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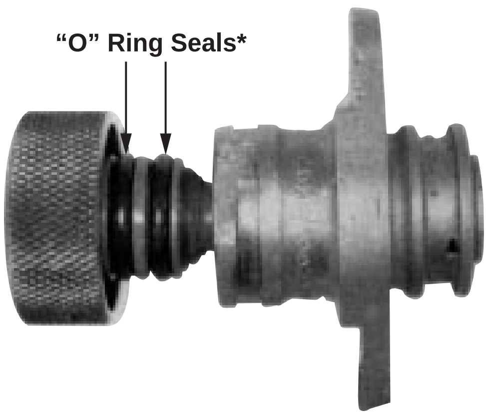
Simultaneous Engine Maintenance Increases Operating Risks

Magnetic Chip Detector Plug and Housing



*Installation of plugs without seals has caused engine failures.

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F L I G H T   S A F E T Y   F O U N D A T I O N

Aviation Mechanics Bulletin

Dedicated to the aviation mechanic whose knowledge, craftsmanship and integrity form the core of air safety.

Robert A. Feeler, editorial coordinator

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On the cover: O-ring seals omitted from magnetic chip detector plugs during simultaneous maintenance of all engines on a Lockheed L-1011 caused the precautionary shutdown of one engine and the flameout of the other two engines on May 5, 1983. The crew restarted one engine and landed the airplane.

(Source: U.S. National Transportation Safety Board)

AVIATION MECHANICS BULLETIN

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Simultaneous Engine Maintenance Increases Operating Risks

Errors committed by the same person or by the same team during maintenance of all engines on a multi-engine aircraft increase the risk of an in-flight total power loss or near-total power loss. Strategies for reducing the risk include a staggered engine-maintenance schedule and redundant checks of completed maintenance.

—

Bart J. Crotty
Aviation Consultant

Transport aircraft jet-engine reliability has improved substantially since jets were introduced into air carrier service. The improvement in engine reliability has increased operational safety and recently has resulted in more approvals for extended-range twin-engine operations (ETOPS) and in extended ETOPS ranges.[1] For most modern transport aircraft, in-flight engine shutdowns and unplanned engine removals are at their lowest rates.

Advances in engine design, operating procedures, condition monitoring and maintenance are key elements in the reliability of modern turbofan engines. Nevertheless, maintenance error sometimes results in an in-flight engine shutdown. The risk of an in-flight shutdown is compounded when the same maintenance tasks are performed by the same personnel on all engines on an aircraft during a single maintenance period, said Boeing Commercial Airplanes Group.[2]

"Maintenance of all engines on an airplane at the same time or by the same individual or team presents the potential for error and the possible loss of thrust from all engines," said Boeing.

An example of such an event was discussed in the previous issue of *Aviation Mechanics Bulletin*.[3] The incident involved a British Aerospace BAe 146, operated by U.K. Royal Air Force 32 Squadron, after a significant amount of oil leaked from all four engines soon after taking off for a training flight in England. Low-oil-pressure indications prompted the flight crew to immediately shut down one engine, to shut down a second engine while on final approach for an emergency landing at London Stansted Airport and to shut down a third engine during the landing roll.

An incident-inquiry report by the U.K. Ministry of Defence said that magnetic chip-detector plugs (MCDPs) had been installed without oil seals (O-rings) in all four engines on the BAe 146. The maintenance on the engines was performed during one work shift by a person who had received no engine-maintenance training and who did not consult the aircraft maintenance manual during installation of the MCDPs in the BAe 146 engines. The engine work was not supervised, and the required engine ground checks were not conducted before the aircraft was released to service.

The circumstances were similar to those of an accident involving an Eastern Air Lines Lockheed L-1011 on May 5, 1983.[4] The aircraft was descending to land in Nassau, Bahamas, when the no. 2 engine low-oil-pressure light illuminated. The crew shut down the engine and began flying the airplane back to the departure airport in Miami, Florida, U.S. The low-oil-pressure lights for the no. 1 engine and the no. 3 engine then illuminated, and both engines subsequently flamed out.

The airplane descended without power from about 13,000 feet to about 4,000 feet while the crew attempted to restart the no. 2 engine. The engine restart was accomplished, and the crew conducted a successful one-engine landing. Because of damage that necessitated replacement of the no. 1 engine and the no. 3 engine, the event was classified as an accident.

The U.S. National Transportation Safety Board, in its final report on the accident, said that the probable cause of the accident was "the omission of all the O-ring seals on the [MCDPs] leading to the loss of lubrication and damage to the airplane's three engines as a result of the failure of mechanics to follow the established and proper procedures for the installation of [MCDPs] in the engine lubrication system, the repeated failure of supervisory personnel to require mechanics to comply strictly with the prescribed installation procedures, and the failure of Eastern Air Lines management to assess adequately the significance of similar previous occurrences and to act effectively to institute corrective action."

During maintenance on both the BAe 146 and the L-1011, replacement MCDPs were not available from the usual sources, and maintenance technicians obtained MCDPs from other sources. The maintenance technician who installed the MCDPs in all four engines of the BAe 146, the maintenance technician who installed MCDPs in the no. 1 engine and the no. 3 engine of the L-1011, and the maintenance technician who installed an MCDP in the no. 2 engine of the L-1011 said that they did not check the units to ensure that they had O-rings.

The L-1011 maintenance technicians, after installing the MCDPs, motored the engines (that is, they turned the engines but did not introduce fuel or ignition to start the engines) for 10 seconds to check for oil leaks. Postaccident tests revealed that leaks can be detected only after motoring the engines for at least 20 seconds.

Boeing cited the following additional examples of in-flight engine problems that occurred after multi-engine maintenance:

- "A [Boeing] 747-200 approaching Rome (Italy) made a two-engine landing after two of the four engines were shut down because of a lack of oil. Both oil filters were found to have been improperly installed;
- "The engines on a [Boeing] 747-100 taking off from San Francisco (California, U.S.) failed to develop sufficient [power], prompting the flight crew to perform a [rejected] takeoff. Subsequent investigation at the gate discovered power stops on the throttles [that had been installed and] used during a maintenance check. These power stops inhibited the engines from achieving their [rated] takeoff thrust;
- "A [Boeing] 737-400 made an emergency landing after low-oil warnings occurred on both engines during climb. Investigation revealed that the hand-crank-cover assemblies on both engines were missing from the engine gearboxes, allowing oil to leak; [and,]
- "During descent on a [Boeing] 747-100, engine no. 2 was shut down because of oil loss, and engine no. 3 was shut down for the same reason eight minutes before landing. Investigation

revealed the improper installation of centrifugal-oil-filter retaining rings in both engines."

Maintenance errors resulting in in-flight engine shutdowns sometimes involve individual carelessness or incompetence, but more often involve other factors.

"The fact that even careful maintenance personnel make mistakes has led to the discovery of several factors common to mistakes," said Boeing. "Examples include the following:

- "Information that is difficult to understand, such as work/task cards and manuals;
- "Interruptions during performance of a task. The interruption may cause the individual to miss key elements of the task, such as replacing the O-rings or oil-cap covers;
- "Inadequate lighting. Personnel not seeing properly can be a contributor to mistakes;
- "Poor transfer of information at shift change. The next shift may not be properly informed of the degree of completion of a task, including work on critical systems; [and,]
- "Airplane design. Component design may cause difficulty for maintenance personnel."

Boeing said that a key strategy that can be used by aircraft operators and repair stations to avoid multi-engine maintenance error is to avoid having the same personnel perform maintenance on multiple engines at the same time.

"Following this strategy should also minimize the potential [for] improper maintenance … on redundant or backup critical systems, such as flight controls, electrical generation and distribution, and hydraulics," said Boeing.

To improve the reliability of their operations, several U.S. air carriers have adopted, for aircraft operated on routes not requiring ETOPS approvals, the maintenance practices and operating practices required by the U.S. Federal Aviation Administration (FAA) for ETOPS approval.

The maintenance practices and operating practices required for ETOPS approval are described in FAA Advisory Circular 120-42A.[5] The advisory circular requires special attention and controls in the following areas: maintenance planning, engine-oil consumption, engine-condition monitoring, defect/discrepancy resolution, reliability programs, propulsion-system-monitoring programs, engine-maintenance training, and parts control.

The following strategies for reducing the risk of a maintenance-error-induced in-flight engine shutdown have been compiled from the ETOPS requirements, maintenance guidelines issued by civil aviation authorities outside the United States, maintenance guidelines issued by transport aircraft manufacturers and other sources:

- Stagger scheduled engine maintenance. To the extent possible, do not schedule engine maintenance on all engines at the same time;
- Assign different workers to perform multi-engine maintenance. When a staggered engine-maintenance schedule is not feasible, use different workers on each engine or on each pair of engines;
- Develop and use special checklists, forms and work cards for engine maintenance and engine-maintenance inspection;
- Depending on the type of work performed, engine operational checks and engine functional checks should be conducted on the ground — by at least one worker who was not involved in performing the work — before the aircraft is released to service;
- Depending on the type of work performed and the extent of work performed — and if the particular engine type does not allow for adequate ground testing — a postmaintenance flight test should be conducted before the aircraft is returned to service;[6]
- Develop and use strict controls for preparing parts kits, materials kits and work packages, and for storing the kits and packages for access by maintenance technicians;
- Review current company requirements and/or regulatory requirements for double inspections or required-inspection-items inspections to ensure that the requirements are adequate to prevent or reduce multi-engine maintenance error;
- Improve training programs. Operators and maintenance facilities should consider establishing a short course of instruction to introduce all maintenance personnel to special efforts for engine-maintenance-error prevention. Such instruction also should be incorporated in engine-type technical training courses;
- Solicit input from those who perform the work. Encourage engine-maintenance personnel to participate in company quality-circle efforts to reduce errors; and,
- Implement a company error-prevention-awareness campaign. The campaign message can be disseminated with posters, stickers and shift meetings.

Airframe manufacturers, powerplant manufacturers, government regulators, industry associations and safety groups can help reduce in-flight engine shutdowns resulting from maintenance error by disseminating information on engine-maintenance errors. This can be accomplished by making available more relevant data and more timely data on error-occurrence rates than have been available in the past, and by publishing information on newly identified engine-maintenance errors and situations that have resulted in engine-maintenance errors.♦

Notes and References

1. U.S. Federal Aviation Regulations (FARs) Part 121.161 prohibits operation of a twin-engine airplane over a route that contains a point farther than the distance equivalent to one hour of flying time (in still air at normal cruising speed with one engine inoperative) from an adequate airport (an airport that meets, or is equivalent to, the certification requirements and operating requirements of FARs Part 139). Nevertheless, operators can obtain approval from the U.S. Federal Aviation Administration (FAA) for extended-range twin-engine operations (ETOPS). ETOPS approvals permit operation of a twin-engine airplane over a route that contains a point that is an equivalent distance of 75 minutes, 120 minutes or 180 minutes flying time (in still air at normal cruising speed with one engine inoperative) from an adequate airport.

2. Murray, Thomas; Robel, Vince. "Multi-engine Maintenance." *Focus on Commercial Aviation Safety* Issue 34 (Spring 1999): 16–19.
3. Crotty, Bart J. "Omission of Oil-plug Seals Leads to In-flight Engine Shutdowns." *Aviation Mechanics Bulletin* Volume 47 (July–August 1999): 1–7.
4. U.S. National Transportation Safety Board *Aircraft Accident Report: Eastern Air Lines Inc., Lockheed L-1011, N334EA, Miami International Airport, Miami, Florida, May 5, 1983*. NTSB/AAR-84/04. March 9, 1984.
5. FAA. *Extended Range Operation with Two-engine Airplanes*. Advisory Circular 120-42A. December 1988.

6. FARs 91.407(b) and 91.407(c) require that a flight test be conducted unless ground tests have shown conclusively that a maintenance procedure has not "appreciably changed the flight characteristics or substantially affected the flight operation of the aircraft."

About the Author

Bart J. Crotty is an airworthiness, maintenance and safety consultant, and the maintenance human factors

chairman for the International Society of Air Safety Investigators. He is a former U.S. Federal Aviation Administration (FAA) airworthiness inspector and trainer, and designated airworthiness representative. Crotty has worked for repair stations, airlines, an aircraft manufacturer, law firms, consulting firms, safety organizations and several non-U.S. national civil aviation authorities. His career spans 39 years, approximately half of that period in non-U.S. locations. He has an FAA airframe and powerplant mechanic certificate and a bachelor of science degree in aeronautical engineering. Crotty resides in Springfield, Virginia, U.S.

MAINTENANCE ALERTS

FAA Orders Replacement of Insulation Covered With Metalized Mylar

To reduce fire risks, the U.S. Federal Aviation Administration (FAA) is ordering the operators of 699 aircraft to replace insulation blankets covered with metalized Mylar.

"While other insulation materials in the current U.S. fleet are safe, tests show that metalized Mylar falls far below the new test standard," FAA said. "It ignites much more easily than other materials and can spread fire because its properties are much different."

The operators — nine U.S. airlines — will have four years to replace the insulation, but FAA said that it would encourage them to replace the insulation at the earliest practical maintenance check.

The proposed airworthiness directives (ADs) would affect McDonnell Douglas DC-10, MD-11, MD-80, MD-88 and MD-90 aircraft. FAA plans to issue a proposal later this year that will apply to all new aircraft.

Operators of the affected aircraft will be required to remove insulation covered with metalized-Mylar and replace it with materials that meet FAA's proposed flame-propagation standard, which is based on the standard for flammability established by the American Society for Testing and Materials (ASTM). Materials that have been shown capable of meeting the ASTM test include polyimide, certain polyvinyl fluorides and certain fluoropolymer composites.

FAA's action follows eight months of testing in support of the development of a new test standard for aircraft insulation. The agency is developing the new standard in cooperation with Canadian airworthiness authorities, Japanese airworthiness authorities and the Joint Aviation Authorities.

Of the 1,230 airplanes worldwide that are affected by the AD, 699 are registered in the United States. The U.S. operators include Alaska Airlines, American Airlines, Continental Airlines, Delta Air Lines, Federal Express, Reno Air, Trans World Airlines, and US Airways. Costs of complying with the AD are estimated at between US$380,000 and $880,000 per airplane.

NTSB Recommends Changes in Autopilot Procedures

The U.S. National Transportation Safety Board (NTSB), citing in-flight upsets of two McDonnell Douglas MD-11 airplanes that were associated with procedures involving their autopilots, has recommended changes in the autopilot system and in pilot training.

NTSB asked the U.S. Federal Aviation Administration (FAA) to require revisions in the MD-11 airplane flight manual and in airline flight manuals to "ensure that pilots are warned about the hazards of applying force to the control wheel or column while the autopilot is engaged."

Other recommendations called for modifications of the MD-11 autopilot system to prevent upsets when manual inputs are made to flight controls and for training programs that provide simulator instruction in proper procedures for disengaging the autopilot and assuming manual control of the airplane. NTSB also asked FAA to review the design of autopilot systems used in all transport category airplanes and to require changes in those that are found capable of causing in-flight upsets when manual inputs to the flight controls are made.

The incidents that prompted the NTSB actions include the in-flight upset of an American Airlines MD-11 near Westerly, Rhode Island, U.S., on July 13, 1996. The airplane was not damaged, but one passenger received serious injuries and another passenger and two flight attendants received minor injuries in the incident, in which the airplane experienced a +2.3-G pitch upset, followed by further oscillations.

The upset occurred after the first officer initiated a descent using the autopilot.

"The captain became concerned that the airplane might not level off at the assigned altitude and instructed the first officer to slow the rate of descent," NTSB said. "The first officer adjusted the pitch thumbwheel on the autopilot control panel; however, this maneuver proved ineffective. The captain then took manual control of the airplane, began applying back pressure to the control column, then disconnected the autopilot."

Data from the flight data recorder (FDR) showed that an immediate pitch upset occurred.

A similar in-flight upset occurred on a Japan Airlines MD-11 near Nagoya, Japan, on June 8, 1997, when the captain initiated the descent using the autopilot but took manual control because he believed the airplane was about to accelerate beyond its maximum operating airspeed. FDR data indicated that the pitch oscillations that followed ranged from +2.78 Gs to –0.5 G. One flight attendant and three passengers received serious injuries in the incident; four flight attendants and five passengers received minor injuries.

NTSB said that Boeing, Douglas Products Division (DPD) — formerly McDonnell Douglas — has said that the MD-11 autopilot cannot respond correctly when manual flight control inputs are made. The company has revised the MD-11 Flight Crew Operating Manual to include a warning against applying manual force to the control wheel while the autopilot is engaged.

FAA Orders Inspections of Electrical Wire Leads on Learjet Anti-ice Systems

The U.S. Federal Aviation Administration (FAA) has ordered operators of several Learjet models to inspect, and if necessary to repair, the electrical wire leads of the horizontal stabilizer anti-ice systems. The inspections are needed to verify that the numbers on the wire leads correspond to the numbers on the connected airframe wiring, in accordance with past Learjet service bulletins.

The affected models are 23-, 24-, 25-, 28-, 29-, 31-, 55- and 60-series airplanes.

If inspection of the wire leads reveals discrepancies, they must be repaired in accordance with procedures outlined in the Learjet Airplane Wiring Manual before the aircraft is flown again. Then a wire identification strap must be installed on the left-hand side and right-hand side of each terminal block, and a warning placard must be installed on the block, in accordance with the service bulletins.

If no discrepancies are found, the wire identification strap and warning placard must be installed.

The inspections must be performed within 100 flight hours after the

Sept. 7, 1999, effective date of FAA's airworthiness directive.

FAA Orders Certain Bombardier Aircraft Inspected for Cracks

The U.S. Federal Aviation Administration (FAA) has ordered operators of certain Bombardier airplanes to inspect fuselage frame angles to detect and correct cracking.

The affected aircraft are Model CL-215-1A10 and CL-215-6B11 series airplanes with serial numbers 1001 through 1125.

Cracks of the fuselage frame angles at the wing front and rear spar attachment to the fuselage could result in reduced structural integrity of the airplane, FAA said.

The eddy-current inspections must be completed before the airplanes accumulate 2,300 total flight hours and within four months after the Sept. 7, 1999, effective date of the airworthiness directive or 150 flight hours after Sept. 7, whichever comes first. The inspections then must be repeated at intervals no longer than every 415 flight hours, FAA said.♦

NEWS & TIPS

Ear Muffs Offer Highest Noise-protection Rating

A hearing-protection product designed for the noisiest work environments, including airports, is available from Mine Safety Appliances Co.

The Apex 30 Muff, which has the highest noise-reduction rating available, is designed for extended wear. The muff is an 8.5-ounce padded headband with ear cups that are designed for extended wear. To enhance comfort, the company also sells Comfort Rings, felt pads that attach with peel-back adhesive to the ear cushions, to absorb excess moisture in warm environments and add warmth in cold weather.

Apex 30 Muff
Mine Safety Appliances Co.

For more information: Mine Safety Appliances Co., P.O. Box 426, Pittsburgh, PA 15230 U.S. Telephone: (800) 672-2222 (U.S.) (800) 672-7777 (international). Web site: www.MSAnet.com.

Passenger-boarding Bridge Accommodates Regional Airplanes

A passenger-boarding bridge designed specifically for commuter airplanes and narrow-body jet transports is available from DEW-Bridge.

The bridges can be used on either the terminal building's ground floor or the second floor and meet requirements of the U.S. Americans with Disabilities Act, which calls for barrier-free access for passengers who use wheelchairs. The bridges can connect directly with the terminal building or to a DEW walkway system.

For more information: DEW Engineering and Development, 3429 Hawthorne Road, Ottawa, Ont. K1G 4G2 Canada. Telephone: (800) 579-5438 (North America) or +(613) 736-5100. Web site: www.dewbridge.com.

B-747 Communication Upgrade Kits Receive FAA Certification

The U.S. Federal Aviation Administration (FAA) has issued supplemental type certification for communications upgrade kits made by ARINC for Boeing 747 aircraft.

The kits provide global very-high-frequency (VHF) and high-frequency data-link communications capability and digital VHF 8.33-kilohertz-spacing voice capability. The combination provides worldwide communications coverage, including coverage along polar routes.

For more information: Robert F. Jefferson, ARINC, 2551 Riva Road, Annapolis MD 21401 U.S. Telephone: +1 (410) 266-4651. Web site: www.arinc.com.

Balancing Tool Analyzes Aircraft Vibrations

The Vibrex 2000 analyzes aircraft vibration data to calculate balance solutions and to analyze aircraft vibration levels, according to the manufacturer, Chadwick-Helmuth.

The device also provides helicopter vibration readings that can be used for chart calculations on main rotors, tail rotors, shafts and blowers and that give an overview of rotor and drivetrain vibrations.

For more information: Chadwick-Helmuth, 4601 N. Arden Drive, El Monte, CA 91731 U.S. Telephone: +1 (626) 575-6161.

Aircraft Tow Vehicle Runs on Batteries, Without Tow Bars

The Lektro Tug, a battery-powered, multipurpose aircraft tow vehicle, operates without using a tow bar and saves the added handling time associated with a tow bar, according to the manufacturer.

The Lektro Tug Model AP8850SD is capable of towing airplanes as large as a McDonnell Douglas DC-9 and as small as a Cessna 150. Dual sets of batteries allow for longer operating time. Other models can maneuver lighter-weight aircraft.

For more information: Lektro, 1190 S.E. Flightline Drive, Warrenton, OR 97146 U.S. Telephone: (800) 535-8767 (U.S.) +1 (503) 861-2288 (international).

Deicing System Made for Commuter Airplanes

Ground Support Specialist SD-500 airframe deicer is designed for use on commuter aircraft up to the size of a Boeing 737. The deicer can be operated from three deicing positions, including its tower height of 15 feet (4.6 meters).

The deicing system has a capacity of 500 gallons (1,893 liters), a heating time of about 45 minutes and fluid delivery of 30 gallons per minute (113.6 liters per minute).

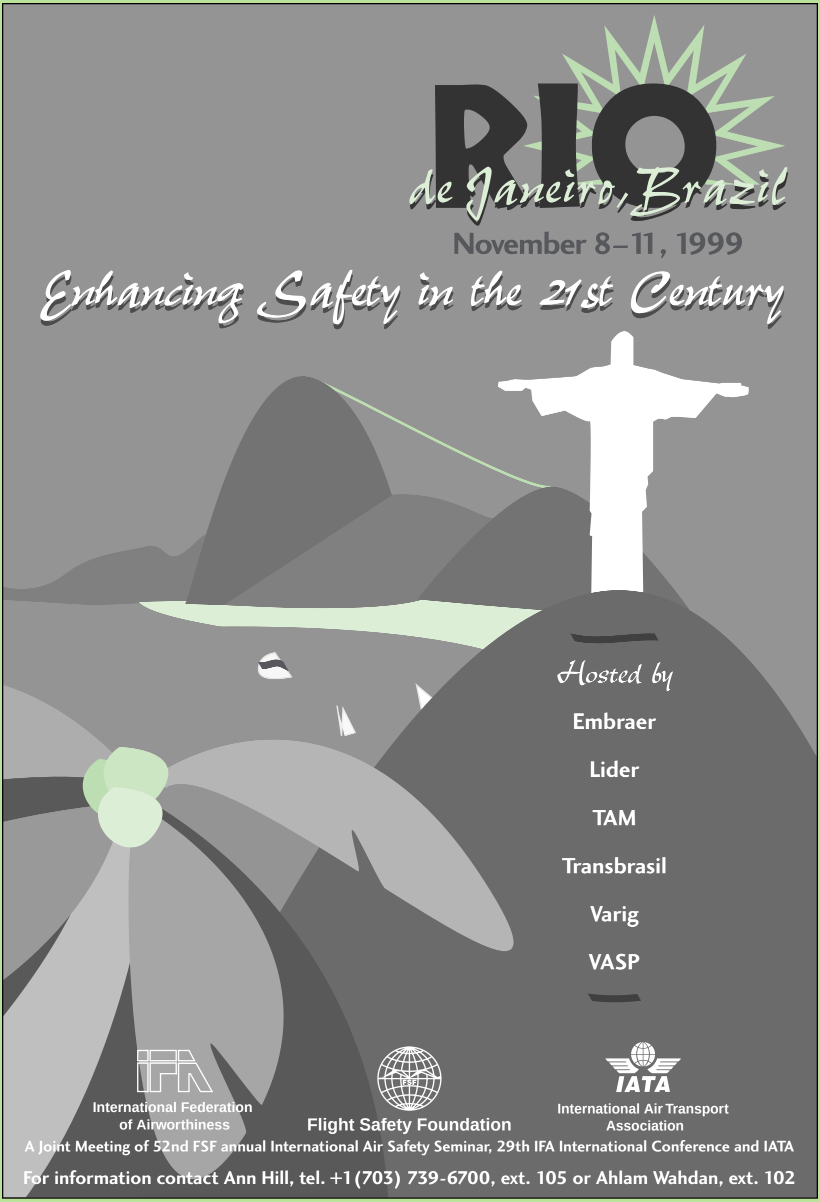
For more information: Ground Support Specialist, 2205 Cole Road, Horn Lake, MS 38637 U.S. Telephone: +1 (601) 342-1412. Web site: www.gssonline.com.

Firm Offers Lease-to-own Ground Service Equipment

First Financial Leasing Co., which specializes in the leasing of airport ground-service equipment, offers equipment for lease with an option to buy the same equipment later at a predetermined price.

Airports can lease passenger buses, fueling trucks, above-ground storage tanks and other items from First Financial. With the lease-purchase program, the monthly payment may be treated as an expense and is tax-deductible for U.S. income-tax purposes, the company said.

For more information: First Financial Leasing Co., 10800 Farley, Suite 265, Overland Park, KS 66210 U.S. Telephone: (888) 756-2521 (U.S.) +1 (913) 345-9300 (international).♦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