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High Temperature Ultrasonic Scanning

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ABSTRACT

Corrosion is one of the Petrochemical Industry's leading causes of equipment failure, repair, and replacement. Plant Equipment and Piping systems are subject to various attack mechanisms at elevated temperature, which if undetected can reduce their reliability. This can result in unscheduled equipment/plant shutdowns, on-stream ruptures and safety issues.

Detecting corrosion and identifying corrosion rates while equipment is on-stream can assist Engineers and operational personnel in managing Plant shutdowns by forecasting equipment life and scheduling equipment repairs and replacement.

INTRODUCTION

High Temperature Ultrasonic Scanning is a non-destructive testing method to inspect Plant Equipment and Pipe while in-service for corrosion and defects. The benefit of this technology is the ability to detect and monitor corrosion and defects of Plant piping & Equipment operating at elevated temperatures up to 725ºF (385ºC).

The primary applications of High Temperature (HT) Corrosion Mapping are Piping, Vessels and Tanks. High temperature ultrasonic scanning systems can also be used to locate wall thinning, determine corrosion rates and monitor defect growth rates for engineering evaluations. Determining corrosion rates while equipment is **on-stream** can assist Engineers and Operational personnel to schedule T&I's and equipment repairs and replacement, therefore lowering the overall risk to the facility.

BACKGROUND

API History: Saudi Aramco participated in a Joint Industry Project (ID-04/96-J PERF Piping Inspection), through the American Petroleum Institute (API) along with Exxon Mobile, Shell, Phillips/Conoco, Chevron, Sun and others. The Company identified and purchased a prototype high temperature ultrasonic scanner from a manufacturer participating in the JIP.

Field trials of the first system HT UT system were conducted at a Refinery and a Gas Plant. The result of field trials with the ultrasonic scanner revealed that numerous modifications were required to adapt it for high temperature scanning. Following items were identified:

- Low magnetizing strength of the scanner wheels caused slippage
- X & Y motor shafts do not have adequate electrical insulation to prevent a short circuit
- Couplant recovery system is required

The first system was sent to the manufacturer for upgrading/modifications and upon completion the system was re-field tested. Results of additional field trials indicated unresolved issues with the first system including: excessive noise, transducer design, inadequate insulation around the X & Y motor shafts, complex operating process, expensive to maintain and generally lacking in support.

During the trials of 1st scanner for the various oil companies involved in the PERF project, a second generation ultrasonic scanning system was designed and constructed to overcome the problems identified with the first system. Saudi Aramco, as part of a Technology Item, initiated purchase of the second-generation high temperature scanner manufactured by Mechanical Integrity (MI) and after delivery immediately started field trials.

The system from MI was more robust, user-friendly and further developed; therefore the system was chosen to be adapted to carry out field trials, and ultimately the successful completion of the Technology Item. This paper will focus on the new generation scanner as it was found to be acceptable in the field up to 725ºF (385ºC).

SYSTEM DESCRIPTION

High Temperature Ultrasonic Scanning system description:

- Scanner with motorized X & Y axis - Mechanical Integrity (Mfg)
    - Cobalt magnetic wheels
    - Motor cooling with pressurized air through vents
- Ultrasonic signal processor - Eight Channel Pocket Scan – Technology Design (Mfg)
- Couplant delivery and recovery system
- Laptop with control, inspection and analysis software
- 250’ Umbilical
- High temperature transducers 2.25 and 5MHz - Technisonic (Mfg.)

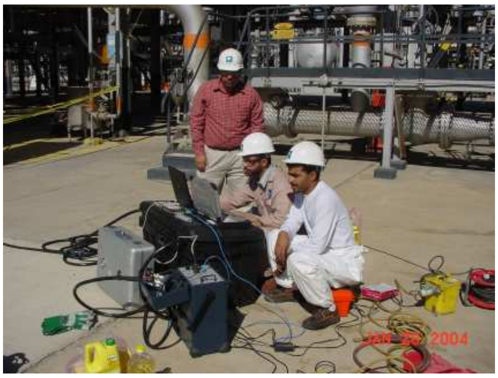

Figure 1: system components and crew

Figure 2: scanner inspecting a vessel

OPERATION

A dual crystal transducer is mounted on a motorized scanner adapted for elevated temperature and is indexed along the X & Y axis to preset distances; encoders provide location information to the computer to control the scanning movement. A 5 MHz, 12.5-mm diameter, ***twin crystal*** compression wave transducer is utilized to introduce longitudinal sound waves into the parent material. One crystal of the transducer transmits sound energy and the second is a receiver, which is optimized for near surface resolution and high sensitivity. The transducer focuses the beam 1” into the material and sound energy is concentrated at the area of interest for maximum defect/corrosion detection. Other transducers are available with frequencies and focal depths to optimize defect detection at different depths in the material.

Cooling the transducer to less than 175ºF (80ºC) is key

- Transducer connections:

- Two openings to deliver oil at 5 psi for coupling sound and for cooling
- Compressed air – one inlet for 5psi air and an outlet hole
- Two Lemo connectors to transmit and receive signals

Figure 3: top of transducers

Figure 5: top of HT transducer

Figure 4: bottom of HT transducer

Figure 6: bottom of transducers

The HT Ultrasonic Corrosion mapping system can operate at ambient temperature to over 725ºF (385ºC) and can inspect contours from flat plate to approximately 8” diameter pipe.

Wire brushing or grit blasting is generally required to expose bare metal and prepare the surface for scanning. In certain situations new and tightly adhering coated surfaces can be inspected at elevated temperatures without removing the coating.

Commercial grade corn oil, canola oil and peanut oil are used as a couplant for conducting sound energy into the examination material. Couplant is sent to the transducer by a delivery system and excess oil is collected by a recovery system consisting of collection trays and a reservoir.

The system is operated with a lap top computer through a 250ft umbilical tethered to the scanner. An eight-channel signal processor analyzes the return signals. Data is collected by the software and can be displayed in A-Scan, B-Scan or C-Scan formats.

Calibration of the system is accomplished by placing the scanner and calibration block on the Plant equipment to be inspected, concurrently heating them to the operating temperature. The scanner and block are removed and the transducer is placed on top of the hot calibration block. The static signal is adjusted to match the known thickness and the gain is typically set to 80% screen height. The system is also calibrated dynamically by placing the scanner on the Plant equipment and setting it into motion, typically 6-8db is added to account for signal losses from heat, transducer movement and surface conditions.

Figure 8: scanner inspection a vessel

Figure 9: operator adjusts the scanner

The software provides ultrasonic responses in three distinct graphical presentations. The A-scan representation of the signal can be seen at the top of the image data plot. The B-Scan shows sliced images of the scanned area; data is analyzed by moving a crosshair type cursor to an area of interest. The C-scan image gives at topographical presentation of the area scanned using different colors that represent preset material thickness as established by the color palette.

The software collects ultrasonic signals, processes the information and assembles each scan to form a planar visual image - a C-scan. Color options are pre-selected from a color palette in the software to optimize the material thickness resolution for improved data interpretation.

Example of a C-Scan

Each pass of the transducer in the Y direction (top to bottom or 300mm in the picture below) is a strip of data that is stacked together by the software. As the Y scans are stacked the image grows in the X direction (left to right). A strip of Y data is missing at 205mm in picture below.

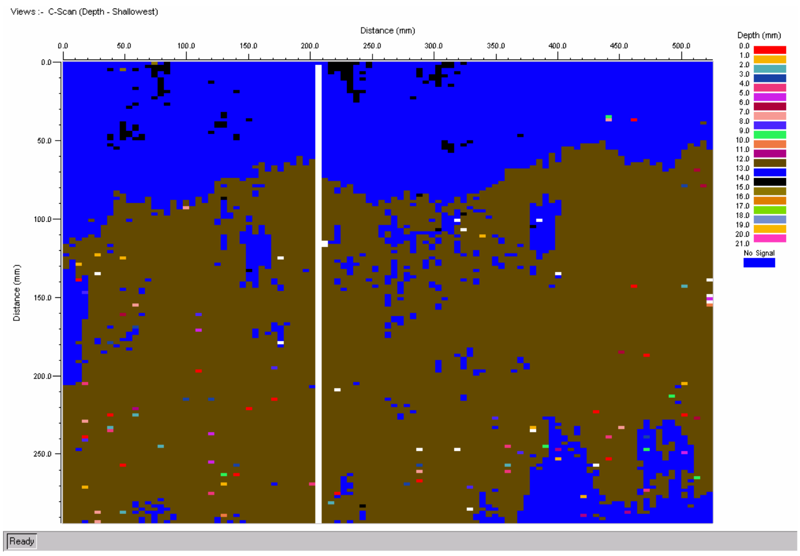

Figure 10: C-Scan showing material thickness 13mm (brown), 14mm (blue) & 15mm (black)

APPLICATIONS

At the start of field trials, excessive noise was experienced at temperatures above 350ºF (176ºC), which resulted in unreliable data. The problem with noise at elevated temperatures was overcome by ordering custom manufactured high temperature transducers and pre-amplifiers. Additional trials revealed that the new transducers solved the problem with excessive noise - corrosion was detected during the field trials on all inspected Plant Equipment operating at elevated temperatures up to 725ºF (385ºC).

Saudi Aramco has successfully performed high temperature ultrasonic corrosion mapping on Reaction Furnace Combustion Chambers, Thermal Oxidizers and Air Pre-Heater Outlet Headers at Refineries and Gas Plants.

A Gas Plant was the site of the first application of this new service. The bottom of a Reaction Furnace Combustion Chamber located in a sulfur train was scanned on-stream while operating up to 350ºF (176ºC) to 439ºF (226ºC). Following are details of the inspection:

- Proponent wanted to know the wall thickness of the vessel and identify any areas of corrosion
- The furnace was similar to another furnace that developed a leak earlier in the year
- Twenty-one scans, each 3M in length were performed

Results have revealed:

- An area of aggressive corrosion measuring 34” x 84” was detected
- Localized minimum wall thickness is 4mm
- Minor general corrosion and pitting corrosion were detected on all scans

Detailed sketches and reports are included in the following pages, which provide thickness information and C-scan corrosion maps of the affected area.

Corroded Area of Furnace

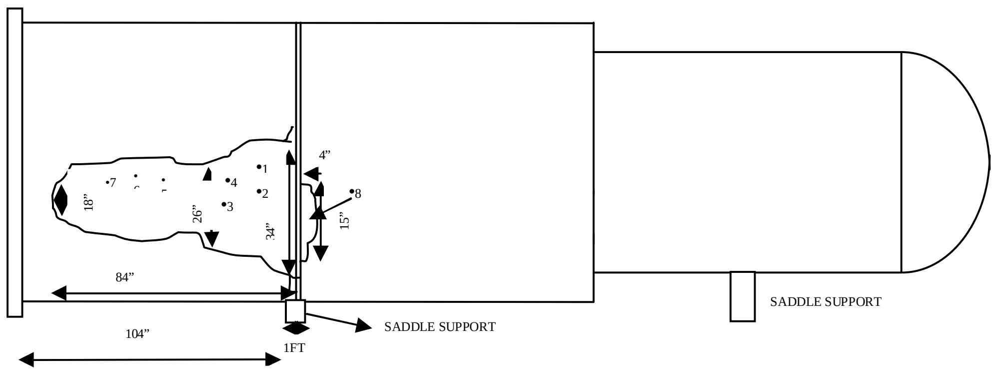

Figure 11: sketch showing area of aggressive corrosion detected with HT UT scanning. A manual UT survey was carried out to confirm the scan

Aggressive corrosion and pitting
Scan temperature 350ºF to 439ºF (176ºC to 226ºC)

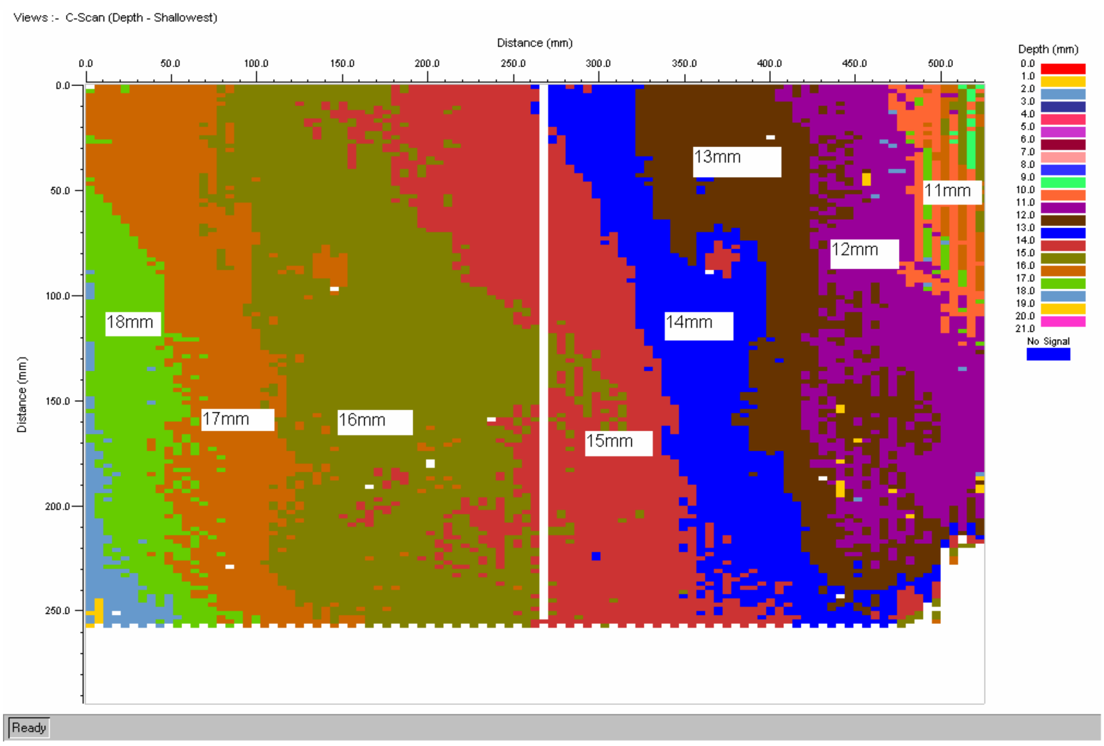

Figure 12: C-scan of Reaction Furnace

The inspection results provide detailed information regarding the condition of the Furnace. The proponent can monitor the equipment with manual UT, establish the corrosion rate in the affected area and schedule a T&I to conduct equipment repairs.

The first application of this new service has saved the Company over $5.3MM by avoiding an unplanned shutdown of the plant based on the following:

Previous failure & unplanned sulfur train shutdown

- Cost to repair equipment = $120M
- Lost service of sulfur recovery = $8,500 / day
- Plant shut down = 45 days
- Lost sales gas $2.5MM / day * 2 days = $5.0MM
- TOTAL = $5.5MM

Cost avoidance

- Cost to repair equipment = $20M
- Lost service of sulfur recovery x 33 days = $280M
- Lost sales gas = $5MM
- TOTAL = $5.3MM

Cost avoidance includes recovery of sales gas, which is normally flared for two days to avoid Plant upsets during an unplanned shutdown.

Fields trials have revealed that regardless of the scanning temperature – when operated within the systems' temperature range – there was little change in the quality of data obtained from the examination. Following are examples of C-scans obtained from various equipment.

Minor corrosion & pitting **General corrosion**

Scan temperature 280-325ºf (137-162ºc)

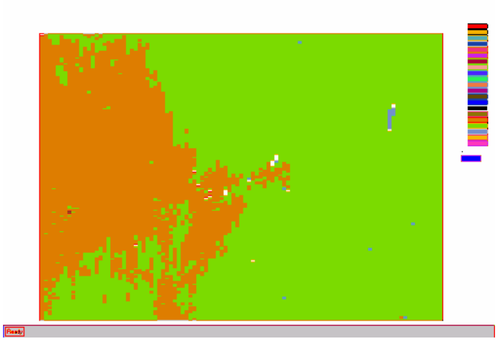

Figure 13: C-scan of a Reaction Furnace

Scan temperature 625-725ºf (330-385ºc)

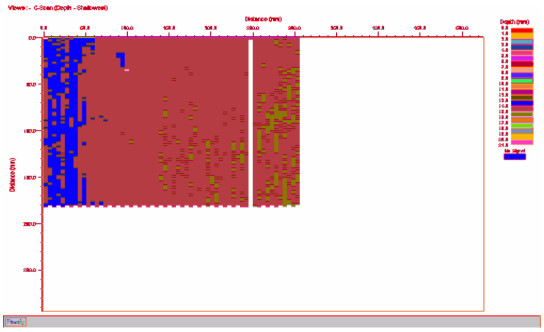

Figure 14: C-scan of an Air Gas Pre-heater

Minor corrosion
Scanning temperature 400ºF (205ºC)

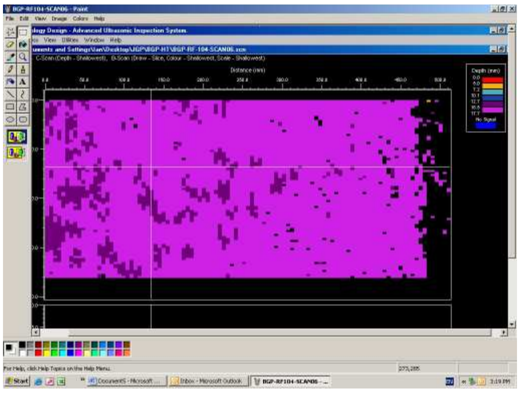

Figure 15: C-Scan showing minor wall loss.

Minor corrosion
Scanning temperature 400ºF (205ºC)

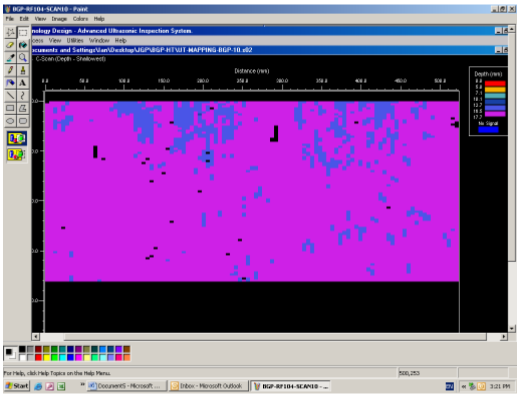

Figure 16: C-Scan showing minor wall loss

Other applications of High Temperature ultrasonic scanning include:

- Engineering evaluations to determine and monitor defect growth rates
- Identify the condition of internal surfaces i.e. pitted, groves or general corrosion.
- Enhance OSI inspection of Plant Equipment and Pipe

CONCLUSION

High temperature ultrasonic corrosion mapping is an effective inspection technique to detect and monitor corrosion at elevated temperatures. Detecting defects and monitoring corrosion while equipment is in-service can assist engineers in managing Plant shutdowns.