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Robert A. Feeler, editorial coordinator

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Infrared Thermography Offers New Possibilities for Nondestructive Testing

Robert A. Feeler
Editorial Coordinator

The accurate measurement of temperature has long been used as a diagnostic tool in medicine. The measurement of body temperature by a thermometer is probably the most familiar tool.

Temperature measurements have been common on aircraft too, for monitoring the engine's condition. Cylinder head–temperature and oil-temperature gauges were among the earliest instruments for assessing or diagnosing engine conditions, but these instruments require permanent installation and are limited to checking temperatures at specific locations.

More precise temperature-measurement devices have provided the aircraft technician with enhanced tools to perform diagnostic tests on static systems and operating equipment. Infrared (IR) thermographic devices are extremely accurate and easy to use. Rather than using a thermocouple, or temperature-sensitive liquid as in the common thermometer, IR temperature measurement does not require physical contact to provide accurate measurements.

IR light is invisible to the human eye, with wavelengths just beyond the red end of the visible spectrum. The

waves are longer than those of the visible spectrum but shorter than radio waves, and have a penetrating heating effect that is used in cooking. Like visible light, IR light can be focused and bent by lenses and filters. This allows equipment to be designed for wide-angle use to scan large areas or objects, or to be focused to microscopic detail.

With the addition of digital electronics and computerization, an IR image can be color-enhanced, rather than presenting only shades of gray. Digitized data also allow the image to be recorded on magnetic tape, displayed on a video screen or reduced to a paper image in black and white or in color.

Radiation Is Proportional to Temperature

IR thermography works on the principle that all objects emit electromagnetic radiation in proportion to their temperature. With the perfection and miniaturization of computerized circuits, these principles have been applied to develop IR cameras with electronic sensors that convert thermal radiation into a signal that can be displayed on a video screen, allowing study of the distribution of temperature across the surface of an object.

The potential uses of IR thermography are vast. Current IR cameras using digital technology and computer enhancement are capable of accurately sensing temperature variations of as little as two-tenths of one degree F. With such sensitivity and accuracy, IR thermography can sense temperature changes as they occur, and this opens new possibilities for nondestructive testing of aircraft components and systems.

"Hot Spots" Indicate Flaws

Using an IR camera, a technician points the lens at an operating component and immediately determines if there are "hot spots" in the IR image. This can be very useful in checking bearings for overheating caused by misalignment or lack of lubrication. With recording devices, a permanent record can be made of the temperature image for future comparison with later results or to create a record for evaluating teardown inspection results. This capability could be invaluable in monitoring rotating equipment such as helicopter tail-rotor drive shafts.

IR thermography has also been applied to the inspection of electrical equipment and integrated circuit boards. If there is a poor connection in an operating circuit, the temperature increase created by arcing appears as a hot spot. In testing an integrated circuit-board component

that is malfunctioning or overheating because of inadequate cooling-air flow, an IR camera can be used to locate the faulty component and to create a permanent record for use when repairing the component.

Exhaust leaks, thin spots in exhaust system components or even an air leak in a pneumatic system can be detected because such problems create temperature variation, which can be detected by an IR camera.

IR Becomes NDT Tool

Every object or material transmits heat at a different rate. If an object is heated (or cooled) and the source of heat (or cooling) is then removed, the rate at which the temperature stabilizes in different areas of the material can signal other anomalies. Any subsurface defect, for example, creates a break in the continuity of the material. That break causes the heat to be transmitted at a different rate, which is easily detected by IR thermography.

IR devices are being used in aircraft inspections that involve composite structures or components. Composites cannot be magnetized, and thus cannot be inspected using magnetic-particle inspection techniques. Fluorescent or visible-penetrant inspection techniques depend on the presence of a surface defect, and so are of very limited use in inspecting composite components. Composites do, however, transmit heat and therefore are ideal materials for IR thermographic inspection.

One of the most common uses of IR thermography is to inspect composite radomes for delamination and water penetration of the honeycomb. The inspection technique consists of heating a radome (see photo, page 4) to approximately 125 degrees F (52 degrees C) for about 15 minutes, and then observing the radome as it cools from various angles. Trapped moisture or delaminated areas retain heat and appear as hot spots in an IR image. By varying the sensitivity of the IR camera and using color enhancement, moisture appears as white or red, and delaminations or bonding voids appear as yellow.

Radome repair shops have found that IR thermography provides an easily understood picture of the radome condition, which can be stored on a standard video cassette recorder (VCR) tape or a hard-copy print. Prints are useful in performing repairs and for providing visual documentation of "before" and "after" conditions. IR thermography is a significant improvement over the moisture-meter method of inspecting radomes, because it allows a visual record.

IR thermography can be used to inspect other composite components such as control surfaces, doors and cover panels.

Radome is heated to 125 degrees F for about 15 minutes prior to infrared (IR) inspection. Trapped moisture or other defects will retain heat longer and appear as hot spots in an IR image.

Various IR inspection methods, some more effective than others, have been developed.

One method was to conduct inspections immediately after an aircraft landed (having been "cold-soaked" while flying at higher altitudes), as it warmed on the ground. But this method proved to be unreliable because it was difficult to control the period prior to inspection because of descent profiles, holding times and taxi times. Ambient ground temperatures also influenced measurements.

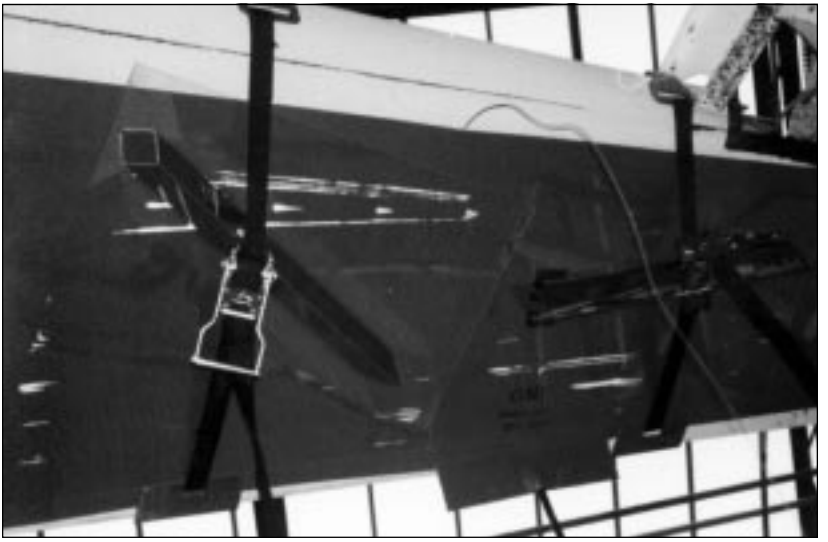
A major manufacturer experimented with artificially cooling airframe structures so that any trapped water would be frozen and would be easily detectable under IR examination because the frozen water retained heat longer than dry material. Although the technique worked, it was impractical because of the large size of the airframes.

The thermographic inspection method most often used involves heating a panel or a structure using large electrically powered blankets (see photo, page 5).

Because IR cameras are so sensitive, inspections should be performed where other sources of thermal radiation are minimal. Inspections should be conducted in areas where the ambient temperature is relatively stable between 41 degrees F and 104 degrees F (5 degrees C and 40 degrees C). To avoid damaging the structure, the heating blankets are thermostatically controlled to maintain the structure's temperature at 140 degrees F (60 degrees C) for about 15 minutes. No part of the structure should be heated to more than 158 degrees F (70 degrees C).

Tests have shown that the best results are achieved when inspection is conducted eight minutes after removal of the heating blankets. This allows enough time for the temperature to equalize across the surface. The consistency of results cannot be maintained if the inspection takes longer than 10 minutes. The angle of observation is also important for producing the best results. The IR camera should be held at an angle close to perpendicular (90 degrees) to the surface under inspection. Optimum results are obtained with the IR camera held at a distance between 3.3 feet and 6.6 feet (one meter and two meters) from the structure.

To conduct the inspection quickly and within the optimum time span, it has been found advantageous to use two people: one to hold the IR



Heating is provided by an electric blanket attached to the structure.

camera and scan the area under test, and a second to mark the surface of the structure to identify the hot spots as displayed on the video monitor (see photo, cover).

IR techniques have enabled manufacturers to differentiate between hot spots caused by water ingress and hot spots caused by embedded structural reinforcements such as hoist fittings, ribs, holes or previous repairs. Limits for the size of hot spots, above which a structure must be rejected and below which the amount of water present is acceptable, have been defined to aid in evaluating results of the inspection. At least one manufacturer has adopted IR thermography as a standard procedure for the inspection of composite sandwich structures.

IR Thermography Plumbs the Depths

One IR thermographic system manufacturer introduced a system that can be configured to perform thermal-wave thermography. This inspection method is said to be capable of locating voids and cracks up to several millimeters beneath the surface of an object.

In this system (Figure 1, page 7), a computerized control unit modulates the thermal input from a laser beam, halogen lamp, hot air gun, etc., resulting in the generation of a thermal wave throughout the entire sample. Because of the specific heat capacities of different materials, the heat flow through the object changes at points where irregularities exist in the material, because there is a defect or void blocking the heat flow.

Thermal radiation is reflected from the material, and the delayed reflections from faults indicate their existence below the material's surface.

The IR camera sensor (which replaces film) converts the image into thousands of individual elements called pixels. Each pixel (the smallest element of each image) is monitored sequentially by an IR scanner, with four thermographic images digitally recorded during each modulation cycle. The external heating source is modulated and synchronized with the scanner by the computer control unit.

Subsequent image processing on the controller provides phase and magnitude images of the sample area, using a process called Fourier analysis. The resulting magnitude image is calculated only from the signal differences, with the effects of reflected external ambient thermal radiation eliminated. The image is said to be independent not only of external signal differences, but also of the effects of external reflections or

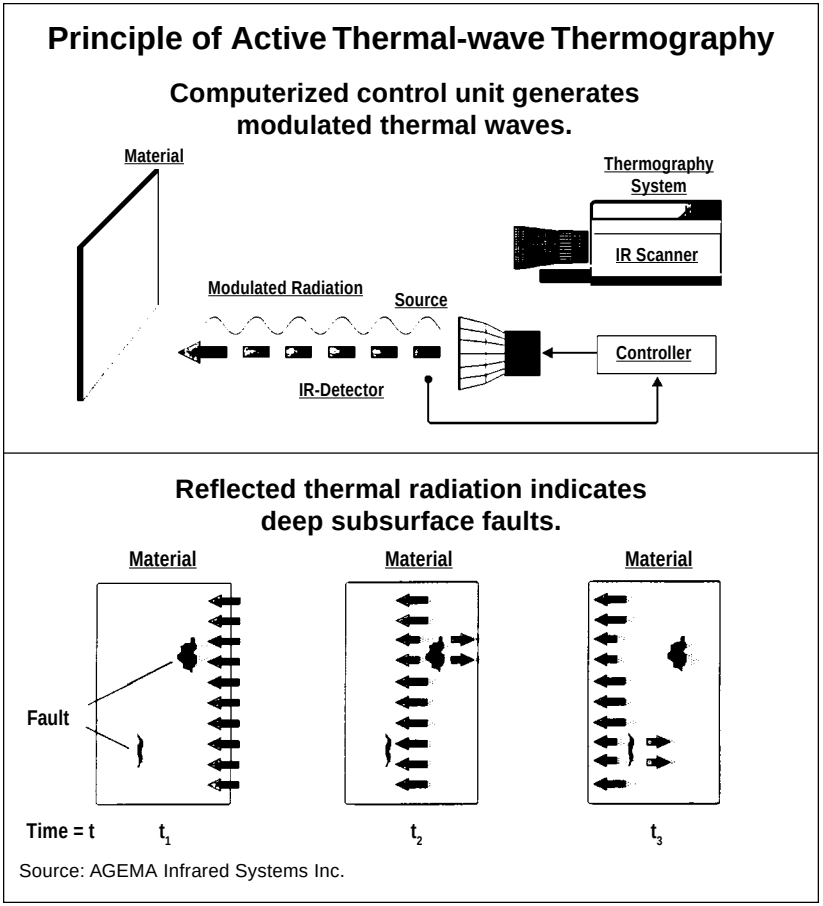


Figure 1

nonuniform heating. As a result, no special preparation of the object's surface is necessary.

This system requires less heating of the object, reducing the likelihood of overheating the material under test. This inspection method is more practical for inspecting large objects such as aircraft fuselages. The system shows promise as an additional or replacement NDT technique.

Editorial note: This article was derived from information provided by AGEMA Infrared Systems Inc., 550 County Avenue, Secaucus, NJ 07094 U.S.♦

U.S. Proposes Exclusion of Mechanical Flight-delay Data from Airline On-time Data

U.S. Department of Transportation (DOT) Secretary Federico Peña has proposed to exclude mechanical delays and cancellations from on-time data filed by U.S. airlines with the DOT.

On-time reporting began in September 1987 and mechanical conditions that caused delays or cancellations were added to the data in January 1995. The DOT added the information because it believed that the additional data would provide more complete information about airline performance.

Nevertheless, airline pilots and maintenance technicians expressed concern that the rule might contribute unnecessary pressure on the mechanics to maintain on-time performance. As a result of the concerns expressed by the pilots and maintenance technicians, Secretary Peña directed the proposed rulemaking.

The on-time data have been published in the DOT's *Air Travel Consumer Report*, which also included data on mishandled baggage and consumer complaints about airline service. The DOT noted that the flying public can obtain from airline ticket offices and travel agents the on-time performance data on specific flights.

ATA Announces 1995 Publications Catalog

The Air Transport Association of America (ATA) has published its 1995 publications catalog, which lists more than 60 titles.

Topics include:

- Airports;
- Cargo;
- Electronic data interchange;
- Government affairs;
- Industry statistics;
- Engineering, maintenance and material; and,
- International ATA agreements and passenger services.

New products include an expanded offering of publications in CD-ROM

format, which can be used with Windows, Macintosh or UNIX systems. For more information, call (800) 497-3326 in the United States, or (301) 490-7951 outside the United States.

Rolls-Royce Completes Acquisition of Allison

Rolls-Royce plc has received U.S. government approval for its acquisition of the Allison Engine Co. The purchase, which was originally announced in November 1994, was completed at a price of US$525 million. With the addition of Allison to the Rolls-Royce family of aircraft engines, the company has an installed base of more than 50,000 engines. Allison's line of small turbine engines in the C-250 series powers helicopters, and its 501D13/22 series powers large turboprop aircraft such as the Convair CV-580 and Lockheed Martin C-130.

With the recent introduction of newer turboprop and midsize turbo fans, Rolls-Royce Chairman Sir Ralph Robins said, "Now that we have received regulatory approvals, Allison becomes part of a major aerospace group for the first time and strengthens Rolls-Royce's position as a world-leading power systems business."

ARTEX and AAGSC Call for Greater Attention to Ground-safety Issues

The International Air Transportation Section (ARTEX) of the U.S. National Safety Council and the Australasian Airline Ground Safety Council (AAGSC) have issued a joint statement commenting on the proceedings of the Ramp Safety Seminar presented by the U.K. Flight Safety Committee in November 1994.

The U.K. seminar chairman said that accidents and incidents that occurred on the ramp have been largely ignored because ramp safety has typically had a lower priority than flight safety. But recent efforts by the industry have proven that fatal and serious injury rates in ramp activities can be improved.

The ARTEX efforts to reduce fatalities and injuries occurring in pushback operations were given as an example of what can be accomplished when operators and contractors cooperate. Representatives of the insurance industry called on all airlines and servicing contractors to develop a ground-safety culture by employing specialists who could share their knowledge.

ARTEX and AAGSC believe that a strong ground-safety discipline administered by a dedicated staff is as essential within an airline today as the flight safety staff. The 1995 National Safety Council's 83rd Congress and Exposition will be held in Dallas, Texas, U.S., on Nov. 5–10, 1995. The next ARTEX/AAGSC conference, which will be hosted by AAGSC, is scheduled for January 1996 in Sydney, Australia.♦

MAINTENANCE ALERTS

This information is intended to provide an awareness of safety problems so that they may be prevented in the future. Maintenance alerts are based upon preliminary information from government agencies, aviation organizations, press information and other sources. The information may not be entirely accurate.

Airworthiness Directive Issued on Counterfeit Connecting-rod Bolts

The U.S. Federal Aviation Administration (FAA) has issued an airworthiness directive (AD 95-07-01) that applies to a wide range of Textron Lycoming reciprocating engines. The AD has a "before the next flight" compliance deadline and affects Lycoming engine series 0-360, 0-540–541 of all models and variations. Six instances had been reported of connecting-rod bolts that had been sold as Lycoming Part Number 75060 and had failed in service. Investigation disclosed that these bolts were counterfeit and did not meet the required specifications for this part number.

Superior Air Parts Inc., a vendor for the bolts, apparently purchased unknowingly a number of the suspect parts. The bolts may have subsequently been sold or installed in the affected engines. Superior has issued a Service Bulletin and contacted all operators of engines reworked by Superior and operators to which they sold such parts. Other vendors may also have obtained and resold the counterfeit parts.

The counterfeit parts can be identified by the lack of any head markings. Detection of imperfections is not possible without metallurgical

testing of the connecting-rod bolts. Superior is cooperating with the FAA to identify the source of the counterfeit parts and has offered parts and labor credit to their customers who are affected by the AD.

Technicians involved in the maintenance and inspection of affected Lycoming reciprocating engines should become familiar with all aspects of the AD.

Unapproved B-727-200 Parts Improperly Released into the Field

In Advisory Circular (AC) 43-16, *General Aviation Airworthiness Alerts*, Alert No. 202, the U.S. Federal Aviation Administration (FAA) alerted technicians to the release of unapproved Boeing 727-200 parts. An investigation of Hamilton Aviation, Tucson, Arizona, U.S., disclosed that more than 300 parts had been returned to service, contrary to the requirements of Federal Aviation Regulations (FARs) Parts 43 and 145. The unapproved parts can be identified by the phrase "visual inspection only" in the remarks section of the airworthiness approval tag.

If parts meeting this description are in your possession or are presented to you for installation, you, as the certificated technician, are required to ensure that they meet all requirements of FARs Part 43 and are properly released for return to service prior to installation.

Parts Produced Without FAA Approval

An investigation by the U.S. Federal Aviation Administration (FAA) has found that parts manufactured without an FAA Production Approval were sold by D&D Air Inc., San Clemente, California, U.S. The parts included components designed for the Lockheed Martin L-1011; McDonnell Douglas DC-8, DC-9, MD-80 and MD-11; and Boeing 707, 727, 757 and 747. It is not known whether the parts were substandard.

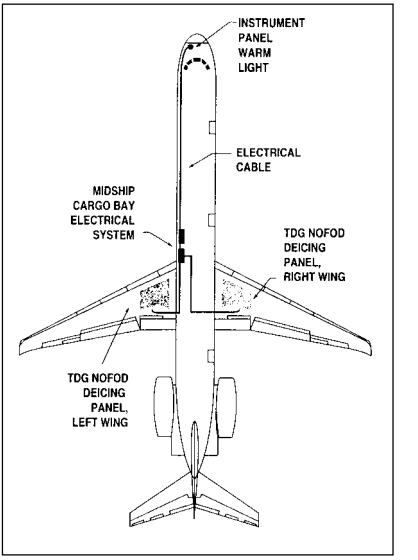
The specific part numbers covered by the Suspected Unapproved Parts (SUP) Safety Alert were published in the FAA *Air Carrier Summary* for the week ending March 25, 1995. A copy of that article is available from the FAA, Attn.: AFS-643, P.O. Box 25082, Oklahoma City, OK 73125-5029 U.S.♦

McDonnell Douglas, TDG Aerospace Develop Alternative to Repetitive Inspections of MD-80's "Cold Corner"

McDonnell Douglas MD-80 series aircraft require inspection of the upper-wing surface prior to takeoff to ensure that no ice has formed over the "cold corner" of the fuel tanks. The ice is caused by "cold-soaked" fuel creating a below-freezing skin temperature after landing, even when ambient air temperatures are well above freezing. If rain or drizzle is present, a nearly invisible layer of ice can form on this area. On takeoff, this ice can break off and enter the engine inlets, resulting in severe damage to the engine blades and stators.

The U.S. Federal Aviation Administration (FAA) has issued an airworthiness directive (AD-92-03-02) calling for the pilot to physically examine the affected area of the wings prior to each takeoff, whenever the conditions were such that ice could form.

An FAA-approved alternative to this procedure has been developed. Working with McDonnell Douglas, TDG Aerospace Inc. has developed a thin heating element, approximately 40 square feet (4.5 square meters) in size, that is bonded to the upper-wing surface. Some 30 existing mechanical-fastener positions on the forward and aft spars are used to secure the unit in place. The overlay is only 0.125 inch (0.38 centimeter) thick and has no adverse aerodynamic effects.



NOFOD Overwing Ice Protection System from TDG Aerospace Inc.

The system, called NOFOD, is designed to activate automatically when the wheels touch the runway on landing and remain on while the aircraft

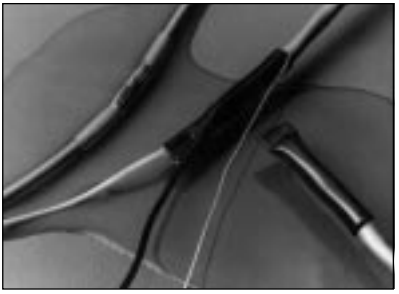
is active at the gate and until it lifts off on the next takeoff. A simple "Warm/Fail" annunciator light on the console indicates to the crew if the system is properly functioning and has reached a safe de/anti-icing temperature. After successfully testing the system on three of its MD-80s through two winters, American Airlines has elected to install the NOFOD system on all of the 260 MD-80s in its fleet.

For more information contact: TDG Aerospace Inc., 7031 Koll Center Parkway, M.D. 140, Pleasanton, CA 94566-3107 U.S. Telephone: (510) 417-0913. Fax: (510) 417-0913.

PVC Heat-shrinkable Tubing Creates Environmental Seal

Insultab Inc. has introduced a polyvinyl chloride (PVC) tubing that is said to create an environmental seal to protect electrical connections, wire splices, etc. This dual-wall heat-shrinkable tubing features an adhesive that flows and sets to create a barrier against oils, chemicals, most solvents and water.

The tubing has a two-to-one shrink ratio and is heat-activated at 212 degrees F (100 degrees C). It is ultraviolet (UV)-resistant and claimed to be very effective for outdoor use in



PVC Heat Shrink Tubing from Insultab Inc.

exposed areas. The tubing is available in sizes from 3/16 inch to one inch (4.76 millimeters to 25.4 millimeters) interior diameter, in either black or clear material. Literature and samples are available from: INSULTAB Inc., 50 Everberg Rd., Woburn, MA 01801 U.S. Telephone: (800) 468-0800 in the United States or (617) 935-0800 outside the United States. Fax: (617) 935-0879.

Tamper-evident Labels Enhance Security And Safety

Kroy Inc. has announced a new tamper-evident thermal transfer tape that can be used in its K2000 label and bar-code portable printer. After the label is affixed to an object's surface, any tampering with the label, such as lifting or attempting to remove it, will cause the word "VOID" to appear on both the label and the object to which it was affixed.

Tamper-evident labels from Kroy Inc.

Developed in response to requests from several aviation operators, this label tape is intended to enable the operator to ensure the integrity of its aircraft. The tamper-evident label is said to resist chemicals, water and ultraviolet light and can be used to secure access panels, doors and critical entry points.

To learn more about this product, contact: Kroy Inc., P.O. Box C-12279, Scottsdale, AZ 85367-2279 U.S. Telephone: (800) 733-5769 in the United States or (602) 948-2222 outside the United States.

Screw Remover Included in New U.S. Industrial Catalog

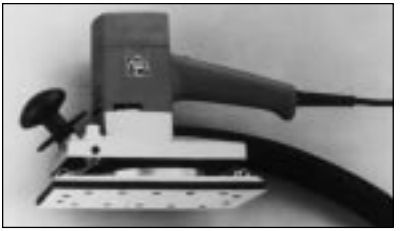
Every technician has been frustrated with removing a screw that seems impossible to get out. The U.S. Industrial Tool & Supply Co. 1995 product catalog includes the Heavy Duty Screw Removal Tool, which is designed to solve this problem. The tool will accommodate all 1/4-inch (0.6-centimeter) hex drive bits and can thus be used for straight, Phillips, tri-wing or high-torque screws.

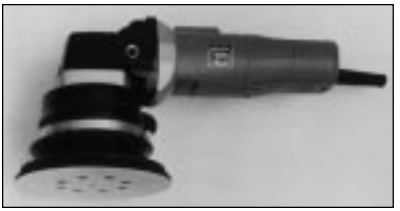
The tool provides a pivoting locating and security fastener that enables the tool to be secured to an adjacent screw hole to hold the driver in place while removing the problem fastener. The unit folds for compact storage. For more information, contact: U.S. Industrial Tool & Supply Co., 15101 Cleat Street, Plymouth, MI 48170 U.S. Telephone: (800) 521-4800 in the United States or (313) 455-3388 outside the United States.

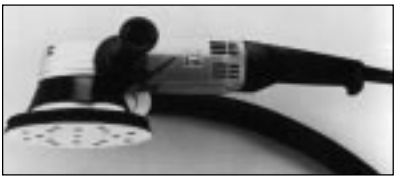
Unique Sanding System Eliminates Dust

Dust and particles from sanding of composite repairs creates a potential health hazard to technicians. Fein Power Tools Inc. has introduced a system of sanding equipment that it says eliminates the dust before it becomes airborne. The system, which is dubbed “dust-free,” uses sanding discs and pads that have holes in the abrasive surface and backing pad.

Each sanding unit is connected through an extractor system, using a flexible hose and roll-around collector. Extractor slots around the edge of the random-orbit and half-sheet







Dust-free Sanding System from Fein Power Tools Inc.

sanders are said to eliminate the need for a shroud that might block the user's view of the work piece. The units can be used with either wet or dry sanding methods. Collector units range in size from 10- to 22.4-gallon (37.9- to 84.8-liter) capacities. For more information, contact: Fein Power Tools Inc., 3019 West Carson Street, Pittsburgh, PA 15204 U.S. Telephone: (412) 331-2325. Fax: (412) 331-3599.

New Eddy-current Instrument Detects Surface Flaws

Centurion NDT Inc. has introduced a nondestructive flaw-detection device that is small enough to be carried in one hand, and is powered by two AA batteries. According to the manufacturer, the unit is capable of detecting cracks or surface flaws as small as 0.005 inch (0.013 centimeter) deep in ferromagnetic materials. The ED-400 Portable Eddy-current Testing Unit weighs less than one pound (0.45 kilogram) and the unit measures just 3.5 inches (8.9 centimeters) x 7.1 inches (18 centimeters) x 1.9 inches (4.8 centimeters).

The meter on the unit indicates probe unbalance as the interchangeable probe is passed over a flaw, and an audible alarm can be set to alert the operator. The manufacturer says that the probe design uses a unique feature that renders the instrument

ED-400 Portable Eddy-current Testing Unit from Centurion NDT Inc.

insensitive to background changes in magnetic permeability and requires no "lift-off" compensation, a common concern with other eddy-current inspection devices. The unit is said to be capable of producing reliable results without removing paint, scale, oxidation and other coatings.

Unlike other methods of surface crack detection, such as magnetic-particle and liquid-penetrant testing, the eddy-current inspection process leaves no contaminating materials or residue on the part being inspected. For more information, contact: Centurion NDT, 707 Remington Road, Suite 9, Schaumberg, IL 60173 U.S. Telephone: (708) 884-4949. Fax: (708) 884-8772.

Protective Breathing Apparatus Catalog Available

The Survivair Co. has published a brochure that illustrates a full line of protective breathing apparatus for use in dangerous-air environments. The brochure also describes the company's product training programs that help employers to train their workers in respirator use and maintenance.

Survivair claims to be the first U.S. manufacturer of self-contained breathing apparatus to receive the International Organization for Standardization (ISO) 9001 certification. According to Survivair, the ISO certification is becoming as important to the breathing-apparatus purchase decision as the National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA) and National Fire Protection Association (NFPA) standards.

For more information, contact: Survivair, 3001 S. Susan Street, Santa Ana, CA 92704 U.S. Telephone: (800) 821-7236 in the United States.♦