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FEATURING:

CORROSION TESTING WITH REAL-TIME 2-D ULTRASOUND CAMERA IMAGING

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Corrosion Testing with Real-Time 2-D Ultrasound Camera Imaging

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Editor's Note: This is another example of technological cross-sharing. This technology migrated from the aerospace industry. Use of this particular technology is already transferring to the process industries as the following trial cases illustrate.

Technicians inspecting oil & gas installations and petrochemical plants employ a wide variety of nondestructive testing (NDT) techniques. A new technology has recently been developed that utilizes a real-time portable imaging device, known as the Acoustocam™, which has distinct advantages in finding internal corrosion. The system, shown in **Figure 1**, allows minimally-trained technicians to scan areas of suspected internal corrosion from the exterior and produce C-scan images along with thickness readings. For this article, NDT inspectors in field trials tested this technology on steel pipes and storage tank bottoms to demonstrate its effectiveness in locating and quantifying subsurface corrosion.



Figure 1. Acoustocam™ with encoder and dual-element transducer on an 8" pipe.



Figure 2. NDT technician performing field inspection.

THE CORROSION PROBLEM

Ensuring the integrity of pipelines and storage tanks is crucial. Unscheduled plant and pipeline shutdowns caused by corrosion costs U.S. oil & gas and petrochemical companies enormous sums of money annually in product losses, production downtime, and environmental cleanup efforts and fines. Accordingly, the industry invests heavily in inspection personnel and equipment to detect and monitor corrosion. In spite of these efforts, the National Society of Corrosion Engineers estimates that these costs can be reduced by up to 25 percent by implementing best practices and taking advantage of new technologies.

TRADITIONAL SOLUTIONS

When inspecting pipes and tanks, NDT technicians often use ultrasonic testing (UT) devices to detect and measure internal corrosion, pits and laminar indications such as blistering and delaminations. Traditional UT on steel structures can be tedious and prone to human error. Moreover, traditional point UT thickness readings merely quantify thinning at the point of the reading and are not comprehensive enough to find all areas affected by corrosion; yet more advanced techniques such as traditional Automated UT (AUT) are expensive and require extensive training.

AUT also has time-consuming, multi-step setup and analysis processes, often requiring both a skilled examiner and a highly-trained and experienced inspector when attempting to detect corrosion and other subsurface defects over large areas. Considering the shortage of qualified NDT inspectors and the length of down time required, the end result can often be high inspection costs.

A NEW TECHNOLOGY

After years of ultrasonics and digital imaging research, Imperium, Inc. has developed and patented a technology called Digital Acoustic Video (DAV™), which allows the capture of high-resolution ultrasound C-scan images. In essence, it is a camcorder for ultrasonic testing. This innovative technology has been packaged as the Acoustocam™, a device with a camera probe that makes intimate contact with the metal being tested and a touch screen controller that shows real-time C- and A-scans. This technology first caught on in the aerospace industry, identifying and sizing in-service carbon fiber composite delaminations and disbonds on Boeing's 787 Dreamliner airplane. Over the years, the technology has been improved for steel and now provides a useful and cost-effective option for detecting, sizing, and monitoring corrosion on equipment in the oil & gas and petrochemical industries.

While highly sensitive (capable of detecting pits as small as 0.6mm in diameter, 0.024”), the system is simple enough to use that any examiner with minimal training can generate a real-time C-scan image of a pipe or tank back wall, and rapidly locate any internal corrosion within seconds. The entire process of generating a reliable and easy-to-understand 2-D map is very quick; it takes just three minutes to set up, calibrate, and scan a 1’ square area. Large areas can be 100% inspected in the same time that individual measurements obtained every six inches would take. An examiner searching for hidden or undiscovered corrosion can inspect steel through coatings such as fusion bonded epoxy or polyethylene. While coatings will be removed should corrosion be found, significant costs can be avoided by proving that there is no corrosion or need for further inspection.

To facilitate decision making, the system includes a Wi-Fi feature for remote, real-time inspection data communication. In addition, it features user-tailored reports to enable effective maintenance.

C- AND A-SCANS

The system can generate C-scan images in real time. As shown in **Figure 3**, a transducer emits sound waves which are reflected by an acoustic beam splitter onto the metal target. The sound waves are reflected back through the acoustic beam splitter, a water-filled tube, and an acoustic lens that focuses them on a microelectronic ultrasound-sensitive detector array that produces a digital acoustic image. The detector array, shown in **Figure 4**, is highly sensitive – it is made up of 120 by 120 pixel elements (i.e. 14,400 pixels) - and is able to generate and record C-scan images at specific depths within a target object at the rate of 30 frames per second, similar to a conventional camcorder.

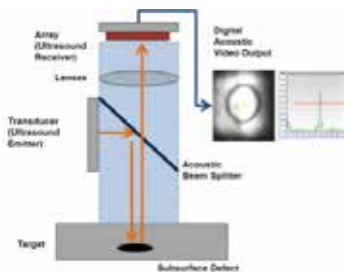


Figure 3. Optical imaging techniques were applied to ultrasound.

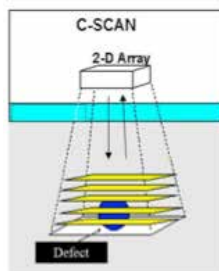


Figure 4. The patented microelectronic detector array images slices of a target object.

The image produced represents a 1” field of view of the material’s subsurface. C-scans of the steel show dark regions to identify areas of corrosion and rounded pitting on the subsurface structure. This is because sound waves that hit rounded areas (typical of deep wear or pits) or jagged pieces (typical of corroded metal fragments) get scattered and very little energy returns to the camera lens, thus producing a dark image. Alternatively, when sound waves strike flat back surfaces (and flat-bottomed pits), signals get reflected straight back to the camera as light, thus producing a white image.

The system also produces standard A-scans simultaneously with its C-scans. By trailing a dual-element 5 MHz external transducer behind its camera head, thicknesses are shown while simultaneously displaying C-scans that show rear surface images. This technology makes it very difficult to miss corrosion, because even if the A-scan indicates no change in thickness, the evidence appears on the C-scan display. The system is highly intuitive, allowing almost anyone to see rear surface corrosion on steel in just a few minutes.

SCANNING PIPES

The system includes a wheel encoder that permits large area scanning. By scanning adjacent parallel strips of pipe (with diameters as small as 3”), an NDT technician can stitch together a 2-dimensional image with embedded A-scan readings immediately. The resultant corrosion map serves as a visible examination report for an inspector to review and validate results. Corrosion maps may be printed or electronically stored on standard computer systems for future analysis and review of corrosion growth rates.

For this article, an inspector used the system to scan an 8” diameter steel pipe with an “H” carved into the rear side to simulate backside corrosion, as shown in **Figure 5**. As shown in **Figures 6 and 7**, the corresponding corrosion maps clearly show the damaged area and the individual thickness readings. **Figure 8** is a snapshot of the display screen showing simultaneous real-time C- and A-scans.



Figure 5: Steel pipe with “H” carved into rear side.

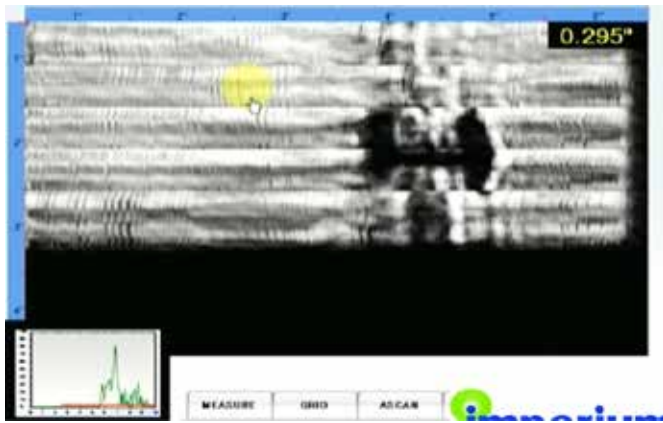


Figure 6. C-scan images of 8" diameter steel pipe with thickness reading of 0.295".

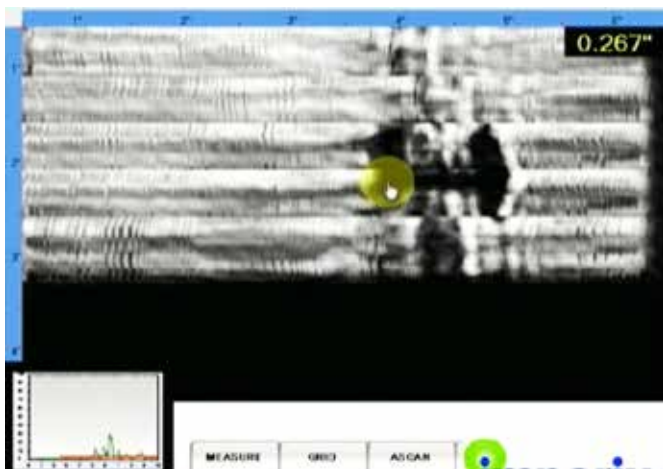


Figure 7. C-scan images of 8" diameter steel pipe with thickness reading of 0.267" at damaged area.

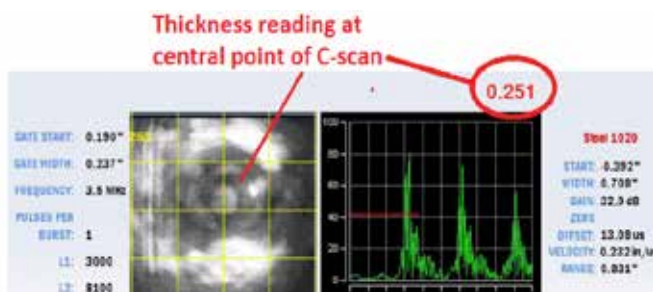


Figure 8. Display screen showing x-y sizing and depth of corrosion.

In a second pipe test, an inspector used the system to scan a section of rough, curved steel pipe. As shown in **Figure 9**, C-scans allow the inspector to locate the damaged back side area with surprising clarity.

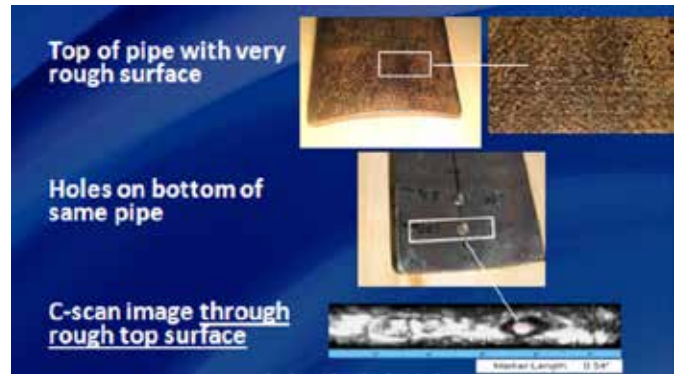


Figure 9. Images from scan of an 8" rough curved pipe section.

In yet another pipe test, the system was used to inspect a 6" diameter heating pipe from a North American coatings and specialty products manufacturing facility. While largely free from corrosion, the back wall of the 3/8" thick pipe had a large area of thinning and pitting from years of condensate buildup. As shown in **Figures 10 and 11**, the device was mounted on a trolley specifically designed for piping applications in order to guarantee perpendicular imaging. As shown in **Figure 12**, the inspector was able to generate a 2-D C-scan image that showed the thinning and pitted area.



Figures 10 and 11. Inspection of a 6" steel pipe.



Figure 12. Inspector identifies thin area of 6" steel pipe using the 2-D C-scan as a guide.

SCANNING STORAGE TANK BOTTOMS: A NEW PROVE-UP TOOL

Storage tank bottoms have their own specific issues as leaks are not always readily visible to the naked eye. The tanks could experience serious losses before the owner even suspects a problem. Inspectors need to be able to see underneath the tank floor to look for corrosion that can lead to leaks. Corrosion problems can start small but quickly grow

into bigger problems. Typically, magnetic flux test leaking (MFL) is performed first on a storage tank bottom, and then is followed by an ultrasound flaw detector. The study that follows shows that the system can serve as a quicker, more quantitative method of performing UT prove-up than a flaw detector.



Figure 13. A technician in the field inspecting petrochemical storage tanks.

One storage tank section is shown in **Figure 14** below. An inspector was able to set up the device, calibrate it, locate the area of corrosion, and create a 2-D C-scan – all in less than 5 minutes.



Figure 14. The system being used on a storage tank bottom cutout.

As shown in **Figures 15 and 16**, the C-scan showed a typical thickness of about 1/4" and a thickness of 0.172" at a corrosion blister.

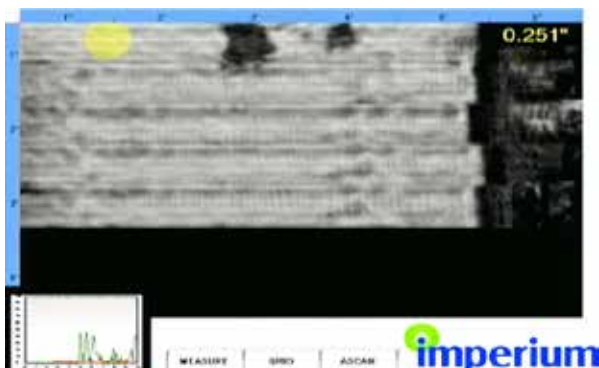


Figure 15. 2-dimensional stitched image of 1/4"-thick storage tank with area of corrosion identified.

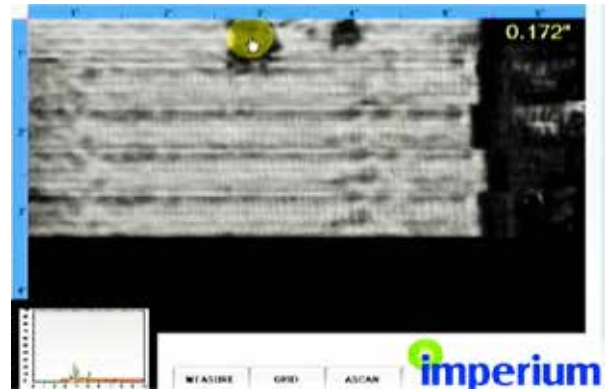


Figure 16. 2-dimensional stitched image of storage tank showing corrosion area with thickness of 0.172\"/>

One system operator commented, "We timed it – and on average it takes six minutes to locate a flaw using a standard D meter and only 22 seconds with this device. The probability of detection is far superior to standard thickness readings. We are now able to quickly and easily identify problem areas that could potentially lead to much bigger issues."

COMPARED TO PHASED ARRAY FOR CORROSION DETECTION

To document the system's effectiveness versus Phased Array, Imperium commissioned an independent third party to conduct an objective comparison. The system and a popular PAUT device were used to inspect three steel pieces: a stepped standard, a corroded panel, and an 8" diameter pipe (see **Figure 17**).

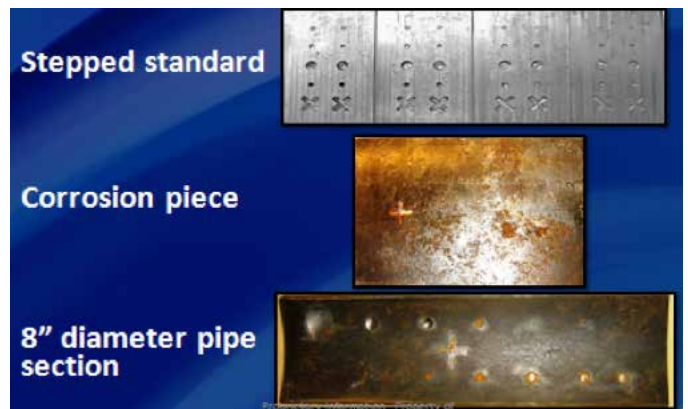


Figure 17. Targets studied in the "face to face" comparison.

As shown in **Figure 18**, the system was superior in inspecting the stepped standard, producing a cleaner image and resolving smaller holes much more distinctly.

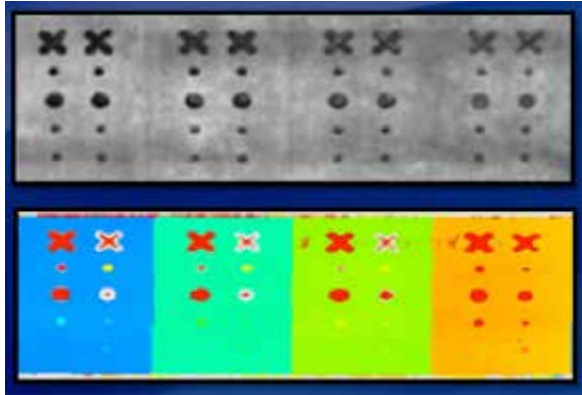


Figure 18. Results from stepped standard inspection.

As shown in **Figure 19**, while inspecting the 1/4"-thick corroded steel panel, the system showed more distinct dark marks indicating damaged areas and produced fewer erroneous signals.

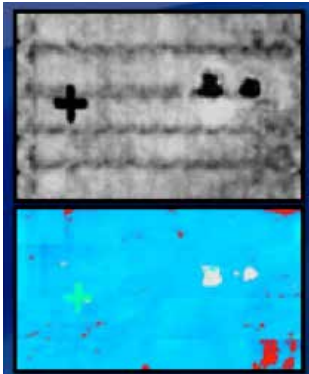


Figure 19. Results from inspection of corroded steel panel.

While inspecting the 8" diameter pipe, as shown in Figure 20, the system identified the rear surface cross mark and holes with helpful contrast, as compared to the confusing array of colors produced by the PAUT device.

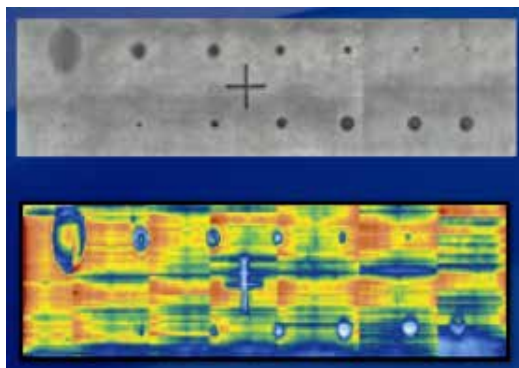


Figure 20. Results from inspection of 8" diameter pipe.

Following these studies, the system was compared to the popular PAUT in aspects related to cost: price point, inspection time, and training and experience required. **Figure 21** displays the results.

Inspection time per square foot (includes setup)	5 minutes	15 minutes
Required Training	16 hours	160 hours
Required Experience	Level I or Level II	Level II NDT
Availability of Technicians	Available	Limited
Required Technicians	1	1-2

Figure 21. Corrosion mapping cost comparison.

CONCLUSION

The Acoustocam™ is a simple, real-time, and effective UT diagnostic tool available to NDT inspectors in the oil & gas and petrochemical industries. As shown in this article, it has the potential to provide better inspection results in less time than alternative technologies, and it requires minimal training to operate properly. By producing actual images of defects, the system arms inspectors with qualitative information together with easily interpreted images and quantitative data.



Bob Lasser co-founded Imperium with his father, Marvin Lasser, Ph.D., in 1996. Bob has published over 40 technical papers related to Imperium's technology and holds two U.S. patents for digital acoustic imaging. Mr. Lasser received his BS in Mathematics from the University of Michigan.



Dan Oehl has a BA in Philosophy from the University of Pittsburgh and an MBA from the Thunderbird School of Global Management. He has no NDT experience at all, but can produce a clear C-scan image using the Acoustocam™.

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