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Repair of Aircraft Windows Is Often Practical and Cost-effective

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Repair of Aircraft Windows Is Often Practical and Cost-effective

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Don Moyer
Norton Performance Plastics Corp.

Easy to damage and costly to replace, aircraft transparencies — cockpit and passenger windows, sight gauges and lenses — are the third largest aircraft-maintenance cost. Their cost ranks just behind hydraulics and fuel system parts, and even ahead of rubber.

Passenger windows constitute the largest number of repairs and replacements, but cockpit windows represent the bulk of the expenditures because of their much higher unit cost. Cockpit windscreens typically cost between US$2,400 and $25,000 apiece, vs. $95 to $1,000 for a passenger window.

Until recently, industry practice favored replacement more than repair. But cockpit windows do not have to be replaced as often as many operators believe. Some damage, if recognized early enough, that might once have been considered unrepairable can be repaired.

A typical repair costs 50 percent to 80 percent less than replacement. And nearly half of all damaged cockpit windows can be repaired to a "like-new" condition. Relamination and other repairs are feasible for transparencies used in most pressurized-cabin aircraft.

Economics of Repair Have Improved

As new windows have become larger and more expensive, repair costs have remained relatively stable. So the economic advantage of a repair has increased, as airlines and corporate operators continue to be pressed to cut operating costs. For a large airline, the savings can amount to US$3 million a year.

Most forward cockpit windows are glass or have glass outer layers (for abrasion resistance) with a polyvinyl butyral (PVB) membrane. Side or aft cockpit windows are generally laminated acrylic. The transparent heating elements for defogging and defrosting are embedded at the interface between the PVB and the outer ply.

Much cockpit window damage is sustained from inside the cockpit. A major cause is banging and scraping by clipboards placed on the cockpit glare shield. Crew members' rings also scratch the window when the pilots reach for a clipboard or other item. Automatic shoulder harnesses or seat belts can also cause window damage when the buckle flies up during retraction.

Of course, exterior factors also cause cockpit window damage. Hail, bird strikes, debris from the runway during takeoff and heavy rain all contribute to chipping, pitting, scratching and seal erosion. Severe thermal and pressurization cycling coupled with exposure to 600-mph winds create tiny cracks called crazing that can impair pilot vision.

Another common type of damage is delamination, which is the separation of the acrylic or glass pane from the PVB membrane. This damage is usually the result of aging, coupled with thermal and pressurization cycling.

Yellowing or milkiness of the window are also frequent problems. These conditions result from aging and moisture encroachment into the PVB layer between the window layers. Yellowing or milkiness may not seriously impair visibility, but they can become unsightly and prompt maintenance personnel to question a window's serviceability.

Micro-crazing Attacks Passenger Windows

In passenger windows, the most common problem is micro-crazing — the appearance of hundreds of tiny surface cracks. Initially, the problem is more cosmetic than functional, although it is often a source of passenger concern and complaint.

The same problems also can affect the lenses protecting exterior lighting. Lenses are not normally in a crew's line of sight, making lens damage less noticeable. But if lens damage goes unnoticed too long, there is the risk of damaging the electric circuitry or contaminating the circuitry with dirt or water.

In most cases, the best way to reduce damage is to remove the cause. That becomes a matter of educating flight and maintenance crews.

To prevent interior scratching, aircrews must break the habit of putting clipboards on the glare shield. To prevent exterior scratching, cleaning crews should avoid cleaning the windows with mops and water, an all-too-common practice. Usually such mops contain enough sand and grit to cause small scratches. They can also exacerbate damage already caused by normal wear. Clean water and clean, soft cloths will go a long way toward reducing window repairs and replacement costs.

Early Detection Is Key to Reducing Costs

To maximize the likelihood that a window can be repaired, early detection of damage is essential. Early action will yield major savings throughout the lifespan of the aircraft.

What follows is a description of the early warning signs for each type of common problem.

Bubbles. These are signs of delamination. A pattern of "champagne bubbles" — lots of little ones — indicates a possible thermal controller problem that causes overheating of the window. (See photo, page 4.)

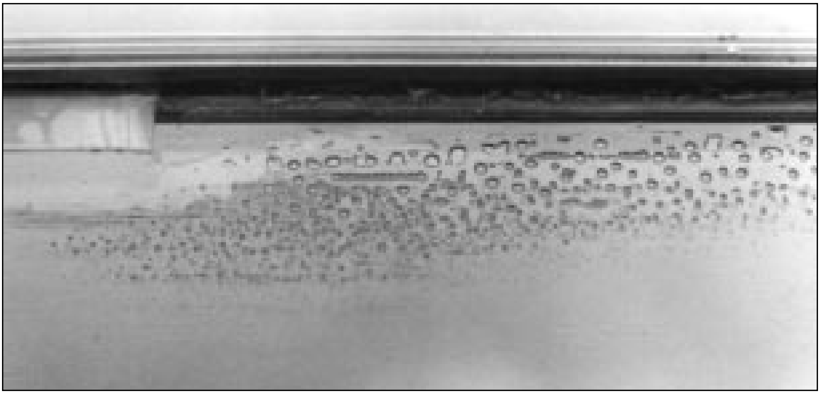
Large delamination bubbles at window edges indicate age and usage. (See photo, page 5.) These bubbles can reduce visibility, but the window can be repaired. The window should be pulled and repaired as soon as bubbles are noticed, before irreparable damage occurs.

Crazing. The indication is obvious. The key is to identify and repair crazing in its earliest stages. Inspection from the interior, while holding a bright light at various angles on the outside, will make this condition much more obvious.

Crazing can spread quickly. If deep enough, the crazing can provide a pathway for less repairable damage.

Micro-crazing. This looks like a web of tiny cracks on the exterior surface. It is the most common problem in passenger windows. Identified early, it can be corrected. Left unchecked, it can require early replacement of a window.

Milkiness. The indication is obvious. Milkiness, which is usually caused by moisture entering airspace that is caused by delamination, can



Bubbles are an early warning of delamination, which is repairable if early action is taken.

often be corrected. (See photo, page 6.)

Yellowing. Although the problem is primarily cosmetic, there is no known way to correct yellowing, other than replacing the pane. It is nonreversible.

Distortion lines. These are indications of the deterioration of heating elements caused by fatigue breakage.

The windows are deiced by wire grids or heating films in the vinyl interlayer. Repeated flight cycles and associated deflections of the window may cause individual wires to break. Thus, the window is partially heated, resulting in fogged areas and localized poor visibility.

Thermal stresses in the glass also can lead to more serious damage. Some wire breakage may be tolerated unless the pilot's vision is impaired, but such damage should be monitored closely. Distortion lines may also be caused by localized repairs, for example, where a maintenance worker sands only one scratch or pit.

Loose connections. When inspecting cockpit windows, carefully check all electrical connections to the defoggers and window-heating elements. Proper heating and defogging can reduce thermal cycling stresses and prevent electrical arcing and other damage.

Assessment Precedes Repair

Once the repair facility receives a damaged window, it creates an inspection chart indicating the problem areas and classifying the damage as delamination, chips, crazing etc. The aircraft operator receives a copy of the chart for examination and approval of a repair.

Not all windows that are brought into a repair station require repairs. On the other hand, some are so badly damaged that repair is no longer possible. These two conditions also signal that operators may not be sufficently educated about the care and repair of their aircraft windows.

If a repair is not required, the customer is notified and disposition instructions are requested. A serviceable window can be tagged as "serviceable," and returned to the customer. Under U.S. Federal Aviation Regulations, a window purchased from an aircraft window broker must have a proper certification and documentation of condition before it can be installed in an airplane.

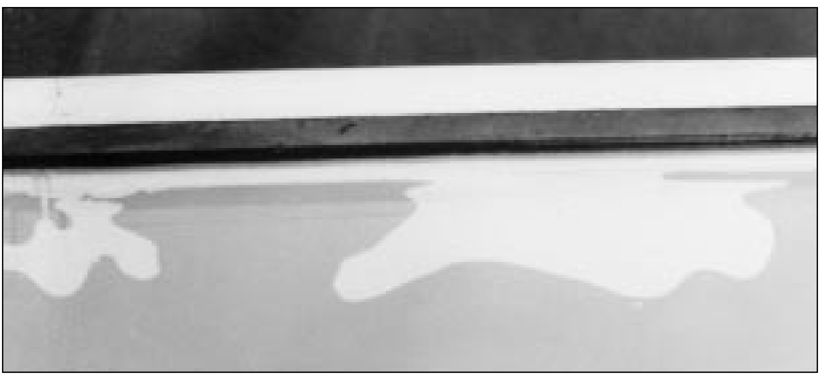
Relamination Resembles Original Manufacture

Procedures for repairs are as follows:

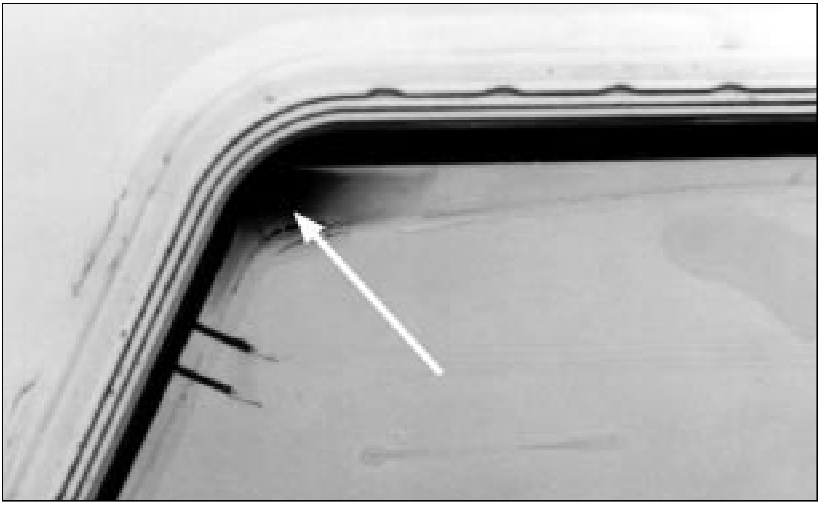
Relamination. To eliminate bubbles indicating delamination, the window is disassembled, cleaned and relaminated in a large autoclave to new-window specifications. A log generated during the repair documents the time-temperature-pressure cycle for each step.

The relamination process is much like the original manufacturing cycle; a delaminated transparency is repaired and cured in a special vacuum package. Pressure and heat are applied in an autoclave.

After relamination is completed, transparencies are polished and matched to their original frames and reassembled.



Delamination is a common but repairable type of damage.



Discoloration (shown by arrow) is a frequent problem in cockpit windows. Some discoloration, including milkiness, is repairable, but yellowing cannot be repaired.

The repair technician then compares the repaired window with the inspection chart. This check is used to confirm that all repairs were completed and all specifications were met.

Milkiness removal. The window is dried and, in most cases, relaminated to eliminate air spaces so that no new moisture can enter.

Surface scratches. If the scratch is shallow, it can be ground or polished out if window thickness permits. Deeper scratches may require replacement of one of the two panes that make up the entire window.

Crazing. This problem is usually solved by grinding and polishing the window surface, assuming acrylic thickness and original equipment manufacturer (OEM) specifications permit.

Preventive Maintenance Eases Repair

Making the most of window repairs requires careful attention to routine care, maintenance and inspection procedures. The first step is to minimize preventable damage. The next step is to identify the damage early enough to make repair possible. A single scratch can be enough reason for a cockpit window to be removed and inexpensively repaired to like-new condition.

Some relaminators and repair stations might provide on-site “how-to” training for maintenance and flight crews on window care, inspection and repair, in addition to informative literature.

The progress made in cockpit window repair gives the aircraft operator an opportunity for significant maintenance-cost savings.♦

About the Author

Donald W. Moyer, a registered Professional Engineer, has worked since 1991 for Norton, where he develops radome and transparency products and services. His 30 years in the aerospace industry have included design and experimental engineering positions at Pratt & Whitney Aircraft and at General Electric Aircraft Engines. He was also responsible for product development and sales at Dexter Composites.

Moyer holds a mechanical engineering degree from Rose-Hulman Institute and an M.B.A. from Case Western University, both in the United States.

Singapore Institute Offers Aircraft Maintenance and Engineering Conference

The Singapore Institute of Aerospace Engineers recently announced the schedule for its New Challenges in Aircraft Maintenance and Engineering Conference ’96. The conference will be held at the Westin Stamford Hotel, Singapore, on Feb. 1–2, 1996. The conference will focus on trends in regional aircraft maintenance, and the challenges and opportunities arising from these regional businesses.

It is intended to provide a forum for regulatory authorities, aircraft/engine manufacturers, engineers and maintenance specialists to exchange views and examine strategic aircraft maintenance issues, evaluate key challenges and technologies available, and study their applications to aircraft maintenance.

Individuals interested in attending or participating should contact: Temasek Management Services Pte. Ltd., 8 Shenton Way, 39-01 Treasury Building, Singapore 0106.

HAI Offers Free Inventory Software Module

Helicopter Association International (HAI) is offering a free, cost-effective, time-saving parts inventory feature that automatically interfaces with its maintenance malfunction information reporting (MMIR) system. According to HAI, the inventory module is programmed in Microsoft FoxPro for Windows and maintains a complete computerized record of an operator’s inventory.

The inventory module enhancement to the MMIR software tracks issuing, cost and receipt of parts and materials; provides standard inventory reports; identifies substitute and related parts numbers; tracks multiple vendors and locations with associated costs and quantities; stores unique items for a “vendor name/vendor number” and part number combinations; allows for alternate/multiple costing methods; and indicates order quantities and reorder levels.

To receive a free inventory module, contact: HAI, 1635 Prince Street, Alexandria, VA 22314 U.S. Telephone: (703) 683-4646.

Human Element Workshop Schedule Announced

Richardson Management Associates Ltd. of Montreal, Quebec, Canada, has announced the fall schedule of its workshop, The Human Element in Aviation, intended to enable participants to enhance their management skills and improve organizational performance by addressing the human element. Subjects to be covered include managing relationships, defining and exercising authority, conflict resolution, effective communications, motivating people, employee morale and its effect on safety, and performance and well-being.

The workshop is scheduled Nov. 1–10, 1995, in Vancouver, British Columbia, Canada, and Jan. 13–16, 1996, in Montreal, Quebec, Canada. For more information, contact: Richardson Management Associates, telephone (514) 935-2593.♦

MAINTENANCE ALERTS

Failed Leading-edge Flap Actuator Leads to Emergency Landing

In February 1995, a Boeing 737-200 made an emergency landing in South America after the pilot reported the loss of hydraulic system A and the standby hydraulic system. The airplane was severely damaged in the landing and seven passengers were injured in the evacuation.

An examination disclosed that the inboard leading-edge flap actuator on the right wing had separated from the front wing spar and the hydraulic lines connected to the actuator had been ruptured.

In reconstructing the events leading to the accident, investigators learned that the pilots' first realization of a problem came when the flaps were selected "up" and the "in-transit" light for the No. 3 leading edge flap remained illuminated. This was followed by the No. 2 engine increasing in power. When attempting to reduce power, the No. 2 power lever could not be moved. The low-pressure light for hydraulic system A illuminated and soon after the crew noted that hydraulic fluid quantity and pressure were decreasing.

Hydraulic power on the B-737-200 is provided by three independent sources: system A, which is pressurized by two engine-driven pumps; system B, which is pressurized from two electrically driven pumps; and the standby system, which can be used to restore hydraulic pressure to certain systems if system A or B is lost. Standby hydraulic pressure is provided by one electrically driven pump.

Hydraulic system A provides operating pressure to the inboard brakes, inboard flight spoilers, ground spoilers, ailerons, elevators, rudder, trailing-edge flaps, leading-edge devices, landing gear, nose-wheel steering and thrust reversers. Hydraulic system B provides operating pressure to the outboard brakes, outboard flight spoilers, ailerons, elevators and rudder. The standby system provides operating pressure to the rudder, leading-edge devices and the thrust reversers.

The crew was eventually able to retard the power on the No. 2 engine and attempted to electrically extend the trailing-edge flaps using the alternate extension system. Visual inspection from the cabin indicated that both leading-edge devices and trailing-edge flaps were in the retracted position, so the crew elected to execute an “all flaps up” landing. The airplane touched down on the wet runway at a speed of 183 knots. Reverse thrust was not available during the landing roll because of the loss of hydraulic pressure. The airplane touched down near the 1,300-foot (397-meter) point of the runway, but was unable to stop or remain on the runway, eventually departing the runway some 10,000 feet (3,050 meters) after touchdown. The nose landing gear collapsed, the right main landing gear folded into the wheel well, and the No. 2 engine separated from the wing before the airplane stopped.

Examination disclosed that the No. 3 Krueger flap actuator had separated from its aluminum aft support fitting. The area of the front wing spar below the fitting showed evidence of contact from the actuator, and in the same area, one of the No. 2 engine start-lever cables had been damaged and the thrust-lever cable had been knocked off the pulley and wedged against its bracket. The three hydraulic lines connected to the failed actuator were broken. Subsequent examination of the failed aft support fitting revealed evidence of corrosion on and around the fracture surface.

The aluminum support fittings for these Krueger flap actuators were the subject of a Boeing service bulletin (SB) in 1981. The SB called for visual and eddy-current inspections until the fittings were replaced with a steel fitting. This airplane was in the group of affected serial numbers. The operator had not elected to take the terminating action of replacing the aluminum fittings with steel and was continuing to inspect the fittings only by visual means.

It was also found during the investigation that the hydraulic fuse in the standby system of the accident airplane did not function as intended to prevent the total loss of fluid after the line had been breached. A test of the fuse revealed leakage in excess of allowable limits, caused by corrosion of the magnesium piston in the fuse. These fuses were also the subject of a Boeing service letter in 1981. Normal maintenance procedures do not verify the proper functioning of these fuses and a malfunctioning unit can remain in service undetected for some time. Similar hydraulic fuses are used in other aircraft and have been the subject of Airworthiness Directives (ADs) on de Havilland DHC-7 and DHC-8 aircraft.

Based on the findings of this investigation, the U.S. National Transportation Safety Board (NTSB) issued recommendations calling for the U.S. Federal Aviation Administration (FAA) to issue an AD calling for repetitive eddy-current inspections of aluminum Krueger flap aft support fittings on B-737-100/200 airplanes until the fittings have been replaced with steel parts. A second recommendation was issued calling for the replacement of magnesium pistons in hydraulic fuses installed on B-737-100/200 aircraft and for further research to determine what other transport category airplanes might currently be fitted with similar potentially faulty parts.

Undetected Disc Defect Results in Engine Failure

In June 1995, a ValuJet Airlines McDonnell Douglas DC-9-32 suffered an uncontained failure of the No. 2 JT8D-9A engine at Atlanta, Georgia, U.S. The engine failed during the takeoff roll. The takeoff was aborted and the aircraft was able to stop on the runway. The crew and 57 passengers were successfully evacuated. One passenger was seriously injured and several suffered minor injuries in the evacuation. The cabin attendant who had been seated at the aft door was also injured by shrapnel resulting from the uncontained failure when engine fragments penetrated the fuselage. The airplane was destroyed in a subsequent fire.

The ongoing U.S. National Transportation Safety Board (NTSB) investigation has determined that during the initial takeoff roll, the seventh-stage high pressure compressor (HPC) disc on the No. 2 engine failed. Examination of the failed disc (P/N 774407) revealed that the failure originated at one of the shielding holes in the disc. The shielding holes are aligned with the disc tie-bolt holes and are designed to redistribute and reduce stress concentrations in the disc. The holes are below the base of the compressor blades and cannot be inspected without disassembling the engine.

Metallurgical examination showed that the failure was caused by a fatigue crack that originated at a corrosion pit in a shielding hole. There was evidence that the corrosion pit had been plated over during an overhaul of the disc in 1991. It also appeared that the size of the corrosion pit exceeded the manufacturer's allowable limits at the time of overhaul. Examination of the crack striations and calculations based on the engine's service record since last overhaul indicated that the crack would probably have been detectable at the time of the last overhaul. Metallurgical examination of the disc also revealed numerous other cracks, out-of-limit pitting and plated-over corrosion in the other shielding holes. The remainder of the engine appeared to have been well maintained and was in good condition.

The operator's records showed that the engine was one of 23 such engines acquired from Turk Hava Yollari (THY). THY, a Turkish domestic and international airline, operates an airframe and engine overhaul facility, servicing JT8D engines, in Istanbul, Turkey. The engines were acquired with the purchase of nine DC-9 airplanes and five spare engines. Of the 23 units, at the time of the failure, three had been overhauled, two were undergoing repair and two were awaiting disassembly for overhaul. The remaining 15 engines had not been overhauled and remained in service. To date, no evidence of cracks, out-of-limit pitting or improper assembly and maintenance have been found in the discs that have been available to the NTSB for examination.

THY was authorized by the U.S. Federal Aviation Administration (FAA) to overhaul JT8D engines in 1976 and this authorization was reapproved on a biannual basis until 1986. At that time, THY elected to drop the authorization because the company had few customers that required their engines to be overhauled by an FAA-approved agency. In 1994, THY requested and received the FAA certification under U.S. Federal Aviation Regulations (FARs) Part 145 as a JT8D overhaul facility. Between 1986 and 1994, THY continued to overhaul JT8D engines presumably in accordance with the manufacturer's manuals and procedures; however, they received no FAA oversight of the JT8D activity. THY reports that since 1985, the company has conducted 500 engine overhauls.

THY's shop records indicated that the failed disc was subjected to a "C" check, which under their system involved overhaul and included stripping, inspecting and replating of the disc. The manufacturer's manuals provide overhaul facilities with inspection guidance, allowable damage limits and repair procedures. Although the manual material is quite detailed, the

NTSB was concerned that it might be misunderstood, particularly if translated into another language. The NTSB has therefore recommended that the language concerning inspection and damage limits be changed to prevent any future misunderstandings about the amounts of allowable and repairable damage, and the procedures required for inspecting and repairing the disc prior to returning it to service.

The NTSB is also concerned about the safety of other JT8D engines processed by THY during the period in question and has therefore recommended that an Airworthiness Directive be issued calling for a special inspection of the seventh-stage discs last overhauled by THY, prior to reaching 3,000 cycles since that last overhaul and inspection.

NTSB also expressed concern over the process by which the THY engines were accepted for service in the United States. Investigation has determined that an FAA-designated airworthiness inspector (DAR) was responsible for determining the airworthiness of the airplanes purchased and brought into the United States by this operator and another consultant was used to determine airworthiness of the five spare engines. Most of the engine records provided were in the Turkish language and both the DAR and the consultant apparently assumed that THY was an FAA-approved JT8D repair station at the time the engines were last overhauled. In fact, THY's certification was not valid at that time and the overhauls, facilities and procedures were not subject to FAA oversight.

As a result of this finding, the NTSB has also recommended that the FAA provide additional guidance to DARs and aviation maintenance personnel to ascertain whether facilities that have overhauled or repaired aircraft, aircraft engines and components that are later presented for acceptance in the United States were properly certificated for the work performed at the time the work was accomplished.♦

Special Bubble Test Enhances Leak Detection with Ultrasound

UE Systems Inc., the manufacturer of the Ultraprobe 2000 ultrasonic inspection system, has developed a liquid leak amplifier (LLA) fluid designed to detect extremely low-level gas leaks that would normally not be detectable.

Liquid Leak Amplifier (LLA) Fluid from UE Systems Inc.

The LLA fluid has a very low surface tension and thus bubbles do not have to be visible to detect leaks. As bubbles form and collapse, they produce strong ultrasonic signals that are easily detected by the ultraprobe. Bubbles also form and collapse almost instantly, so waiting time is minimized.

For more information, contact: UE Systems Inc., 14 Hayes Street, Elmsford, NY 10523 U.S. Telephone: 1-(800) 223-1325 inside the United States; (914) 592-1220 outside the United States.

UV Light Ensures Clean On-board Water

Maintaining the cleanliness of potable water supplies in aircraft systems can be a problem, especially for operators that need service in out-of-the-way locations. A Canadian company now offers an ultraviolet-light water sterilizing unit that can be installed in the airplane’s water system.

According to the manufacturer, the NPS-A2 unit is compact, measuring 11 inches × 15.5 inches × 4 inches (28 centimeters × 39 centimeters × 10 centimeters), and weighs only 9.5 pounds (4.3 kilograms) installed. When installed on the outlet side of the potable water tank, the unit ensures that all dispensed water is pure, tasteless and free of any contaminants. The manufacturer said that the unit can continuously treat water at the rate of 1.5 U.S. gallons (5.7 liters) per minute and the ultraviolet lamps are rated for 3,000 hours of operation. The solid-state unit generates no additional heat, is self-monitoring and meets all U.S. Federal Aviation Administration (FAA) and U.S. Food and Drug Administration (FDA) requirements for on-board water treatment equipment.

For more information, contact: International Water-Guard Industries Inc., 575 Powell Street, Vancouver, BC V6A IG8 Canada. Telephone: 1-(800) 667-0331 in the United States or Canada; (604) 255-5555 elsewhere; Fax: (604) 255-5685.

Fuel Storage Tanks Designed to Meet 1998 Safety Requirements

The Areo-Power Co. offers a series of above-ground fuel storage tanks that incorporate features intended to meet U.S. Environmental Protection Agency (EPA) and U.S. Occupational Safety and Health Administration (OSHA) requirements for such facilities. EPA regulations now mandate that any underground tank installed after Dec. 22, 1998, must meet these more stringent standards.

The above-ground tanks incorporate a double-wall unit with concrete insulating material between the two tank walls. The insulating liner will also absorb fuel during a pool fire. The outer steel wall provides the required secondary containment and protects the insulating material. According to the manufacturer, the double wall with interstitial leak detection, emergency shutdown and other features also enable the units to meet all OSHA regulatory standards.

The tanks are available in capacities ranging from 300 U.S. gallons to 20,000 U.S. gallons (1,136 liters to 75,700 liters) and custom installations can be designed for any application. For more information, contact: Areo-Power Unitized Fueler Inc., 103 Smithtown Boulevard, Smithtown, NY 11787 U.S. Telephone: 1-(800) 242-2736 in the United States; (516) 366-4362 outside the United States.

Safety Shoes Without The Steel Toe Guard

Many technicians and airport workers are required by local or company regulations to wear protective footwear. In the past, all protective shoes required a steel toe guard to provide the level of desired protection. But the steel shell had disadvantages.

It often triggered security alarms and metal-detection units, and because steel is a good conductor of heat or cold, it often made the wearer uncomfortable in extreme climatic conditions.

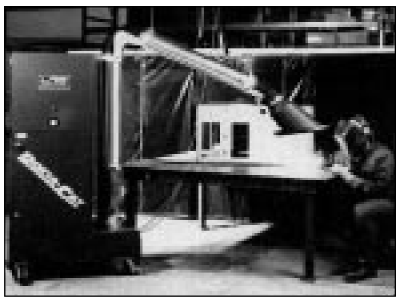
Mainstream-All American Footwear has introduced a line of safety shoes that the manufacturer says will provide better protection without these disadvantages. The shoes incorporate an Ultec 2000 nonmetallic toe cap made from a plastic composite that is said to be stronger than steel, yet weighs only one-third as much. It will not activate metal detection devices and the plastic is said to be a much better insulator than the metal materials.

The shoes will be available through Work 'n Gear, which caters to health care, construction and service industries. For more information, contact: The Kotchen Group, 968 Farmington Avenue, West Hartford, CT 06107 U.S. Telephone: (203) 233-0884; Fax: (203) 233-7236.

Portable Filtration System Captures Noxious Fumes at Source

United Air Specialists Inc. has developed a portable vent hood and collection system for use in areas where fumes, dust, mists or smoke are created by work processes. The Porta-Cat portable air cleaner is said to capture pollutants at a greater distance than comparable units. The unit is lightweight, and with its industrial-grade casters, is easy to move to where it is needed.

According to the manufacturer, the air cleaner and its filtration system offer efficiencies up to 99.9 percent and a media collection surface up to 30 percent greater than industry standards. As a result, the filter changes and maintenance requirements are said to be much less frequent. The unit helps to meet U.S. Occupational Safety and Health Administration (OSHA) compliance. Intended for use in applications such as welding, brazing and soldering, it is effective against dry chemicals and powders, carbon dust, sanding dust and oil smoke. When supplied with a charcoal after-filter, the unit is effective with mist and nuisance odors.



Portable Filtration System from United Air Specialists Inc.

For more information, contact: United Air Specialists, Inc. 4440 Creek Road, Cincinnati, OH 45242 U.S. Telephone: 1-(800) 551-5401 in the United States; (513) 891-0400 outside the United States.♦

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