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CORROSION DETECTION DEVICES

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Army Corrosion Summit--2004

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ABSTRACT

Nondestructive Examination Systems' specialists at the Department of Energy's Savannah River Site have unique, remotely controllable, corrosion detection capabilities. The corrosion detection devices most frequently used are automated ultrasonic mapping systems, digital radiography imaging devices, infrared imaging, and eddy current mapping systems. These devices have been successfully utilized in a variety of applications, some of which involve high levels of background radiation. Not only is corrosion located and mapped but other types of anomalies such as cracks have been detected and characterized. Examples of actual corrosion that has been detected will be discussed along with the NDE systems that were used.

Westinghouse Savannah River Company, a prime contractor to the Department of Energy, has collaborated with other government agencies in conceiving, designing, fabricating, deploying, and supporting automated inspection devices. The collaborative working relationships, which WSRC has had with other government agencies, have been highly successful and very beneficial. In every case technology has been transferred in both directions; thus benefiting both agencies.

INTRODUCTION

The fact that metals corrode does not come as a surprise to anyone. Corrosion affects all of us. Many of the things that are corroding aggravate us and cost us money. It has been reported that corrosion costs in the United States alone are estimated to be close to $300,000,000,000 a year, or approximately 3.2 percent of the U.S. gross domestic product.

Those who live in states where they put salt on the roads to melt snow and ice must diligently monitor the condition of their automobiles or they end up with side panels like the one shown in figure 1. One somewhat expects and accepts this kind of degradation on a twenty-year old car, but when a two-year old Lexus shows signs of rust we tend to get a little upset!

Figure 1: Rusted Side Panel

Corrosion accelerated fatigue failures can be catastrophic! A tragic example of that occurred in 1988 when a nineteen-year old Boeing 737 lost a major portion of its upper fuselage in full flight at 24,000 feet. The pilot, somehow, managed to land the plane, as seen in Figure 2. One flight attendant was sucked into the hole that had opened up in the fuselage and was swept to her death. Many others were injured.

Many fatigue cracks were detected in the remaining fuselage skin lap joints; however, the National Transportation Safety Board's report

Figure 2: The Aloha Incident

attributed the incident to the failure of the maintenance program to detect corrosion damage.

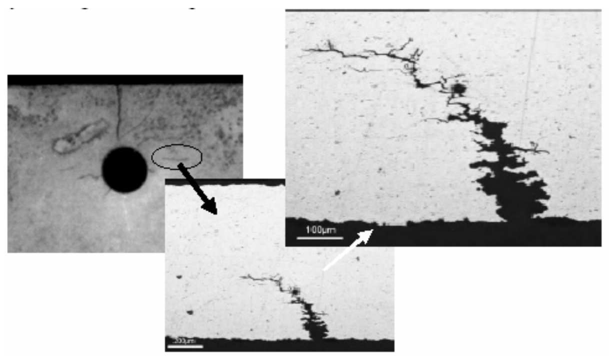

Figure 3: Rivet Hole Crack & Photomicrographs

Figure 3 is an example of a corrosion assisted crack around a rivet hole. Until the Aloha Incident almost all inspection of a jet aircraft's skin was done visually. In this paper we will discuss better ways to detect corrosion—before it becomes a matter of life and death.

Pipeline failures, due to internal and external corrosion, have also resulted in both monetary and human losses.

The photo in figure 4 is the bottom of a pipeline that has corroded underneath the external insulation. If the condition is left undetected, the pipeline could fail at the least opportune moment, causing loss of property and possible loss of life.

In this paper we will discuss some of the latest developments in the detection of corrosion. We will also describe some of the nondestructive examination devices in use at the Department of Energy's Savannah River Site that could be made available to other government facilities.

Figure 4: Corrosion Caused by Condensation

SURVEY OF NDE METHODS

A variety of nondestructive examination methods have become available that are viable candidates for the detection of corrosion. Those that will be considered are visual, ultrasonic, radiographic, eddy current, electromagnetic acoustic transducer scanning, thermographic inspection, and ground penetrating radar.

Being aware that no NDE method produces absolute discrimination of deleterious anomalies requires judicious selection of the test to be used and a careful selection of inspection points to maximize the benefits of inspection.

Visual Inspection

As mentioned previously, visual inspection has been and continues to be the primary method to detect corrosion. And, one might argue, even the most sophisticated inspection technique includes the human element. "Touching" the object being evaluated and looking at it carefully is a very important part of the inspection process. Pilots of commercial aircraft make a careful visual inspection of their aircraft prior to takeoff, because they are ultimately responsible for the safety of their passengers.

Visual inspection requires good vision, adequate lighting, and knowledge of what to look for. Enhancement of visual inspection can be done by using low power magnifying glasses, or when inspecting tubing, the use of boroscopes or video cameras.

Ultrasonic Inspection

Ultrasonic Testing (UT) methods utilize sound waves to interrogate an item. They can be used to measure the thickness or length of an item. UT can also be utilized to detect flaws such as cracks or pitting, detect liquid inside a component, measure the length and detect corrosion of buried anchor rods or interrogate concrete. Automated ultrasonic inspection systems, have been successfully used to detect subsurface corrosion and cracking in piping, storage tanks, and aircraft components.

Ultrasonic thickness meters have often been used to check pipelines for corrosion. While these meters can determine wall thickness (and wall thinning) it is very difficult to detect localized, internal corrosion with these devices. Ultrasonic thickness mapping of specifically selected inspection points provides far more information about the condition of a piping component, tank wall or floor.

Automated ultrasonic inspection systems, and in particular phased array UT systems, can be successfully used to detect subsurface corrosion on piping, tank walls, aircraft lap-joints and microcracking around rivets of high speed aircraft.

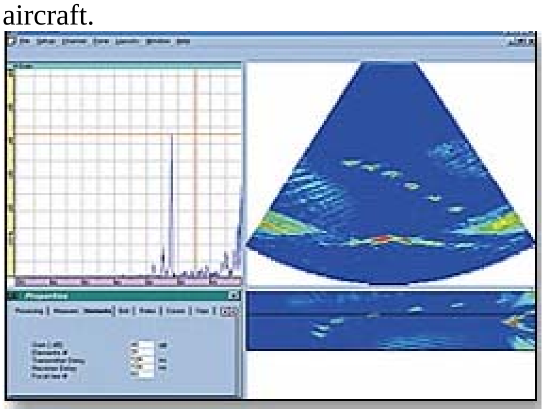

Figure 5: Phased Array Scan Presentation

Phased array UT systems generate a beam with various probe elements pulsing at slightly different times. By precisely controlling the delays between the probe elements, beams of various angles, focal distance, and focal spot size can be produced. The illustration shows how a beam can be focused at an angle and a given distance by firing the left elements slightly ahead of the corresponding elements on the right. It is possible to change the angle, focal distance, or focal spot size, simply by changing the timing to the various elements.

The sectorial scan is a real-time side view generated from a single inspection point, without any physical motion from the probe.

Radiographic Inspection

Radiographic inspection provides more information about the condition of a component than any other method; however, radiographic inspection requires the use of dangerous, ionizing radiation. It also requires access to both sides of the component being inspected—and it is expensive.

Radiographic films have been the primary method to "capture" images of the component under investigation; however, there are several image recording methods now available. Space does not allow a comprehensive discussion of the various methods. One of the newer image recording devices, referred to as computed radiography, employs the use of photostimulable plates. These plates can be used much the same as conventional films. Important differences are that they are reusable, they are more efficient at collecting data than film, and because the latent image is digitized the resulting data set has far greater "dynamic range" than what can be seen on a film.

Other important methods for "capturing" radio-graphic images are lens-coupled, charge coupled devices; direct imaging flat panel devices; linear arrays; and image intensifiers. All of these devices can be configured in programmable automated scanning systems such as is shown below. The collected image data provided by each of these image collection devices can be enhanced, stored, and retrieved, as can be seen in the data acquired on a 24 inch diameter, insulated pipe that was in service (Figure 5). The data is uniquely quantifiable.

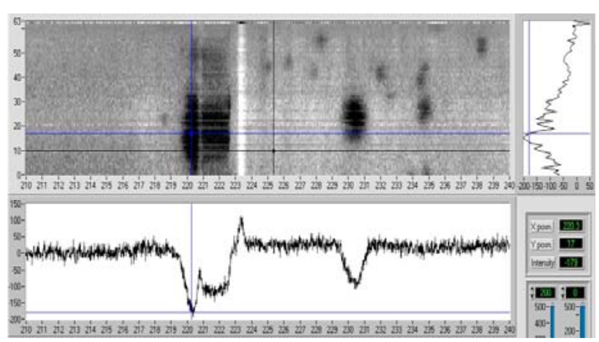

Figure 6: DR of Corroded Pipeline

Eddy Current Inspection

Eddy current inspection is used quite extensively in the aerospace industry. Eddy current inspection devices aid in the detection of surface (or near surface) anomalies. Eddy current technology is also an excellent, inexpensive tool used for material sorting and measuring coating or material thickness. Specialty tubing manufacturers rely on automated eddy current inspection devices to test their products. Eddy current thickness mapping can be performed to detect corrosion in aluminum aircraft skins.

Electromagnetic Acoustic Transducer (EMAT)

Electromagnetic Acoustic Transducers induce ultrasonic waves in metals without the need for a coupling medium. The method is designed for rapid assessment of corrosion in piping even if the piping is coated or at temperatures up to 500°F. A volumetric interrogation of the full circumference of a pipe run is accomplished with the EMAT devices astride the top of the pipe, as shown in figure 7. Anomalies that have been detected in long runs of piping by this method are erosion, pitting, cracking, etc.

Figure 7: EMAT Assembly on Pipe Run

Thermographic Inspection

Thermographic inspection is commonly referred to as infrared inspection. This inspection method is being successfully used throughout industry. Locating hot spot defects in electrical services has been particularly effective. Other uses include the determination of process liquid or catalyst levels in chemical towers and/or columns. And boiler tube corrosion has been successfully characterized with a scanning thermal line device that was developed by the Langley Research Center.

Thermographic images are acquired in real-time and advanced processing provides information about coating defects and/or thickness variations in the coating and sub-surface corrosion spots.

Lawrence Livermore National Laboratory has developed a dual-band infrared computed tomography system that can search for hidden defects on bridge decks and airplane fuselages. The dual-band infrared images are acquired as maps. The data is then processed, revealing corrosion damage and other surface and sub-surface anomalies. As can be seen in the photo, the entire system can be mounted and operated from a specially equipped vehicle.

Fig. 8: Dual-Band Infrared Mobile Unit

Ground Penetrating Radar

Recent developments in both hardware and software have both contributed to the availability of ground penetrating radar systems that can provide 3-dimensional information about reinforced concrete. In the photo are computer generated images that show the location and level of rebar in a concrete slab.

This system was developed by Geophysical Survey Systems, Inc.

Figure 9: Severely Degraded Bridge Supports

GPR requires access to only one surface, and is faster, safer and is less expensive than radiography. In the photo above the rebar in the bridge supports is seriously degraded. GPR can provide information concerning rebar that is below the surface.

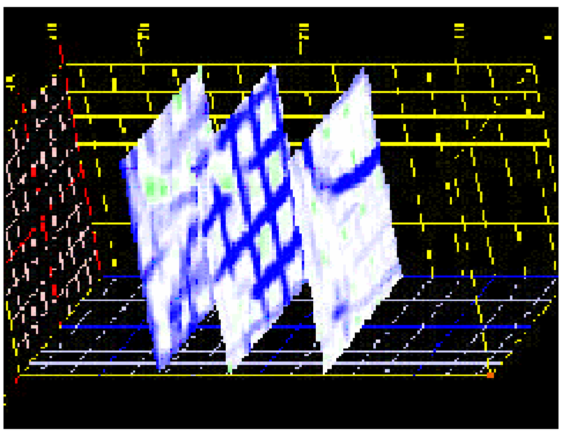

Figure 10: GPR 3D Rebar Image

GPR has been found to be useful in evaluating existing structures for continued use, modification or for repair.

WESTINGHOUSE SAVANNAH RIVER COMPANY'S NONDESTRUCTIVE EXAMINATION CAPABILITIES.

The Department of Energy's Savannah River Site is much like other government agency facilities. The facilities are aging, and corrosion has taken its toll. Fortunately, no one was injured when the tower in figure 11 collapsed.

Figure 11: Fallen Tower

In the photo that follows the inventor of Sound Anchor™ (Bill Hinz) is performing the specialized ultrasonic examination on the anchor rod of a tower.

Figure 12: UT Anchor Rod at SRS

WSRC's Savannah River Technology Center (SRTC) specialists have developed extensive expertise in competencies related to corrosion prevention, detection and mitigation. SRTC has over 150 engineers focused on materials and reliability systems. SRTC has worked with DOE and other government agencies to evaluated and mitigate corrosion and deterioration in a variety of materials and environments. SRTC provides material selection, environmental testing, coating and repair technologies.

NDE Systems engineers and Materials NDE & Consultation specialists have been called on to provide non-intrusive, field-deployable NDE methods that provide the information that operations and facilities personnel need to ensure that personnel and the environment are not endangered.

As seen in the photo below, the walls of a storage drum are severely degraded.

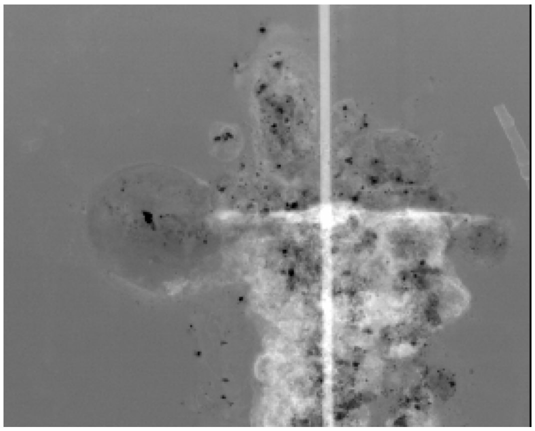

Figure 13: Corroded Hazardous Waste Drum

Corroding drums become more serious when there is a possibility of releasing radioactive debris or hazardous waste to the environment.

Corroding storage tanks that contain highly radioactive waste are also a concern at the Savannah River Site. The Department of Energy has committed itself to turning high level waste into glass billets, but, until that task is accomplished, the storage tanks must be monitored.

High Level Waste Tank Ultrasonic Testing

Highly radioactive waste is safely stored in underground tanks. The tanks are 5 to 45 feet below grade. Access to these tanks for NDE is limited. SRTC performs remote visual and automated ultrasonic inspections of the tank walls through access ports that vary in diameter from 5 inches to 8 inches. The access ports provide entry into a 30 inch wide annular space.

In the figure below is a photo of one of the wall crawlers that has been developed. The crawler automatically positions radiation-hardened ultrasonic transducers, cameras, and light sources.

Automated ultrasonic inspections are performed on a regular basis to monitor the tank walls for cracking, corrosion, pitting and other forms of degradation.

Figure 14: Tank Wall Crawler

The following figure shows UT data of pitting corrosion that was acquired on a cooling water line. Dark blue represents base metal thickness. The differing hues represent variations in the thickness of the pipe wall.

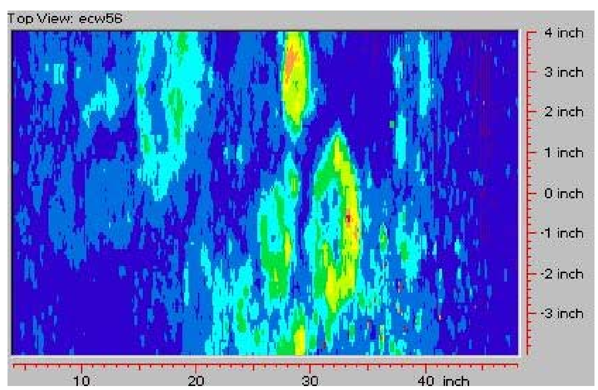

Figure 15: UT Data of Cooling Water Line

Filmless Radiographic Imaging

WSRC's NDE System design engineers and specialists have been recognized internationally as experts in conceiving, designing, integrating, and deploying filmless (digital) radiographic imaging devices. Filmless radiographic imaging devices that they have provided are operating at Hanford, Washington; Kansas City, Missouri;

Oak Ridge, Tennessee; and Los Cruces, New Mexico.

Filmless imaging systems that have been deployed at the Savannah River Site have been used to interrogate hazardous waste drums, highly radioactive storage devices, closure welds on pressurized reservoirs, B-25 low level waste boxes, 3013 assembly inner container lid configuration and the closure welds on the outer containers, and the circumferential welds on 4000 drums.

The image of the corroded hazardous waste drum, shown in figure 13, was acquired with a field deployable filmless imaging setup similar to the one shown in figure 16.

Figure 16: Drum DR Imaging Setup

Most of the filmless imaging systems, developed by the SRS team, have been cabinet enclosures such as is shown in figure 18. These systems have been used to acquire radiographic images on everything from NASA shuttle hardware, to a failed-Plutonium filled storage container.

A 420 kVp DR cabinet enclosure above and one that is similar to it are being used to ensure the integrity of 3013 assembly closure welds. Porosity as small as 12 mils in diameter and incomplete fusion were imaged in some of the pre-production closure welds.

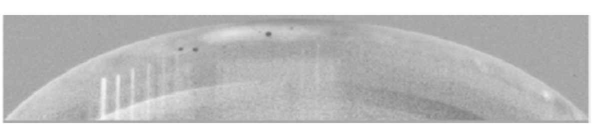

Figure 17: Closure Weld Porosity

Figure 18: 420 kVp DR Cabinet Enclosure

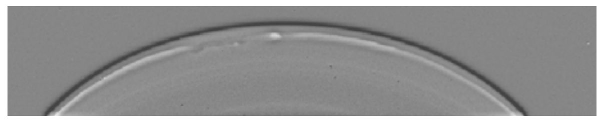

Figure 19: Weld Anomaly in Closure Weld

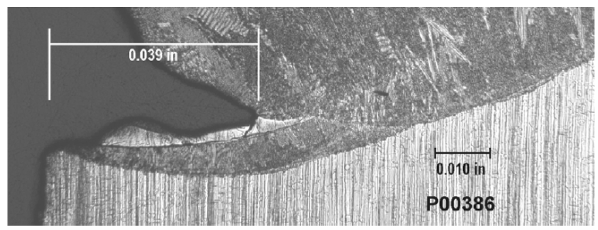

Figure 20: Photomicrograph of the Weld Anomaly

A field-deployable filmless radiographic imaging system that WSRC's DR team will be testing is shown in Figure 21 This imaging device can be transported by land or by air to any emergency site. The device is being evaluated for the Defense Threat Reduction Agency.

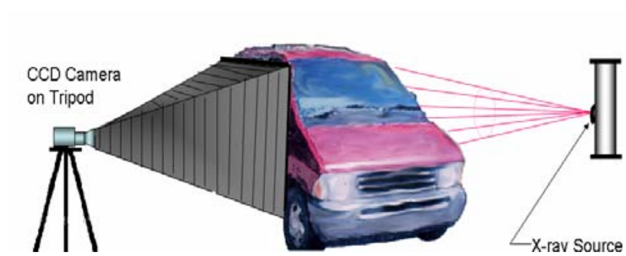

Figure 21: Field Deployable DR Imaging Concept

The scintillating screen will have a 34 by 51 inch field of view. Connecting the scintillating screen to the charge coupled device camera will be a one of a kind, camera bellows. The purpose of the camera bellows is to eliminate light. WSRC's radiation background subtraction experience will be useful in those situations where a radioactive "dirty bomb" has been transported to a potential target.

A device similar to that, illustrated in figure 21, could be used to inspect piping and vessels for corrosion or blockages.

Conclusions

Corrosion is a fact of life, but things could be worse. Corrosion prevention specialists are doing their part to minimize untimely failures resulting from failed components. And never have there been more nondestructive examination tools available to assist plant engineers in detecting corrosion at early stages.

Early detection and prompt remediation can extend component life, protect the environment, and ensure employees a safe working environment.

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