The NDT Technician A Quarterly Publication for the NDT Practitioner

Focus

Alternative NDT Techniques for Prudhoe Bay Pipeline Failures

by John J. Nyholt

In August of 2006, a major petroleum company experienced the second loss of containment incident within the year on the pristine and environmentally sensitive North Slope of Alaska. Both leaks resulted from internal pitting corrosion on or near the bottom half of 0.85 m (34 in.) diameter transit pipelines. These lines transport 400 000 barrels of petroleum per day across 11 miles of Alaskan tundra.

The failure meant an immediate shutdown of approximately three percent of the petroleum supply to the lower 48 states. The potential for environmental disaster and the ensuing shutdown were quickly brought to the attention of environmental groups and jurisdictional authorities and, as quickly, to the attention of national media. Americans watched as the balance of environmental responsibility and energy dependence came to rest on the nondestructive testing (NDT) community. This article describes the investigation and application of fast-screening NDT techniques to ensure pipeline integrity and increase inspection efficiency.

Background

After shutdown, the U.S. Department of Transportation (USDOT) issued a legally binding *Corrective Action Order* (CAO) that mandated exclusive use of automated UT to examine the 4 to 8 o'clock sectors (radially designated) of all pipelines throughout the petroleum transit system. Inspection with UT would require the removal of polyurethane insulation panels and preparation of pipe surfaces throughout the system. A machine applied anti-corrosion tape coating half of the pipeline created further difficulty. The number of insulation workers and ultrasonic technicians needed to accomplish the removal and inspection tasks was initially thought to be beyond what the North Slope could provide for in terms of temporary housing and travel logistics. At its height, NDT work alone would require 108 UT technicians working in alternating 12 h shifts.

The task before the petroleum company inspection team was to investigate alternative NDT corrosion screening techniques that could be submitted to the USDOT for possible modification of the standing CAO. The fast-screening NDT techniques needed would have to detect 50% wall loss inside surface pits at a 3:1 aspect ratio. The consequences of another failure required 100% *probability of detection* (POD) of any discontinuity that met or exceeded the criteria.

Ultrasonic Method

During the inspections, UT was acknowledged as the only NDT method that could measure absolute remaining wall thickness within localized corrosion areas. All other methods were considered screening techniques subject to ultrasonic validation and measurement.

Each pipeline was segmented into 0.3 m (1 ft) inspection intervals, creating approximately 52 000 discrete areas to be screened for corrosion. Areas with less than 25% wall loss were ultrasonically tested to record minimum and average wall thicknesses within the segment. The team of 108 UT technicians inspected an average of 283 segments per day. Automated UT rates were 4.5 to 6.0 m

Focus *continued on page 2.*

Contents

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FROM THE EDITOR

John Nyholt's article, "Alternative Techniques for Prudhoe Bay Pipeline Failures," describes the inspection of two transit pipelines crossing 11 miles of ecologically fragile tundra in Prudhoe Bay, Alaska as "a balance between environmental responsibility and energy dependence." Indeed, the two lines deliver 400 000 barrels of crude petroleum daily but within a tenuous eco-system where extensive and permanent damage can be done should petroleum leaks occur. Interior surfaces of the pipelines had become severely compromised, in some places, as much as 70 to 80% of wall thickness had been lost. As an NDT Corporate Level III Inspection Specialist, Nyholt's job, along with the company Corrosion, Inspection and Chemicals Team, was to find and implement alternate NDT techniques to quickly and accurately detect the USDOT mandated 50% wall loss with 100% probability of detection. As he explains, it was a concerted effort from all members of the NDT community that resulted in positive outcome for both the environment and energy consumers.

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Tech Toon

… And that would be one of our trainees.

Focus *continued from page 1.*

(15 to 20 ft) per crew, per shift — unusually low, requiring additional manual scanning. Unlike automated UT, manual UT provides no ultrasonic image or permanent record of thickness measurement. Unless a successful alternative NDT technique could be found and accepted by the USDOT, the inspection of 52 000 areas was going to take 184 days.

Neither manual nor automated UT in its current configuration could inspect remaining wall thicknesses at welds, supports, or anchor points. Internal corrosion in these areas, however, was not considered preferential and inspection of them was deferred to the intelligent pig (robotic *pipeline inspection gage* inserted into the line) run that would follow external tests.

Axially orientated *electromagnetic acoustic transducer* (EMAT) technology was trial tested for pipe support touch point corrosion and was determined to detect greater than 30% wall loss from 0.5 m (20 in.) away from the support.

Tape stripping was later suspended in lieu of performing automated UT through 4 mm (0.16 in.) thick anti-corrosion tape, 8 mm (0.31 in.) at overlaps (Fig. 1). Ultrasonic performance on tape wrapped pipe was found to be fully equivalent to bare pipe inspection provided the tape was bonded and uniform. Areas where the tape wasn't properly bonded were infrequent and were marked for tape removal and reinspection with automated UT. Absolute ultrasonic thickness measurements could be obtained by applying *time of flight* (TOF) delay correction factors of –10 mm (–0.39 in.) for single tape layers and –23 mm (–0.91 in.) for double tape layers. Ultrasonic echo-to-echo coating compensation mode was not used; pitting responses could interfere with proper UT signal gating. Ultrasonic testing amplitude sensitivity was established by 6 mm (0.25 in.) *flat bottom hole* (FBH) response on a bare calibration block followed by an applicable dB transfer value.

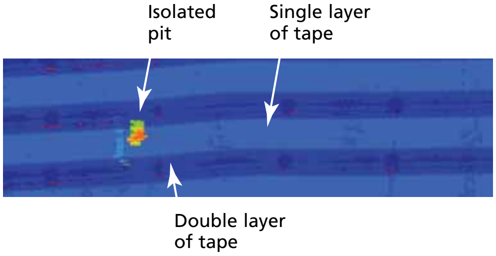


Figure 1. Automated ultrasonic testing image of isolated pit made through single and double layers of anti-corrosion tape .

Alternative NDT Corrosion Screening

Alternative corrosion screening techniques to complement or replace ultrasonic techniques had to maintain discontinuity detection thresholds while increasing NDT production tenfold. All commercial techniques were considered for application but, because of the highly isolated nature of material damage in the petroleum transit lines, the extreme consequences of another failure, and the inspection opportunities afforded by complete removal of the polyurethane insulation panels, only those techniques using a small, localized energy field were chosen. Real time data analysis was also a consideration as was the need to minimize further preparation of pipe surfaces.

At the end of preliminary assessments, four electromagnetic techniques were favored for fast screening of isolated pitting. Electromagnetic techniques do not require direct surface coupling, allow for real time inspection of large areas without labor-intensive surface preparation, and can speed up inspection without sacrificing test sensitivity or data quality. Of the four techniques considered as automated UT alternatives, only two were selected as short-term solutions.

EMAT. Electromagnetic acoustic transducers (EMATs) use a permanent or electromagnetic driver/coil arrangement to create various ultrasonic wave modes within carbon steel. Figure 2 demonstrates compression wave mode. In guided wave UT mode, EMAT typically generates a 5 cm (2 in.) wide sound beam that averages material volume and detects localized wall loss across the span of two permanent or electromagnetic driver/coil sensors. A mechanized scanner moves axially at a scan rate of roughly 75 to 150 mm (3 to 6 in.) per second.

LFET. *Low frequency electromagnetic testing* (LFET) uses an electromagnetic driver/coil arrangement to create magnetic lines of flux through the volume of carbon steel material. Corrosion causes changes to nominal conditions of the field. Signals produced by these changes are received by a pickup coil measuring magnetic flux amplitude and phase (Fig. 3). EMAT technology is well established in industry and recognized in ASTM document E 1816[1] whereas LFET technology is newer. Similar to magnetic flux leakage in its sensor arrangement and usage, it offers electronic phase analysis and intuitive data interpretation.

Technique Trials

Performance of EMAT and LFET equipment was assessed under actual field conditions. A meticulous effort was made to disregard expectations based on preconceptions or manufacturer's data. The 0.75 m (30 in.) decommissioned pipeline selected for trials was subjected to preliminary testing with intelligent pigging to provide known pitting corrosion areas for study. Computed radiography provided images of pitting. Ultrasonic thickness measurements with tape coating thickness compensation provided pit depth and aspect ratio information. A wide range of pit sizes, depths and morphologies were used to establish discontinuity depth detection thresholds and minimum detectectable discontinuity aspect ratios for each method (Figs. 4-7).

Field Trial Summary

EMAT. Performance attributes for EMAT testing were as follows (Fig. 5):

- EMAT demonstrated 100% POD for 25% wall loss isolated pitting at a 3:1 aspect ratio in a 9 mm (0.375 in.) pipe wall [limited to T2 mode at 0.28 m (11 in.) probe spacing].
- EMAT can detect 30% wall loss at a 4:1 aspect ratio in a 9 mm (0.375 in.) pipe wall wrapped with anti-corrosion tape.
- Ten percent of anti-corrosion tape wrapped EMAT indications were false positives. False positives are not detrimental to the POD of EMAT testing but require rework with other NDT techniques.
- EMAT is susceptible to attenuation (as with all guided wave UT) with false calls due to outside or inside surface

Focus *continued on page 4.*

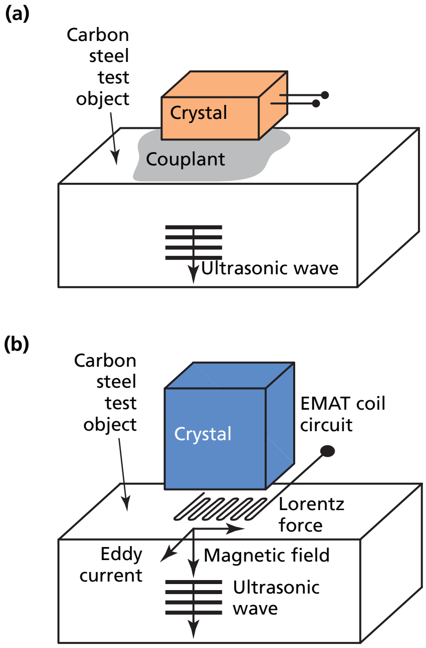


Figure 2. Diagrams contrasting compression waves generated by (a) conventional ultrasonic testing with couplant and (b) waves generated by electromagnetic acoustic transduction.

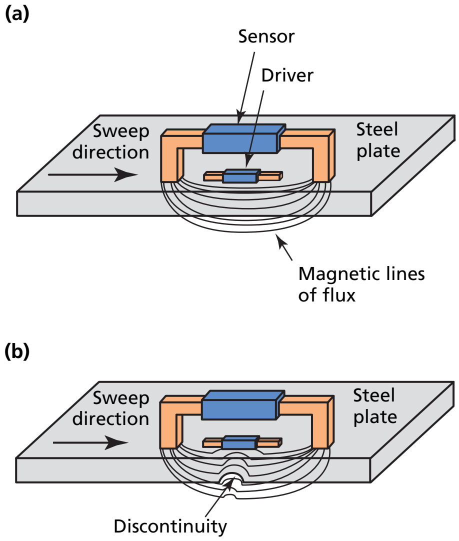


Figure 3. Electromagnetic driver creates (a) magnetic flux lines that reflect the nominal condition of a volume of steel with no discontinuities and (b) flux lines that deviate from the nominal condition to indicate a discontinuity.

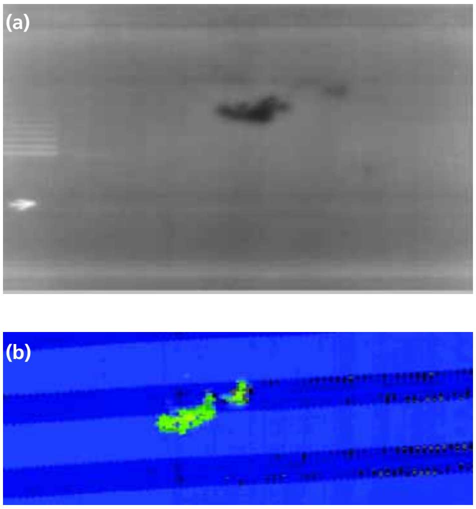


Figure 4. A typical example of corrosion pitting as it appears in (a) a computed radiographic image and (b) the same pitting example as it appears in an automated UT image made through anti-corrosion tape (68% wall loss).

Focus *continued from page 3.*

boundary conditions. Internal sludge may deaden EMAT responses.

- A two-man crew using EMAT can inspect 300 m (1000 ft) per day, 150 m (500 ft) per day on tape wrapped pipe.
- EMAT provides a permanent image of the entire inspection segment.
- EMAT Indications must be followed up with UT thickness measurement.

LFET. The following LFET performance attributes were noted (Fig. 6):

- LFET demonstrated 100% POD for 25% wall loss isolated pitting at a 3:1 aspect ratio.
- LFET performance remains unchanged on pipe wrapped with anti-corrosion tape.
- LFET has a false positive overcall rate of less than 1%.
- LFET can verify false positive EMAT indications.
- LFET performs better than automated UT and EMAT on fluorocarbon resin repair tape.
- Inspection coverage for a two-man crew using handheld LFET instrument is limited to 60 m (200 ft) per day. With automation and improved probe fixtures, scanning production is increased to 3 m (10 ft) per min.
- LFET indications must be followed up with UT thickness measurement.

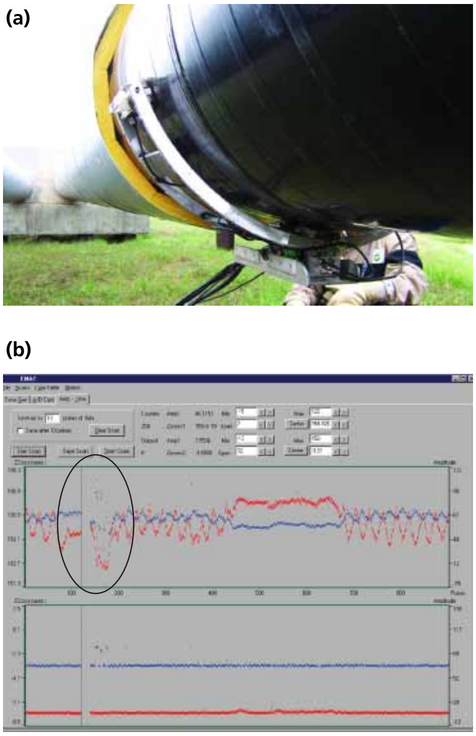


Figure 5. Field trial conducted for EMAT scanner shows (a) scanner installed on test pipe with pitting example described in Fig. 4 and (b) EMAT response to pitting sample (75% wall loss). Red line represents EMAT signal amplitude and blue line is time-of-flight. Saw-tooth pattern indicates tape bonding effects. Flat data segment to right of pitting response represents area where anti-corrosion tape was removed from pipeline for comparison purposes.

Field Implementation

After three weeks of NDT production and development, the performance boundaries of the alternative NDT screening techniques were established, although not yet approved by the USDOT. Until this time, hundreds of insulation strippers, tape scrapers, and ultrasonic technicians had been working simultaneously, around the clock with only one acceptable surface preparation and inspection technique. Even in August, fatigued workers were enduring working conditions that included cold, frequent rain, mud and standing water. Anticipating USDOT acceptance of data along with formal approval of the technology, advance NDT crews began to implement the alternative NDT techniques immediately upon approval by the NDT development team. Trial results were presented to USDOT officials and an independent NDT subject matter expert from the U.S. Department of Energy. Many officials (including the U.S. Secretary of Transportation) were in attendance to personally witness NDT technicians apply the alternative NDT techniques in repeated field performance trials. The alternative techniques were accepted by the USDOT and the CAO was modified after three weeks.

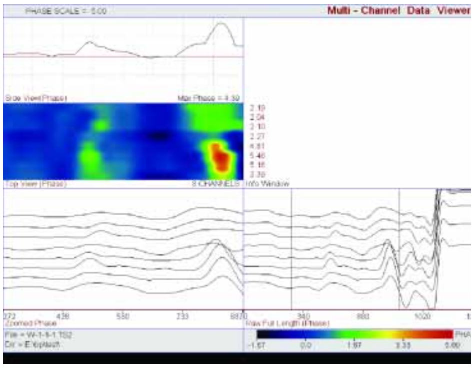


Figure 6. LFET response to pitting sample described in Figs. 4 and 5. Eight line scans below C-scan image indicate individual LFET sensor phase angle responses.

Pipe Crawler Development

Upon USDOT approval, the company NDT lab in Houston, Texas began work on robotic multi-channel sensor arrays for LFET and automated UT. Most of the UT and LFET work done to this point had been done by hand. Automated UT had continued to be inefficient. To obtain the needed tenfold increase in inspection production, further mechanization of these techniques was necessary. Deep water NDE research and development projects already underway at the Houston lab included LFET and automated UT. Mechanical phases of the projects showed potential for application at the North

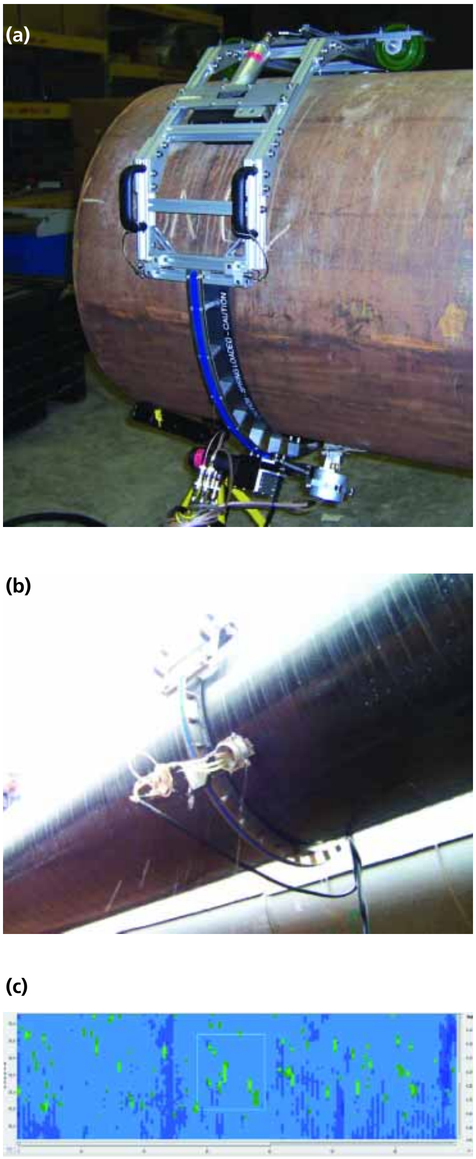


Figure 7. Axial scanning automated UT crawler; (a) closeup of scanner in trial tests, (b) in use on petroleum transit pipeline, and (c) C-scan image of pitting generated by crawler in trial testing.

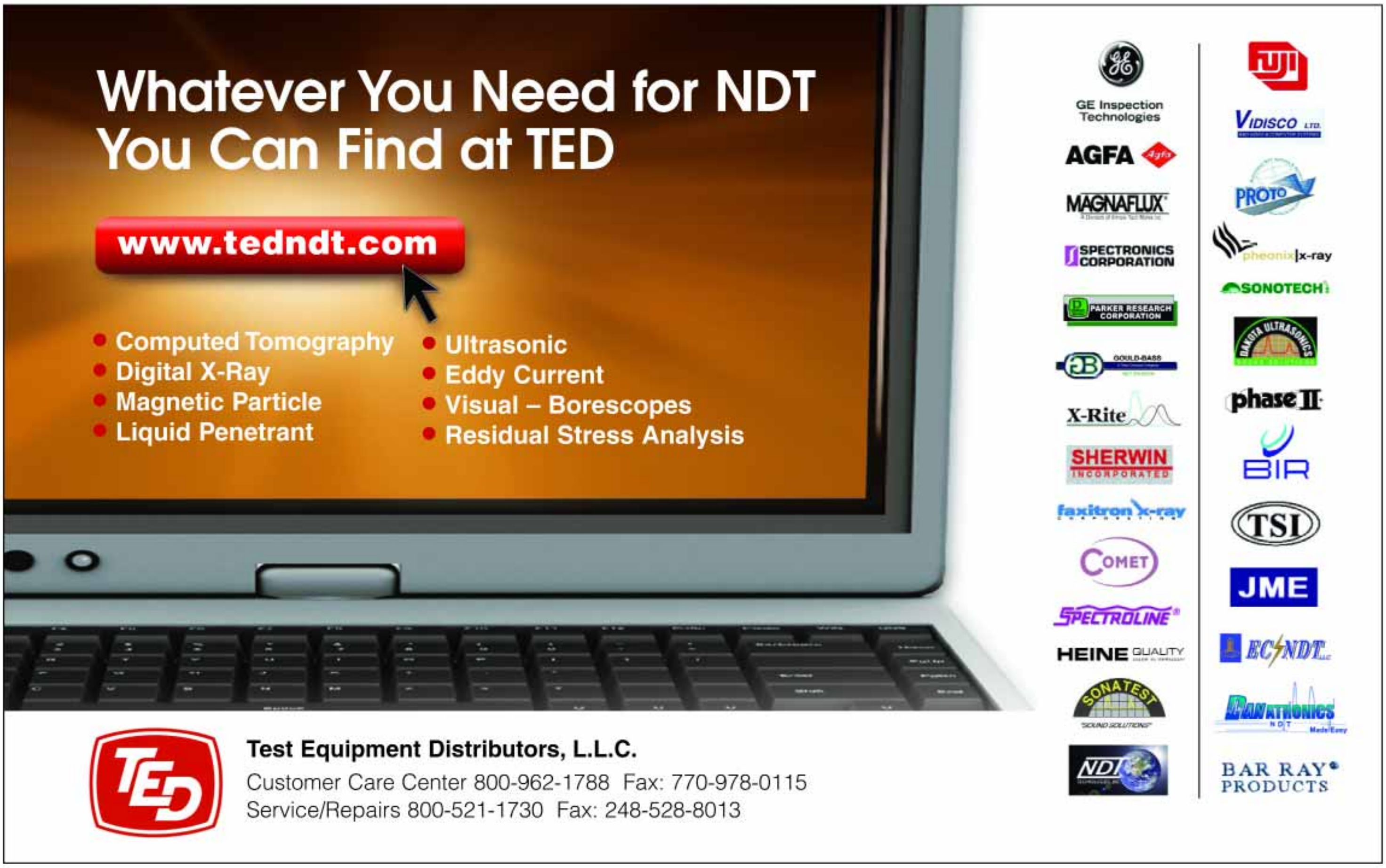
Slope site and were hastened into service in an ambitious three-week pipe-crawler construction program; all other work at two NDT development firms suspended until the machines could be fabricated.

Figure 7 shows an axial scanning automated UT crawler capable of continuous ultrasonic imaging of the 4 to 8 o'clock sectors of 0.85 m (34 in.) pipe. The two-piece clamshell assembly runs autonomously from pipe support to pipe support, a distance of about 18 m (60 ft). At which point, the crawler is removed and redeployed in a 5 min. procedure for the next scan segment. The system runs at a rate of 9.75 m (32 ft) per hour with a single UT transducer and can increase the rate to 30 m (100 ft) per hour by implementing a four-transducer array and data merging software. Figure 7c shows a typical automated UT crawler data sample for a pitted pipe area.

By using an automated UT crawler, NDT technicians could now spend 90% of their time monitoring data collection from the comfort of a truck parked nearby. Areas that had been inaccessible because they were over bodies of water or at extended elevations could now be inspected without scaffolding. The potential for injuries or accidents related

Focus ***continued on page 6.***

Figure 8. LFET axial scanning array; (a) closeup in trial configuration, (b) in use on petroleum transit pipeline, and (c) LFET data from pipe segment in trial configuration in 8a (compare to C-scan image of pitting in same pipe segment in Fig. 7c).



Dear *TNT* Readers,

Do you know what a UT level II needs to learn to get up to speed with phased array UT? Are you proficient in the use of shims and strips in magnetic particle inspection? Do you know how film and digital RT are different and the best application of each? Can you tell us about the envelope method of discontinuity sizing from API 5UE, or how to use acoustic emission in weld testing?

These are topics *TNT* would like you to write about. Consider becoming a *TNT* contributor. We're an official journal of ASNT and as such, can offer you recert points for your contribution. Three points per published paper.

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Focus ***continued from page 5.***

to fatigue and exposure was now greatly reduced.

LFET is highly sensitive to *sensor liftoff* from the carbon steel surface yet can tolerate up to 6.35 mm (0.250 in.) in nonconductive coatings while maintaining discontinuity sensitivity. Figure 8 shows a mechanized 160-channel LFET axial scanning array capable of continuous and autonomous inspection. Each of the 20 sensor cars is equipped with a separate wheel system and is spring tensioned into a surface conforming array to control liftoff. The LFET scanner can test 18 m (60 ft) of pipe and provide real time data in just 6 min.

The 50% wall loss 3:1 pit aspect ratio discontinuity criteria mandated by the CAO worked in favor of EMAT and LFET screening tools. Each had a tendency to ignore pits below this criterion, thus reducing the time needed for data analysis. For example, both the LFET data shown in Fig. 8c and the automated UT data set in Fig. 7c are from the same section of pipeline. Only a few of these pits in the 3 m (10 ft) automated UT scan were of interest and those showed up in the LFET scan.

Findings

Necessity drives invention. The daunting task of large scale inspection in a remote area brought many NDT personnel together with just two goals. While under significant pressure, implement the NDT techniques that were already known to work; then come up with new NDT techniques that could do the job better and faster. In less than a month, both goals had been accomplished. As the new inspection tools were pressed into service, both transit line inspection rates and data quality steadily improved, as did USDOT confidence in their ability to perform. The western petroleum transit line was approved for production. Three weeks later, the eastern petroleum transit line was returned to service. Despite challenging workloads and difficult living conditions, NDT technicians and NDT engineers had presented a concerted effort. The open discussion and free exchange of ideas had facilitated solutions for the set of problems that appeared with each new day and ultimately to the timely and environmentally responsible restoration of a vital natural resource (Fig. 9).

REFERENCES

1. ASTM E 1816, *Standard Practice for Ultrasonic Examinations using Electromagnetic Acoustic Transducers (EMAT) Techniques*. West Conshohocken, PA: ASTM International (2002).

John J. Nyholt is an NDE Corporate Level III, Inspection Specialist for BP North America. In conjunction with the BP Corrosion, Inspection, and Chemicals Team, he was the BP NDE Subject Matter Expert tasked with investigating alternative NDT corrosion screening techniques at Prudhoe Bay, AK in 2006. He also teaches NDT at San Jacinto College in Houston, Texas (281) 366-2933, <john.nyholt@bp.com>. **TNT**

Figure 9. Petroleum transit pipelines at Prudhoe Bay cross 11 miles of eco-sensitive Alaskan tundra. The eastern and western transit lines deliver a total of 400 000 barrels of North Slope crude petroleum to the lower 48 states on a daily basis.

Feature

Microbiologically Induced Corrosion

by Roderic K. Stanley

Corrosion stems from many causes and myriad variables affect the rate at which it occurs, especially where *microbiologically induced corrosion* (MIC) is concerned. How quickly and where in pipelines this type of corrosion will occur is particularly hard to predict. Engineers and scientists have conducted studies of corrosion to measure and model it. However, computer modeling isn't always accurate, and the "smart" pigs that implement the modeling are difficult to calibrate and aren't really so smart.

Metabolic Activity

Microbiologically induced corrosion results from the *metabolic* activity of *microorganisms*, bacteria that cause metals, as well as other materials such as plastic and concrete, to deteriorate. Pitting caused by bacterial attack can usually be characterized by rounded pits with etched sides, edges, and bottoms (Fig. 1). MIC pits also often have a terraced effect (Fig. 2).

Severity Sometimes Unexpected

Severe MIC is sometimes found in pipelines and process piping systems where the amount of corrosion should have been only minimal. It is noticed especially at the bottom of the line where water accumulates or at oil/water interfaces (Fig. 3). Microbiologically induced corrosion becomes problematic when steels are in constant contact with nearly neutral water that has a pH between 4 and 9 and a temperature between 50° and 122°F (10° and 50°C) and is more pronounced if the water is stagnant or slow-moving. MIC is usually in the form of pitting corrosion under these conditions.

Colony Structure

Corrosion causing microbes form colonies. The outside surface of the colony is populated with *aerobic* microbes that produce *polymers* (slime) to attract inorganic material. This makes the colony look like a pile of mud and debris. The aerobic organisms on the exterior surface of the colony can use up all available oxygen, giving the *anaerobic* (absence of oxygen) microbes (*sulfate reducing bacteria* or SRBs) inside the colony a hospitable environment, and this permits enhanced corrosion under the colony. SRB colonies can also form deposits that are conducive to under-deposit corrosion (crevice corrosion).

Biological action increases the severity of corrosion in steel and stainless alloys as a result of (a) disruption of the films that form on metals, (b) biological deposits on metal surfaces, and (c) production of corrosive materials such as H_2S from SRBs. While aerobic corrosion of iron is a chemical process, anaerobic corrosion of iron is linked to SRB activity. This type of microorganism can exist in diverse environments. Unfortunately, the biomolecular mechanisms for iron corrosion and metal reduction and their connections to central metabolism and basal cellular processes occurring with SRBs are poorly understood. Though the genome of a common SRB, Desulfovibrio vulgaris, is providing insight to the bug's metabolism for corrosion and inorganic contaminant immobilization.

Additional Information. For more information on microbiologically induced corrosion, check the following links:

- <www.corrosionsource.com> Click the Handbook tab.
- <http://www.asminternational.org> Pdf download "Biological Corrosion Failures."
- <http://octane.nmt.edu/WaterQuality/corrosion/microbes.htm>.

Rod Stanley is owner and CEO of NDE Information Consultants in Houston, Texas. He is an international expert in tubular inspection and chairs the API Resource Group on Coiled Tubing. (713) 728-3548; <rkstanley@ndeic.com>. **TNT**

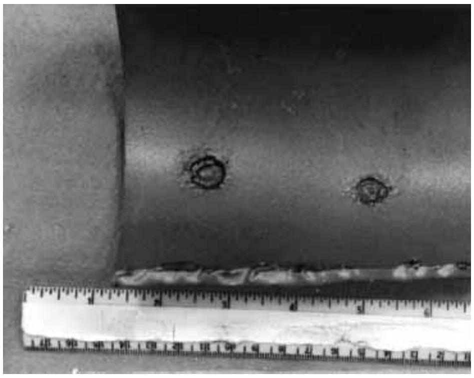


Figure 1. Bacterial attack is usually characterized by rounded pits with etched sides, edges, and bottoms.

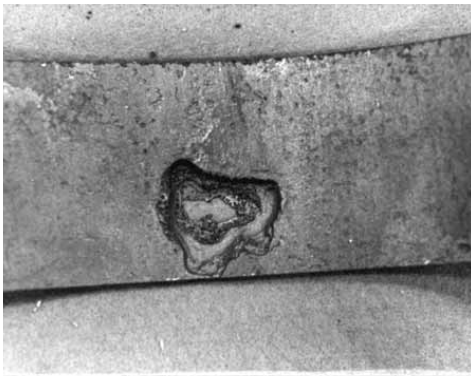


Figure 2. Microbiologically induced corrosion pits often have a terraced effect.

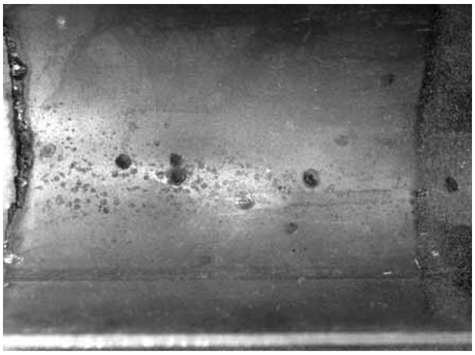


Figure 3. Although microbiologically induced corrosion normally occurs at the bottom of the line where water accumulates, it has also been detected at the 3 and 9 o'clock positions, presumably at the oil and water interface.

PRACTITIONER PROFILE

Joshua Jones

Not everyone enjoys committee work but Joshua Jones has a mission. He is a member of the ASNT GPR ad hoc Committee that is working to make ground penetrating radar a unique NDT method. As part of that charge the committee is developing a body of knowledge.

What was your first exposure to NDT?

I've done construction work in the past and had seen inspectors here and there on jobsites. Just by osmosis, I was aware of what they did and why. The equipment was interesting and the work didn't seem that difficult. So I decided to pursue it.

How did you obtain training?

I started as an NDT assistant and my training was pretty much on the job at first. Then, once I completed the training in the College of Oceaneering, I was certified in magnetic particle, liquid penetrant and ultrasonic testing. I've also taken RT training. The rest has been through my employers. I currently hold Level II certification in RT, MT and PT and a Level I in UT.

Why did you choose underwater NDT?

Well, I was going to become a commercial diver just because I loved to dive — and I still do. I picked NDT as my specialty because I was already working in the field as an NDT assistant at the time. I could have picked welder or diver medic. After graduating, I went to work for various companies as an underwater NDT specialist but soon realized that spending long hours under the water weighted down with dive weights and wearing heavy equipment wasn't going to be for me. I decided to apply the NDT skills I had acquired to regular NDT.

What type of NDT work did you do after leaving commercial diving?

I went to work as an NDT technician and worked in turn for several companies doing pretty much the kinds of NDT that I do now. I did a lot of X-ray on concrete and weld X-ray. One of the companies also did GPR or ground penetrating radar and that's where I began to learn that technology. But for the most part, we did qualifications of tanks and welds on tanks. I've done a lot of MT, PT on boiler tubes in power plants. I've also done a lot of lab work and moved from that to running a penetrant line for a company that did finishing work for aerospace.

What type of NDT do you do now?

I specialize in ground penetrating radar. I've worked with almost all of the GPR machines in use in the industry; primarily on concrete but I've also used it to map out utility lines in soil. The technology is easy to understand and apply — like using a giant fish finder. The equipment sends microwave pulses into the concrete and some of that energy bounces, or is reflected, from any inclusions and back to the equipment where it produces a signal shaped like a hyperbola — a big "pip." It tells you that the steel or conduit is running at right angles to your scan direction. The goal is to map out all inclusions; steel, plastic conduit — everything the contractor wants to avoid. We've done GPR on bridges to locate post tensioning strapped to the bottom of the bridges and beams and on large commercial structures before a remodel — even on residential structures to confirm sufficient footing and post tensioning. We also use X-ray to inspect concrete. I do RT on welds, some MT and PT and, once in a while, I do ET.

Is your work principally in the field or in a lab?

If needed, I sometimes help out in the lab. The company where I work now is a field-testing facility, but does some in-lab — parts inspection, aerospace. We also do welder qual (qualification) for outside companies; testing welders to make sure they can do their job correctly and that their welds are acceptable.

What are your current responsibilities?

I'm still NDT all the way, but I'm considered the facilities manager now. I make sure all our crews have the NDT equipment they need and I'm also in charge of vehicle maintenance.

Has your ASNT membership been a benefit to your career?

Absolutely, it's a great way to get to know a really interesting group of people. Learning NDT on your own is hard. The opportunity to share ideas or question more experienced members really helps you out.

How involved are you in ASNT?

I attend just about every local Section meeting.

At the national level, you're currently a member of the GPR Ad Hoc Committee, correct?

Yes, and the GPR body of knowledge sub-committee.

What is the purpose of those committees?

We're developing a body of knowledge in the hopes that GPR will become a recognized testing method in its own right. In that event, it will be required for GPR technicians to become certified. Essentially, at this time, an individual can buy the equipment from the manufacturer, take manufacturer training and then go out and perform GPR testing. There's no standardized program or certification in place to document levels of skill or training.

What publications are being considered for the body of knowledge?

Right now, GPR publications don't really exist. So, we're starting from scratch and using established methods as models. Our first step has been to decipher information provided by all the different manufacturers of GPR equipment so that we can build new documentation applicable to NDT. The information provided has been pretty broad because the technology and equipment are capable of doing so much. Much of it is focused for geophysical applications like soil sampling or water flow under asphalt. We are trying to consolidate everything we've learned and focus it at first for concrete.

You enjoy committee involvement.

I do. And I want to take it as far as I can. I'll take on just about anything they will throw at me.

If someone considering an NDT career asked for advice, what would you tell him or her?

It's fun and a constant learning experience. It's not difficult — not really hard work and there's a lot to keep a person interested. A lot of people don't know that NDT exists. The problem is just getting people to get their foot in the door.

What are the growth areas of NDT — methods, industries?

Well, the NDT industry needs technicians in all methods. But, if you've got a person that's technically oriented, UT is the way to go. UT technicians are always needed. RT technicians are too. RT is sometimes dirty and can be dangerous if procedures aren't followed carefully but RT technicians are always needed. **TNT**

INBOX

Q: What is a "Body of Knowledge" and how does it relate to NDT?

A: The term "Body of Knowledge" (BoK) describes the knowledge for a given area of expertise, and is also used to describe the repository that documents that knowledge. In the case of NDT, the most commonly recognized documents are those that list the knowledge requirements required to achieve a certain level of qualification. The BoK used by ASNT is the standard *ANSI/ASNT CP-105: Topical Outlines for Qualification of Nondestructive Testing Personnel.*

Q: Please clarify the difference between "standard practice," "standard guide" and "standard test method" in ASTM specifications. S.P. Tamil Nadu, India

A: Definitions of terms are usually given in the foreword of the various volumes of the *Annual Book of ASTM Standards.* The following definitions with discussion can be also found in the ASTM publication *Form and Style for ASTM Standards.**

guide: Compendium of information or series of options that does not recommend a specific course of action. Increases awareness of information and approaches in a given subject area.

practice: Definitive set of instructions for performing one or more specific operations or functions that does not produce a test result. Examples of practices include, but are not limited to application, assessment, cleaning, collection, decontamination, inspection, installation, preparation, sampling, screening and training.

test method: Definitive procedure that produces a test result. Examples of test methods include, but are not limited to identification, measurement, and evaluation of one or more qualities, characteristics or properties. A precision and bias statement shall be reported at the end of a test method (see *Form and Style for ASTM Standards*, Section A21).

Q: I have read the "Focus" article in the January issue of TNT and would like clarification on the stop bath emulsifier content. A makeup of 0.25% emulsifier content for the test comparison is mentioned. What emulsifier should be used? Should it be a fresh emulsifier or should it be from the emulsifier bath in use? When will the results of the CNDE fluorescent penetrant inspection research become part of the AMS 2647** standard? Z.H., Selangor, Malaysia

A: The comparison sample should be made up from a fresh emulsifier. The concentration is based on experience at a major airline, one of the CNDE company participants in the generation of the best practice document. The next version of *AMS 2647* is expected to be submitted for ballot in the summer of 2007. L.J.H. Brasche, ISU, Ames, Iowa

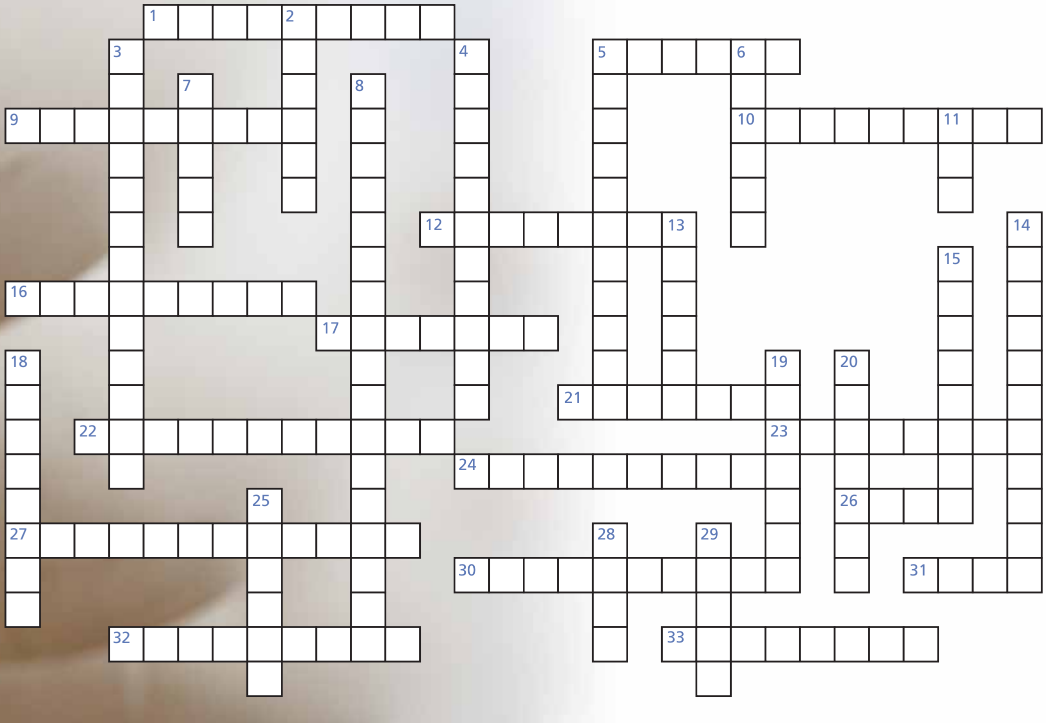
* Download a pdf of ASTM's *Form and Style for ASTM Standards* at <http://www.astm.org/COMMIT/Blue_Book.pdf>.

** SAE AMS 2647, *Fluorescent Penetrant Inspection Aircraft and Engine Component Maintenance.* Warrendale, PA: SAE International (October, 1999).

E-mail, fax or phone questions for the Inbox to the Editor: <hhumphries@asnt.org>, phone (800) 222-2768 X206, fax (614) 274-6899 X206, fax (614) 274-6899. **TNT**

Crossword Challenge:

Materials and Processes – Part I



Across

1. Attacks on metals by direct chemical action result in this.
5. Test that uses a pendulum to break a notched specimen to measure energy absorption.
9. Decreases hardness, increases ductility and relieves stress.
10. Cast steel has more of these properties than wrought steel.
12. The direct ________ test provides a measure of a materials's ability to resist surface penetration.
16. Normalizing has the effect of increasing this property.
17. Body-centered cubic is this type of structure.
21. Test to determine ultimate strength of a material.
22. Two approximate equilibrium heat-treatment processes are annealing and ___________.
23. Permanent deformation and ________ are two types of material failure.
24. If an inspection produced a 90% probability of detection (POD) with a 95% __________ level, there is a 5% probability that the POD is overstated.
26. NDT can determine the number and _____ of discontinuities that exist in a material.
27 Eddy current can measure changes in electrical _____________ caused by the effects of heat treatment.
30. Material __________, as used in design are generally determined by material testing.
31. Undesirable by-product of steel-making process.
32. Reduces brittleness.
33. Type of furnace that typically produces highest quality steel.

Down

2. Added to molten metal, this speeds up steel-making process.
3. Kind of hardening that is also referred to as age hardening.
4. Under ordinary usage, metals exist as this type of solid.
5. Cast iron is usually considered when the application only requires high ___________ strength.
6. Steel having 40 ______ of carbon contains 0.4% carbon.
7. The reduction of iron ore by mixing with coke, limestone and oxygen is done in this furnace.
8. Process of returning ductility to cold worked low carbon steel.
11. High carbon, low ductility iron produced in a blast furnace and used to make subsequent types of iron and steel.
13. Using NDT to find surface discontinuities that might result in ______ risers could prevent fatigue failure.
14. ___________ materials (solid and plastic) would have reasonable strength at room temperature.
15. A good ________ control procedure ensures that unexpected discontinuities of a critical size are not present when a component enters service.
18. Properties most important when corrosion resistance is essential.
19. If established criteria are exceeded, discontinuities can propagate and become _______.
20. Work hardening is an increase in strength caused by plastic flow beyond this limit.
25. Stainless steels are corrosion-resistant and contain high percentages of chromium and this element.
28. Iron can exist in several crystalline structures and its properties can be controlled by ____ treatment.
29. Young's modulus of elasticity measures a material's relative stiffness or _____ strength.

Answers

Across
1. corrosion
5. charpy
9. annealing
10. isotropic
12. hardness
16. ductility
17. lattice
21. tensile
22. normalizing
23. fracture
24. confidence
26. type
27. conductivity
30. properties
31. slag
32. tempering
33. electric

Down
2. oxygen
3. precipitation
4. crystalline
5. compressive
6. points
7. blast
8. recrystallization
11. pig
13. stress
14. engineering
15. fracture
18. chemical
19. defects
20. elastic
25. nickel
28. heat
29. yield

Clues for "Crossword Challenge: Materials and Processes" adapted from the *ASNT Level III Study Guide – Basic.* Section III, Chapters 1-5.

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