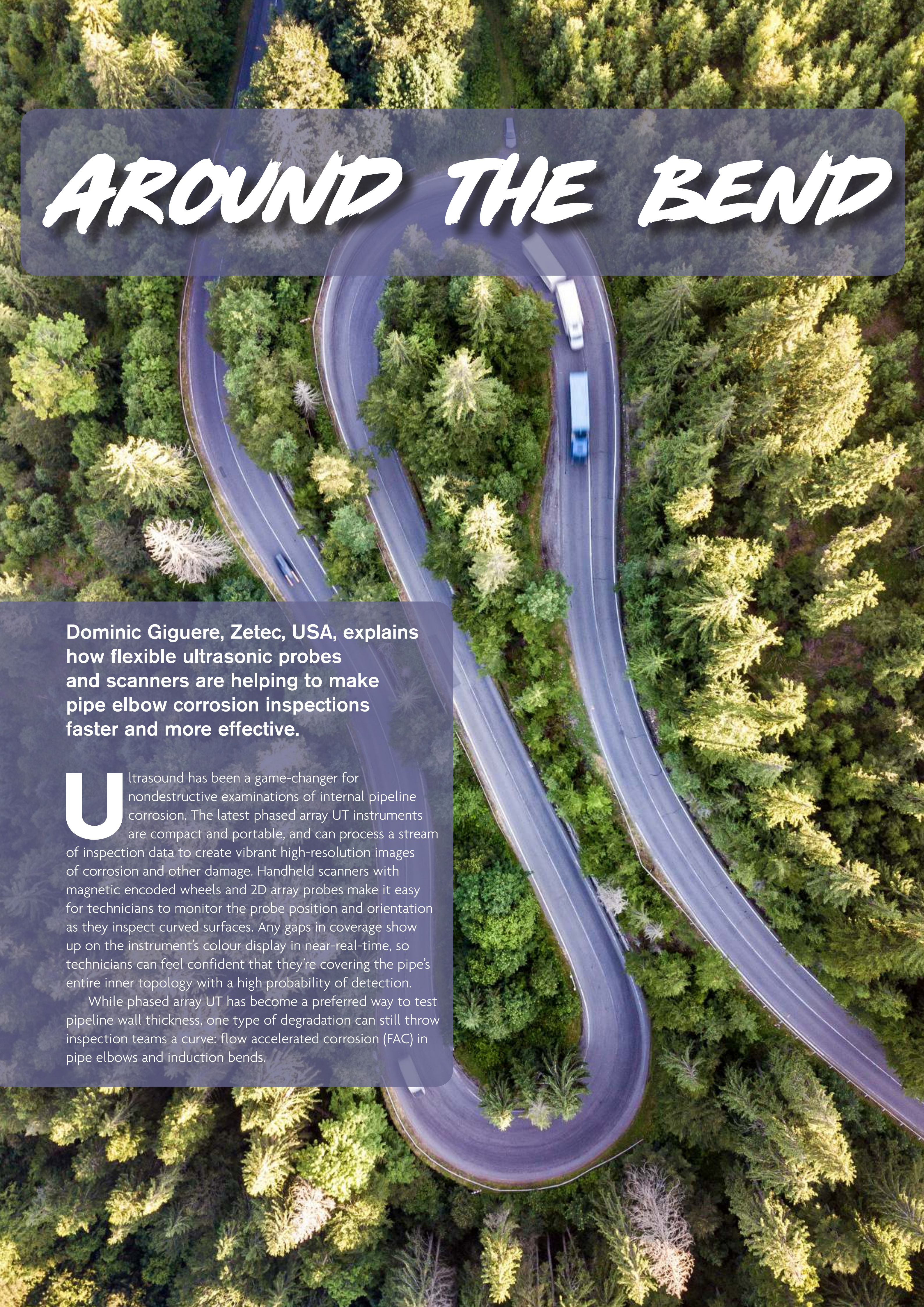

AROUND THE BEND

Dominic Giguere, Zetec, USA, explains how flexible ultrasonic probes and scanners are helping to make pipe elbow corrosion inspections faster and more effective.

Ultrasound has been a game-changer for nondestructive examinations of internal pipeline corrosion. The latest phased array UT instruments are compact and portable, and can process a stream of inspection data to create vibrant high-resolution images of corrosion and other damage. Handheld scanners with magnetic encoded wheels and 2D array probes make it easy for technicians to monitor the probe position and orientation as they inspect curved surfaces. Any gaps in coverage show up on the instrument's colour display in near-real-time, so technicians can feel confident that they're covering the pipe's entire inner topology with a high probability of detection.

While phased array UT has become a preferred way to test pipeline wall thickness, one type of degradation can still throw inspection teams a curve: flow accelerated corrosion (FAC) in pipe elbows and induction bends.

What is FAC?

FAC occurs in pipelines when the movement of fluid causes deterioration on the interior wall. One of the most common examples is carbon steel or low alloy steel pipe elbows, where the flow of water or wet steam gradually wears aways the protective oxide layer on the inside surface of the pipe. The exposed bare metal starts to corrode, exhibiting grooves, striations, shallow pits and other signs of material loss. The pipe wall becomes thinner and the risk of metal failure increases.

A number of factors affect a material's resistance to FAC, including the composition of the steel; the chemistry and temperature of the fluid; and the fluid's velocity, pressure and turbulence as it moves through the pipe.

While the terms FAC and erosion corrosion are often used interchangeably during elbow inspections, FAC doesn't necessarily include abrasion due to particles in the fluid, impingement caused by water droplets in steam or cavitation that occurs when a liquid is subjected to rapid pressure changes. However, these conditions can aggravate the problem.

Figure 1. UT scanner for pipe elbows.

Figure 2. Left: A 1D linear array probe is ideal for most inspections of welds and other defects. Right: The beam-skewing capability of 2D matrix array probes means more accurate wall thickness measurements and better detection of mis-oriented flaws.

With ultrasound, technicians and asset owners can monitor rates of material loss in straight pipe runs. However, pipe elbows are a unique challenge.

With a phased array UT probe, ultrasonic waves enter the material being tested at precise intervals and a set angle. When a wave encounters a defect, some of that energy reflects back and generates an echo. The time it takes for this energy to come back to the probe is calculated and analysed by the UT instrument's software and is presented on the display as a C-Scan for the technician to interpret.

However, it's difficult for a rigid UT probe to traverse the intrados (inner radius) and extrados (outer radius) of a pipe elbow in a concentric position so ultrasonic signals reflect back properly. Technicians can use a combination of probes and wedges to accommodate the convex and concave shapes and variations in material thickness along the pipe elbow, but this adds time, complexity and cost to the inspection.

What's the next step? Ultrasound technicians and asset owners have a handful of options if they want to check for FAC and other defects in pipe elbows.

Spot checks

One approach is to draw a grid on the outside of the pipe to use as a reference for spot thickness measurements along the elbow – it's referred to as a time-based scan mapped over a grid system.

The technician uses a standard 1D linear array probe to check the wall thickness wherever the grid lines cross, or to cover the entire interior of the box.

Either way, drawing a grid and taking thickness measurements by hand, box by box, is tedious work. The only record of examination it produces is a table listing the nominal wall thickness and the minimum thickness at each point on the grid, and there's no code or standard to dictate grid spacing or the number of inspection points. Ultimately, this technique can leave a lot of area in the pipe elbow unchecked and undocumented.

Radiography

Another option is radiography. Radiographic inspections use either portable X-ray or gamma ray generators to direct a beam into the pipe elbow. A detecting device – an imaging plate (undeveloped film sealed in a cassette) – captures the beam after it penetrates the material. The process produces a two-dimensional image (radiograph) of varying densities according to the amount of radiation that penetrates the material and reaches the film. Advancements in technology allow the ability to wrap image plates around pipes.

Unlike digital phased array ultrasound inspections which provide immediate results, the latent negative image on a radiograph must be processed using chemical developer, stop bath and fixer. Inspection quality depends on accurate alignment of the beam with the

Types of ultrasonic probes

When you hear the term 'array' applied to ultrasonic testing, you may just as well be talking about the range of transducer choices available for UT inspections.

Array probes come in a variety of shapes, sizes, frequencies and the number of elements. If you manage or direct nondestructive testing service providers for pipeline inspections, it's important to understand two main types of probe technology.

1D linear array probes

A 1D linear array probe is the most common type of array for straight beam and angle beam inspections. Think of it as a long transducer that's capable of generating and receiving a single ultrasonic beam. No matter how a 1D linear array probe is oriented, the focal point and angle of the beam are fixed.

A 1D linear array probe will meet the requirements for most weld and component-integrity inspections, including reliable detection of surface and subsurface defects and wall-thickness measurements. Because of their versatility and cost effectiveness, 1D probes are used in flexible array probes and scanners developed for the detection of flow accelerated corrosion in pipeline elbows.

2D matrix array probes

2D matrix array probes have elements along two directions. This enables the rapid acquisition of data and the ability to perform a complete volumetric inspection. By exciting each element in a highly controlled manner, a phased array UT instrument and software can produce a precise beam shape at multiple angles and generate two and three-dimensional views of a flaw with speed and accuracy.

2D matrix array probe assemblies and portable phased array instruments are now common for pipeline inspections. These tools have powerful software that allows technicians to virtually position probes on the specimen to ensure maximum volumetric coverage, and then simulate an inspection step by step.

Ultimately, the technician's choice of probe will depend on the job at hand. What kind of access does the inspecting technician have? What materials are used in the welds? What conditions exist around the inspection site (high temps, humidity, etc.)?

The wrong ultrasonic probe type can sometimes give you the same actionable results as having no probe at all. If you're an asset owner, the more information you can provide to the technician, the more straightforward their probe choice will be.

material surface as well as proper exposure time based on the properties of the material.

Because of the safety issues surrounding radiation, a radiographic inspection may require permits and clearing the area of other personnel to ensure they are not accidentally exposed. Here, standards established by organisations like the American Society of Mechanical Engineers (ASME) and the American Petroleum Institute (API), as well as the experience and judgment of the technician, play a critical role in equipment setup and testing.

Flexible array probes

A flexible ultrasonic array probe and scanner can map both straight and elbow aspects of a pipe, and significantly reduce inspection time compared to radiography and conventional UT and grid systems.

Introduced only within the past few years, flexible array probes have a pliable foam wedge that shapes the array of ultrasonic elements to meet the contour of the pipe elbow. This allows the probe to stay concentric throughout the inspection.

The combination of a flexible array probe and an encoded scanner enhances the technician's ability to generate a complete map of the inner surface of the elbow and characterise corrosion. Flexible array probe scanners weigh 1 kg and are easy to handle: magnetic wheels keep the scanner firmly in place as the technician guides it along a scan line or the centreline of the pipe. An encoder maps the pipe's scan axis while the technician can index increments in the second axis with the press of a single button on the scanner.

The newest flexible array scanner, Zetec's ElbowFlex, has a 64 element array and is capable of surface-mapping the interior of pipe elbows from 4 in. nominal pipe size (NPS) to flat. Its encoded data can be saved at a high resolution to generate a detailed C-Scan image of the entire interior surface of the pipe elbow.

Choosing a couplant

Like other ultrasonic probes, a flexible array probe requires a couplant to help ensure a reliable signal.

The most common approach is a water chamber, but water can be messy on a pipe elbow inspection, especially for the technician with a handheld scanner. There are alternatives to water, including acoustic-capable polymer materials that can be moulded around the pipe elbow. Polymer membranes such as Aqualene – a soft, pliable thermoset elastomer – conform to the elbow's convex and concave shapes and stay there, minimising the need for water while providing a reliable way to transfer ultrasonic energy. Other options include standard coupling gel or a mixture of water and gel.

As ultrasound has become a proven technology for pipeline testing, flexible phased array probes and elbow scanners can eliminate a crucial blind spot. They can help technicians and asset owners make more informed decisions about managing FAC and other previously hidden wear-related defects that may be just around the corner.