State-of-the-art flue gas-desulfurization (FGD) technologies have been, or are being, installed on most large coal-fired electric generating units in response to new regulatory emission requirements. Wet FGDs remove sulfur from the flue gas in coal-fired power plants by spraying or bubbling (depending on design) a slurry of limestone and water into the flue gas to react with the SO₂ by forming gypsum. The wet FGD bulk chemistry environment in today’s forced-oxidation systems is typically at a pH of 4.5-6 with chloride range of 3000 to 15,000 ppm. Figure 1 shows the range of materials used in construction of wet FGD absorber tanks for 363 surveyed systems in North America. While a plethora of materials (metallic, organic, plastics, coating, etc.) are available to construct these vessels, almost 40% of the vessels are constructed from duplex or austenitic stainless steels. Since 2004, about 160 of the 363 units have come online. Duplex 2205 material has been used only in these newer generation units.

**Corrosion observations**

Significant corrosion was found in many metallic absorber tanks in forced-oxidation wet FGD systems. The prominent corrosion mechanism is crevice corrosion in underdeposit and scaled regions of the absorber, areas having grind marks, and weld heat-affected zones. Figure 2 shows the microscopic appearance of damage in a 2205 duplex stainless vessel wall. The corrosion initiates on the surface, but generally much more subsurface damage occurs as the corrosion progresses. The worm-holing characteristic of the sub-
surface damage on the wall can make visual inspection challenging. EPRI has knowledge of corrosion on at least 30 vessels, where the corrosion ranges from minor to major. In the major cases, through-wall vessel leaks were observed in less than one year of service, over 50% of weld seams required repairs, and structural integrity assessments were conducted prior to returning the vessel to service.

Current inspection techniques

EPRI produced a visual-inspection guideline for wet FGD vessels. The typical approach for inspection (time permitting) is to drain and clean the vessel. In many cases, adherent deposits and tenacious scale on the vessel walls require removal using high-pressure water wash, bead blasting, or mechanical methods. A visual inspection is then conducted using indirect lighting and hand tools to probe corrosion pits. Scaffolding and man-lifts are required to examine the entire vessel. In some cases, ultrasonic thickness measurements or radiography (Fig. 3) are used to assess the extent of damage after a location is found visually. Large-scale visual inspection is only practical during a long scheduled outage. Radiography can be used for limited investigations, but is impractical for the entire vessel and cannot be conducted while the unit is online. Conventional ultrasonic and/or ultrasonic phased-array technologies have limited applicability for such large areas.

With these limitations, EPRI conducted a feasibility study to evaluate the use of ultrasonic guided waves for FGD vessel inspection. The potential advantages of the technology are:

- Rapid large area scans so the entire vessel can be inspected
- Scanning from the outside of the vessel, eliminating the need for cleaning

Fig. 3 — Comparison between visual examination of corroded seam weld and radiograph of the same area showing subsurface corrosion damage (arrows). Courtesy of American Electric Power.
• Inspecting during operation, so unit shutdown is not required
• Monitoring corrosion by periodic scanning for changes

Applications for ultrasonic guided waves

Southwest Research Institute (SwRI) developed and patented the magnetostrictive sensor (MsS) technique, an ultrasonic guided-wave nondestructive evaluation (NDE) technique for long-range global screening of large structural components such as cables, rods, pipes, tubes, and plates\(^1\). The technique is called MsS because the probe used to generate and detect guided waves is based on the magnetostrictive effects and its inverse effects present in ferromagnetic materials such as carbon and alloy steel.

The magnetostrictive (or Joule) effect refers to a small change in the physical dimensions of ferromagnetic materials—on the order of several parts per million in carbon steel—caused by an externally applied magnetic field. The inverse-magnetostrictive (or Villari) effect refers to a change in the magnetic induction of ferromagnetic material caused by mechanical stress (or strain). Each MsS probe consists of two elements: a coil and a device (such as a permanent magnet) that applies a static bias magnetic field required for MsS operation.

The MsS system includes the MsS transmitter and receiver and a computerized data-acquisition and analysis unit. A single MsS probe generates guided waves in both directions and detects guided waves propagating in either direction. To facilitate examination and simplify data analysis, the system is equipped to control the direction of both transmitted and received waves. This is achieved using two transmitters and two receivers operated according to the phased-array principle.

Because the MsS relies on magnetostrictive effects, it is applicable only to ferrous materials such as carbon steel, alloy steel, and ferritic stainless steel (400 series). However, application of the MsS can be easily extended to nonferrous materials by bonding a thin strip of ferromagnetic material, such as nickel (Ni) or iron-cobalt (Fe-Co) alloy, to the nonferrous material and operating the MsS over that strip. In this case, the MsS generates the guided wave in the strip. The generated guided wave is mechanically coupled to the nonferrous material and propagates in the material. Detection of the guided wave is achieved in the reverse manner.

The thin ferromagnetic-strip approach is also very useful to generate and detect guided waves in ferrous materials. The advantages of the approach over direct generation and detection in ferrous materials are higher MsS sensitivity and no need to magnetize the ferrous material being tested.

Feasibility study on 2205 vessel

The feasibility of inspecting 2205 duplex stainless steel FGD vessels using shear-horizontal (SH) guided waves was investigated using the MsS technique. In the method, 64-kHz SH waves were generated using the thin strip ap-
proach, which involved bonding a 12 in. long × 0.004 in. thick × 2 in. wide (300 × 0.1 × 50 mm) Fe-Co strip to the exterior surface of FGD vessel, and placing an approximately 12-in. long MsS plate probe over the bonded strip. Figure 4 shows a photograph of a bonded Fe-Co strip and a MsS plate probe placed over a bonded strip for testing.

Figure 5 shows an example of some of the data taken from an operating FGD vessel in both the horizontal and vertical directions. The signals labeled as MsS1 are the initial pulse applied to the sensor. Signals labeled as W1, W2, etc., are consecutive weld signals. The SH waves propagated well in the duplex FGD vessel, and the test range achievable horizontally was more than 60 ft (18 m) in one direction. By this, a 70-ft (21-m) diameter FGD vessel can
be fully examined (except for areas interrupted by doors, penetrations, etc.) by scanning vertically at two diametrically opposite locations on the exterior of the vessel.

Based on high signal-to-noise (S/N) ratios of weld signals, defects whose signal amplitude is greater than 10% of the weld signal amplitude are detectable with a S/N ratio greater than three. A detectable defect size over the 60 ft scan distance is estimated to be about 1 in. (25 mm) diameter for 50% through the wall.

It takes approximately 25 seconds to acquire data in both directions at a given MsS position. To scan 50 ft (15 m) vertically at every 2 in. (5 cm) over preinstalled strips with a mechanical scanner, it would take about 2.5 hours. If the strips and the scanning device that carries the MsS probe are installed beforehand, the full vessel NDE can be completed within one day.

**Findings**

The feasibility study showed that the MsS could inspect large areas of an FGD vessel quickly and shorten the inspection time. Once installed, the technique can be used to determine changes in structural condition quickly and efficiently during subsequent examinations. The technique is suitable for long-term, remote, wireless, structural health monitoring, and could help prevent unexpected failures, as it provides for continued condition survey for the Operation/Maintenance Dept. to improve structural integrity management and reduce costs.

**Summary**

Alloy absorber vessels in wet FGD systems are experiencing corrosion, and the current methods of inspection are time consuming. MsS technology is currently ready for FGD vessel inspection and monitoring. Research and procedure work are needed to tailor the technique to the specific structural details of each FGD vessel. Procedures should include scan paths, plate probe length, guided wave frequency, sensor installation protocols, etc., to evaluate the effectiveness of technology on actual vessels, and procedures should be refined as necessary. After demonstrating effective examination capabilities, the technology should be transferred to commercial NDE service vendors in the same way the technology is now being used for pipeline inspections.

**References**


For more information: John Shingledecker is senior project manager, Fossil Materials & Repair Program (P87), Electric Power Research Institute (EPRI), 1300 West WT Harris Blvd., Charlotte, NC 28262; tel: 704/959-2619; email: jshingledecker@epri.com; Website: www.epri.com.