Since 1995, Inspectioneering Journal has provided the oil & gas and chemical industries with information to help optimally manage equipment risk and reliability, cradle to grave.

XRF Inspection of Piping Systems to Reduce Sulfidation Corrosion Risk
This is the first in a series of three articles that will introduce Electro Magnetic Acoustic Transducer (EMAT) and its practical applications in the field of nondestructive testing (NDT).

**EMAT Principles, Advantages and Disadvantages**

EMAT, or Electro Magnetic Acoustic Transducer, is an Ultrasonic Testing (UT) technique that generates the sound in the part inspected instead of the transducer.

An EMAT generates ultrasonic waves into a test object using electromagnetic induction with two interacting magnetic fields. A relatively high frequency (RF) field generated by electrical coils interacts with a low frequency or static field generated by magnets to generate a Lorentz force in a manner similar to an electric motor. This disturbance is transferred to the lattice of the material, producing an elastic wave. In a reciprocal process, the interaction of elastic waves in the presence of a magnetic field induces currents in the receiving EMAT coil circuit. For ferromagnetic conductors, magnetostriction produces additional stresses that can enhance the signals to much higher levels than could be obtained by the Lorentz force alone.

Because the sound is generated in the part inspected instead of the transducer, EMAT is a completely non-contact technique that has significant advantages over more conventional piezoelectric transducers:

- **Dry inspection.** EMATs do not require couplant for transmitting sound, which makes them very well suited for inspection of hot and cold parts, and integration in automated environments.
- **Impervious to surface conditions.** EMATs can inspect through coatings and are not affected by pollutants, oxidation, or roughness.
- **Easier sensor deployment.** Not having wedges or couplant, Snell’s law of refraction does not apply, and the angle of the sensor does not affect the direction of propagation. This makes them easier to control and deploy, especially in automated environments.
- **Ability to generate unique wave modes.** EMATs are the only practical means
for generating shear waves with horizontal polarization (SH waves), which do not travel through low-density couplants. The ability to easily produce Guided SH waves and lamb waves make EMAT ideal for generation of guided waves, used in the inspection of plates, tubes, and rounds.

Even though EMAT has significant advantages over more conventional piezoelectric techniques, it also has weaknesses that limit its application:

- **Material limitations.** EMAT only works on materials that conduct electricity. Contrary to some claims, the material inspected does not need to be ferromagnetic, and EMAT is frequently and successfully used on aluminum, copper, and most metals.
- **Power requirements.** EMAT is less efficient than piezoelectric transducers converting electrical energy into a mechanical force and it requires very high-power to generate the sound. The typical EMAT application will require several cycles of energy with peak voltages ranging from 600V to 1200V. In this regard, Innerspec Technologies has developed an instrument with 2000Vpp/20kW per channel for some extreme applications.
- **Signal-to-noise.** Even with high-power, the amount of sound that an EMAT can induce is normally lower than what can be achieved with a perfectly coupled piezoelectric transducer.
- **Transducer size and magnetic attraction.** EMAT uses powerful permanent magnets or electromagnets to generate the magnetic field, which can be bulky and more difficult to use on ferromagnetic materials. Even though there are some applications that use small sensors, most of them are 25x25mm (1”x1”) in size or larger.

Because of these limitations and as a general rule, EMAT should be considered a complementary technique instead of a substitute to piezoelectric UT. Even though there are many applications that can be solved with both EMAT and piezoelectric systems, most of the growth comes from problems that are very difficult or impossible to solve with more traditional UT methods.

### Conclusions

As a non-contact UT technique, EMAT has important advantages that make it the technique of choice for many applications. Due to recent advances in hardware and software, a lot of its traditional challenges are being gradually overcome, and new solutions are developed every day.

In the next two articles of this series we will introduce field-ready solutions for integrated and in-service applications, and we will explain how this powerful technique is moving forward the field of NDT.

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**Figure 2. temate® PowerBox H Hand-Held Instrument 1200Vpp (8kW) and 1-5 cycles tone-burst**

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**Table 1.**

<table>
<thead>
<tr>
<th>Bulk / Guided</th>
<th>Beam Orientation</th>
<th>Wave Mode</th>
<th>Technique</th>
<th>Main Applications</th>
</tr>
</thead>
</table>
| Normal        | Longitudinal     | Piezo EMAT | • Thickness and Velocity Measurements  
• Flaw Detection  
• Properties Measurement |
|               | Shear Horizontal | EMAT²     |           |                  |
| Angled        | Shear Vertical   | Piezo EMAT | • Flaw Detection  |
|               | Shear Horizontal | EMAT³     | • Flaw Detection, including austenitic materials |
| Surface       | Rayleigh         | Piezo EMAT² | • Flaw Detection (surface) |
| Volumetric    | Lamb             | Piezo EMAT² | • Flaw (including corrosion) Detection  
• Velocity and Properties Measurements |
|               | Shear Horizontal | EMAT³     | • Flaw (including Corrosion) Detection  
• Velocity and Properties Measurements |

1. Generation restricted to EMAT for practical purposes
2. Especially well-suited for generation with EMAT

The distribution of Lorentz forces and the effect of Magnetostriction in the generation of ultrasound are controlled by the design of magnet and the electric coil, the properties of the test material, relative position between the transducer and the test part, and the excitation signal for the transducer.

As a rule, EMAT is capable of generating all wave modes used in ultrasonic testing, including some modes that are very difficult or impractical with conventional piezoelectric transducers.

The table below provides a summary guide of the type of wave and technique available for different applications.

**Borja Lopez, Chief Executive Officer**

Innerspec Technologies, Inc.

Borja Lopez has served as CEO of Innerspec Technologies since July 2001. During his tenure, Innerspec has grown from a niche R&D manufacturer serving the domestic market, to the world leader in EMAT technology and high-power ultrasound. Today Innerspec sells integrated and in-service Non Destructive Testing systems throughout the world from its offices in the US, Spain, China, and India. With more than 50 patents and a world-class team of engineers, Innerspec has developed unique solutions for nearly all industrial sectors including primary metals manufacturing, automotive, aerospace, oil & gas, ship building, and the nuclear industry.