Passenger Safety: United's Top NDE Priority

Inspection at United Airlines encompasses a wide variety of nondestructive examination techniques

BY MARY RUTH JOHNSEN

When you're carrying 300 passengers 30,000 feet in the air, the role of the inspector takes on a special significance. Everything that person does centers on airworthiness — whether a part is fit to be in the air.

The 523 airplanes that make up United Airlines' fleet undergo myriad inspections, both on a routine, scheduled basis and as needed when special circumstances arise. This article details two segments of the airline's inspection activities.

United Airlines (UAL) operates more than 1700 flights a day, transporting approximately 210,000 passengers daily. United Services, the company's maintenance and engineering division, employs 8200 people, including 5400 mechanics and 340 engineers. The division runs 45 maintenance stations around the world. However, the company's primary maintenance facility is the Maintenance Center at San Francisco International Airport, a 144-acre site it acquired from the U.S. Army Air Corps in 1947. The base handles much of the routine maintenance as well as special projects. The NDT Engineering area falls under the Repair, Process & Materials Engineering Department, which is managed by Byron May. In addition to working on its own fleet, United Services performs work, including NDE operations, for many other airlines and the U.S. Air Force.

The Federal Aviation Administration (FAA), the airlines themselves, and equipment manufacturers widely share information regarding aircraft safety throughout the airline industry. Findings from previous accidents certainly play a role in inspection activities as to what airlines look for during inspections. Passenger and crew safety is the paramount philosophy governing NDE operations.

United Services utilizes a variety of NDE techniques, including radiography, fluorescent penetrant, magnetic particle, eddy current, ultrasonics, thermography, visual inspection, and remote visual inspection. Many of the inspectors are multifunctional. Their main job function may be in one area, such as radiography, but they also perform other types of inspections they are trained and qualified for when necessary. May explained that regarding training, United generally follows ASNT guidelines, but works specifically to Air Transport Association (ATA) 105, an airline-specific standard. The company wants its engineers to be the equivalent of ASNT Level IIIs and its inspectors to be equivalent to Level IIs.

Radiography

United Airlines' radiography operation was primarily developed to support airframe inspection — meaning any part of the airplane's structure that doesn't involve the engine — according to Robert Stevens, NDT process engineer. While it still supports airframe, its primary customer these days is the jet engine shop. Neither General Electric nor Pratt & Whitney, makers of the engines used in the company's planes, typically provide part-specific radiography procedures to support repairs, so Stevens is responsible for developing and writing all of UAL's in-house procedures. He works closely with two NDE inspectors developing those procedures and on research and development projects for other NDE applications.

Inspection plays an important role in keeping UAL's fleet of 523 planes well maintained.

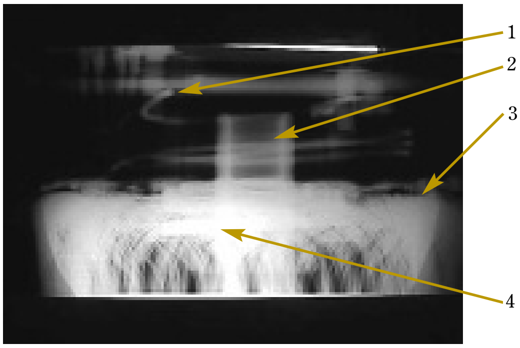

Fig. 1 — Arrows 1 and 2 show the wires that were being checked for correct routing. The wires should be routed from those two connectors to the top of the commutator (arrow 3). Any sign of the lead wires dipping below the top area of the commutator would be a reject condition. In this radiograph, the wires were found to be correctly routed, but a retaining lock/washer was found out of place (arrow 4). This condition was not found in any other fuel pump United inspected.

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Fig. 2 — Pramool Nanongkai paints on fluorescent dye to prepare parts for inspection.

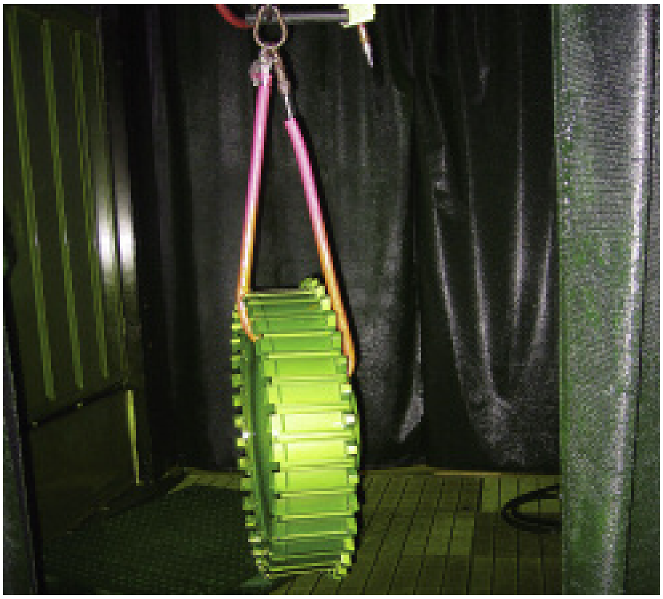

Fig. 3 — A fan hub from a Pratt & Whitney PW2000 engine undergoes fluorescent penetrant inspection to determine its airworthiness. The PW2000 powers United's Boeing 757 fleet.

United's radiography department can perform field or stationary cabinet inspections. It is also certified for both gamma and X-ray radiography, even though the gamma or isotope radiography is not currently needed.

For the airline's needs, manual, film-based radiography is still the most adaptable and effective process, Stevens said. "The benefits of using automated and digital radiography are best realized in manufacturing situations where there's a lot of repeatable inspections and high volumes of identical parts," he explained. "We don't make things here, we fix them. We have to be able to adapt our processes efficiently to inspect a wide variety of parts and repair situations during the workday. Even when we know a specific part or isolated area is susceptible to cracking, other inspection areas and new repairs may require that the part be inspected differently."

Another advantage of film is that it, literally, is flexible. "You can roll it up and put it in an area that other processes can't reach. You also lose very little edge resolution with film, another reason why it can be so effective and flexible for our inspections," Stevens explained. "Film is still the most versatile medium when you're dealing with complex geometries and a variety of applications."

The airline industry doesn't always fall in line with the rest of industry because of the materials it uses, he said. "We're working with superalloys that are as thin and light as possible. We do very little conventional steel." Instead, they deal mainly with materials such as Inconel®, Hastelloy, titanium, and aluminum. In fact, with regard to the penetrameters used in radiographic testing, originally there weren't any thin enough to provide a good indication of contrast sensitivity. "Pratt & Whitney developed standards for penetrameters thinner than the minimum 0.005 in. typically contained in other industry standards. These thinner penetrameters are necessary to provide a good indicator of proper radiographic contrast on materials less than ¼ in. thick." Use of these penetrameters has been adopted at United and Stevens worked with the ASTM Standards Committee to incorporate these penetrameter specifications into ASTM E1025.

When Radiography Is Used

The company utilizes radiographic testing for a wide variety of applications. Some parts are automatically x-rayed whenever they're disassembled, according to radiographer Dennis Montellato.

Weld repairs also undergo radiographic testing. May explained that UAL's use of welding involves little traditional joining. Instead, welding is used either for buildup of worn geometries or crack repair. Repairs to engine cases make up a large amount of the welding and radiographic testing that is performed. Parts made from Inconel 718 are prone to cracking related to heat treatment, May explained, so they're inspected again following heat treatment.

Often, the radiographic department works hand in hand with the welding engineer and welders as new weld repair procedures are being developed. Parts will be x-rayed after each step of the repair to validate that the repair procedure is producing the desired results. This results in excellent repair procedures, Montellato said.

Responding to a Special Call for Inspection

Sometimes special circumstances come up such as an application that required removal and x-raying of the fuel pumps on a large portion of the airline's fleet. Following the National Transportation Safety Board's investigation of the TWA 800 explosion in 1996, the airlines received a Service Bulletin from a fuel pump manufacturer that described a condition the manufacturer had discovered that had not caused any harm but had the potential to do so. Compliance with the Service Bulletin was mandated in an Airworthiness Directive issued by the Federal Aviation Administration, which prescribed a certain amount of time to complete the inspections. The parts could have been sent back to the manufacturer, but to assure the inspections could be completed within the time limits, United Services elected to do the inspections itself.

While it may seem odd to have an electrical part working inside a tank full of jet fuel, that's exactly what happens. The fuel pumps are cooled by being immersed in fuel. So long as they're fully immersed, no oxygen is present and no explosive environment exists. What the Service Bulletin was telling the airlines to look for was a wire not properly routed in the housing at the top of the fuel pump — Fig. 1. Although this type of fuel pump is used in a variety of aircraft, it was suggested to inspect Boeing 747s first because the long-range 747s feature an additional auxiliary fuel tank. As fuel was consumed, it would be possible for the pump to not be fully immersed; therefore, if a wire was not

Fig. 4 — The immersion ultrasonic testing machine is used to look for subsurface discontinuities in parts such as rotating discs.

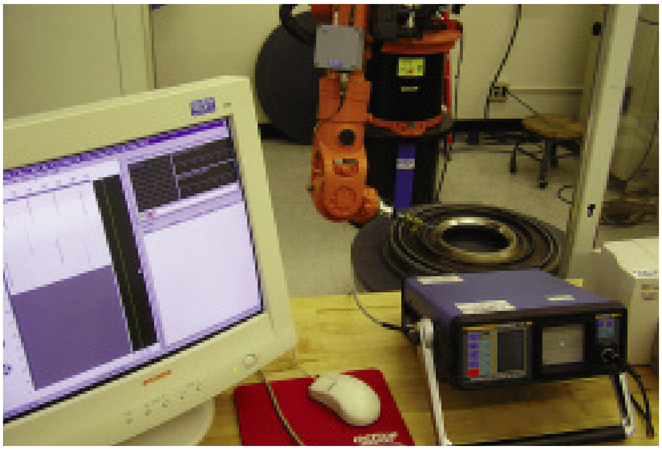

Fig. 5 — The robotic eddy current testing cell.

correctly routed, it could provide an ignition source.

United Airlines mechanics immediately began removing the fuel pumps, with inspections taking place on a nightly basis. "We overhaul most of our own pumps here," Stevens said. "We never found the condition in fuel pumps overhauled in our own shop, but we did find some in pumps that we had available as replacements that came from the manufacturer."

Radiographic testing is now part of the company's fuel pump overhaul process. "The mechanics in the shop, aircraft mechanics, and inspectors all worked together," Stevens said. "Inspections were completed well within the mandated interval."

Other Inspection Processes

Another main inspection area includes two magnetic particle (MT) lines, two fluorescent penetrant inspection (FPI) lines, an immersion ultrasonic/eddy current machine, and a robotic eddy current (EC) inspection cell. Approximately 30 people work in this area, across three shifts. Each shift overlaps by 30 minutes so workers on one shift have the opportunity to communicate anything they need to with the workers on the shift coming on.

With few exceptions, these inspection lines aren't used to perform weld inspections. Instead, they are used to determine airworthiness of individual parts. The MT lines are used to discover surface or just below surface discontinuities on ferrous materials, and the FPI lines to check for surface discontinuities on all materials. The immersion UT machine is used to detect mainly subsurface flaws. The robotic EC inspection cell is used to detect surface flaws only.

Repairs are not permitted on many of the more critical airplane parts, so the lines were developed to validate parts' airworthiness in a higher-production environment, explained Bill Nappi, NDT process engineer.

"We're validating their structural integrity," May said. " and assuring that each part will perform as expected in the future."

Engine parts, landing gear parts, airframe parts all come first from a cleaning area. The MT lines must be validated daily using an evaluation process that includes a Ketos ring. If a distinct magnetic particle buildup shows aligned with seven of the ring's holes, they're assured the magnetic particle bath meets a minimum performance level.

"We check a lot of high-strength steel such as in landing gear," Nappi said. "For engine mounts we're looking for circumferential or axial cracks. We check each part using circular and longitudinal magnetism."

Many parts going through the MT and FPI lines undergo a general surveillance inspection where 100% of their visibly accessible surfaces are inspected. Other parts undergo directed inspections to look for specific conditions based on previous experience or to verify no damage was caused during repair operations.

The FPI line operates automatically or can be used manually. The company primarily utilizes Magnaflux Zyglo® products in two sensitivity levels: Level 4, considered an ultrahigh sensitivity, postemulsifiable penetrant, and a Level 3, water-washable penetrant. The penetrant used depends on the porousness of the surface of the part and whether or not it rotates. All rotating parts such as fan blades are inspected using Level 4 FPI.

"We don't use any visible dye penetrant," Nappi said. "We have eliminated that process because it could kill the fluorescing dye. This could keep a crack from showing up under the black light and so could be dangerous" — Figs. 2, 3.

The FPI lines are validated daily using a standard penetrant sensitivity monitoring (PSM-5) panel. To validate the line, they must locate all five starbursts for Level 4 penetrants and four starbursts for Level 3. The lines are also validated weekly using low cycle fatigue (LCF) blocks.

"The validation process is very important," May explained, "because most of the parts are good. If you're finding cracks very rarely, you need to validate the lines regularly to know everything's working properly."

Many rotating discs are inspected using the immersion ultrasonic testing machine, which can inspect for defects up to 2 in. deep — Fig. 4. Since discs are considered critical rotating parts, they often require the immersion UT method for detection of possible subsurface discontinuities. The machine, which can also perform underwater eddy current testing, has the advantage of data storage capability and the ability to automatically return to any point on the part the operator selects.

The company also utilizes robotic eddy current testing to detect surface discontinuities — Fig. 5. Absolute coil probes are used for 90% of the applications; however, because of their increased signal to noise ratio, differential coil probes are used for fan discs. "Eddy current is a great process for inspecting deep holes for cracks," May said, "but it's not as efficient as FPI for inspecting a large surface." Holes are stress risers and their geometry can make cracks hard to detect."

"We're trying to move more to eddy current to eliminate some of the human factor (as opposed to FPI)," May said, "however, that introduces some other problems with programming, etc." May anticipates some changes to the regulations governing aircraft inspection that will mandate the use of eddy current for certain applications. If that happens, it may require UAL to purchase some new equipment.❖