would be available soon. The operator also planned to review its timing of inspections for chip detectors.

BASI said it was investigating underlying factors of no. 4 bearing failures in CFM-56 engines.♦

NEWS & TIPS

New Adhesive Tapes Seal Liners in Cargo Holds

Two pressure-sensitive adhesive tape products are available for aircraft cargo applications.

Scapa Tapes North America described the T3601 and T3605 tapes as fire-retardant tapes that are designed for joining and sealing the liners of aircraft cargo compartments and for making general repairs in the cargo area. The company said that T3601 is a self-wound, polyethylene-coated, white cloth tape with a natural-rubber-based, pressure-sensitive adhesive and that the tape meets fire-retardancy requirements of U.S. Federal Aviation Regulations (FARs) Part 25.853(a).

Pressure-sensitive Tape
Scapa Tapes North America

The company said that T3605 is a white, polyethylene-coated, high-count, glass cloth tape with a rubber adhesive designed to limit flame penetration. The tape meets fire-retardancy requirements of FARs Part 25.855(d).

For more information, contact: Scapa Tapes North America, 111 Great Pond Drive, Windsor, CT

06095 U.S. Telephone: (800) 801-0323 (United States) and +1 (860) 688-8000 (international). Web site: www.scapatapesna.com.

Materials-testing Device Identifies Surface Flaws

Foerster Instruments' Defectometer 2.837 is a crack-detection instrument capable of finding surface cracks on aircraft wings around rivets, on turbine blades and on wheels, the manufacturer said.

The device is an eddy current instrument that can be used to conduct nondestructive testing of conductive materials for surface flaws. The device functions on painted, lacquered or unfinished surfaces.

For more information, contact: Foerster Instruments, 140 Industry Drive, RIDC Park West, Pittsburgh, PA 15275-1028 U.S. Telephone: +1 (412) 788-8984. Web site: www.foerstergroup.com.

Battery-maintenance System Performs Multiple Tasks

Christie Electric's new battery-maintenance system, the CASP/2500, performs four automatic battery-servicing functions, the manufacturer said. The CASP/2500 automatically processes, charges and reconditions batteries, and performs an auto life cycle function.

New features include clearly labeled front-panel function buttons, a continuous scrolling display of the status of each channel and a "help" function for retrieving user information.

For more information, contact: Christie Electric, 18120 South Broadway, Gardena, CA 90248 U.S. Telephone: +1 (310) 618-8368. Web site: www.christiecorp.com.

Firm Offers Headset Designed For Use on Ramps

Sonetics/Flightcom's Model 4GX pushback headset is designed specifically for use in airline-ramp operations. The 4GX has a 30-foot (9.15-meter) coil-cord with safety loops that can be fastened to a tug. The 4GX also has an optional safety disconnect cord to protect the operator and the intercom jack on the airplane if the wearer walks to the maximum length of the communication cord.

The 4GX's electret microphone and an alternating microphone on-off button allow the wearer to participate in hands-free conversations with the pilot over the open-mike system.

For more information, contact: Sonetics, 7340 SW Durham Road, Portland, OR 97224 U.S. Telephone: (800) 432-4342 or +1 (503) 684-8229. E-mail: sales@flight-com.com.

Firm Introduces New Size Of Towbarless Tractor

Douglas-Kalmar has introduced its fifth model of towbarless aircraft-handling tractor, the Douglas-Kalmar TBL-200, designed to conduct push-back, towing, inter-gate and higher-speed maintenance operations with aircraft ranging in size from the Fokker 70 to the Airbus A300 and Boeing 767.

The towbarless tractor makes one-person towing operations possible, eliminates towbar repair costs and speeds coupling and uncoupling operations, the manufacturer said.

For more information, contact: Douglas Equipment, Village Road, Arle, Cheltenham, Gloucestershire GL51 0AB, England. Telephone: +44 (0) 1242 527921. Web site: www.douglas-tugmaster.co.uk.

Magnetic Sweepers Eliminate Steel Trash

The Shields ALT magnetic sweeper is designed to remove potentially damaging steel trash, the manufacturer said. The sweeper can be mounted on airport service vehicles to pick up metal objects as the vehicles are driven on routine tasks.

The sweeper reduces equipment damage and flat tires caused by metal objects on the ground and reduces the risk of foreign-object damage to aircraft engines. The sweeper requires no maintenance other than periodic removal of the metal objects it collects.

For more information, contact: Shield, P.O. Box 1572, Ventura, CA 93002 U.S. Telephone; +1 (805) 642-4408. Web site: shieldscompany.com.

Static-air Data-tester Uses Microprocessor For Altimeter Checks

Meriam Instrument has introduced a microprocessor-based static-air data-tester that reports altitude, rate of climb and leaks. The portable tester is accurate to within seven feet (2.1 meters) at sea level and 38 feet (11.6 meters) at an altitude of 36,000 feet, the company said.

Readouts are given in feet or meters, with other options for pressure units in inches of mercury, millimeters of mercury or millibars, the company said.

For more information, contact: Meriam Instrument, 10920 Madison Ave., Cleveland, OH 44102 U.S. Telephone: +1 (216) 281-0228.♦

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