

Using Ultrasound To Gauge Internal Corrosion

Written by MT Staff

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Factors to consider when selecting and using ultrasonic gauges to measure remaining pipe and tank wall thickness.

A particularly important problem that faces many industries is measurement of remaining wall thickness in pipes, tubes, tanks, and structural members subject to corrosion. Such corrosion is often not detectable by visual inspection, even when the area is accessible. If undetected over a period of time, corrosion will weaken walls and possibly lead to failures, some with dire safety, economic, or environmental consequences. Ultrasonic testing is a widely accepted nondestructive method for performing this inspection, permitting quick and reliable measurement of thickness without requiring access to both sides of a part.

This article focuses on a class of ultrasonic instruments often referred to as corrosion thickness gauges. These commonly handheld gauges digitally display the thickness of the remaining wall thickness of the part. They usually employ a dual element transducer (or dual probe), which is normally used for corrosion survey work rather than precision gaging work. Dual element transducers are typically rugged and able to withstand high temperatures, and are highly sensitive to detection of pitting or other localized thinning conditions. As their name implies, dual element transducers use a pair of separate piezoelectric elements, one for transmitting and one for receiving, bonded to separate delay lines cut at an angle.

A pulse-echo ultrasonic thickness gauge determines the thickness of a part or structure by accurately measuring the time required for a short ultrasonic pulse generated by a transducer to travel through the thickness of the material, reflect from the back or inside surface, and be returned to the transducer. In most applications this time interval is a few microseconds or less. The measured two-way transit time is divided by two to account for the down-and-back travel path, and then multiplied by the velocity of sound in the test material.

Standard industry practice has been to use dual element transducers for corrosion survey work, particularly when the inside surface of the test piece is pitted or rough. It is the irregular surfaces that are frequently encountered in corrosion situations that give dual element transducers an advantage over single element transducers. All ultrasonic gaging involves timing the round trip of a sound pulse in a test material. Because solid metal has an acoustic impedance that differs from that of gasses, liquids, or corrosion products such as scale or rust, the sound pulse will reflect from the far surface of the remaining metal. The test instrument is programmed with the velocity of sound in the test material, and computes the wall thickness.

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Dual element transducers incorporate separate transmitting and receiving elements, set at an angle, so that the transmitting and receiving beam paths cross beneath the surface of the test piece. This crossed-beam design of dual element transducers provides a pseudo focusing effect that optimizes measurement of minimum wall thickness in corrosion applications. The dual element units are more sensitive than single element transducers to echoes from the base of pits that represent minimum remaining wall thickness. Also, they often may be used more effectively on rough outside surfaces. Couplant trapped in pockets on rough sound entry surfaces can produce long, ringing interface echoes that interfere with the near surface resolution of single element transducers. With a dual element unit, the receiver element is unlikely to pick up this false echo. Finally, dual element transducers may be designed for high temperature measurements that would damage single element contact transducers.

Modern corrosion thickness gauges incorporate internal data logging functions that can be used for statistical analysis of stored thickness data. Documentation capabilities may range from simple printouts of thickness readings to the transfer of data to a computer to generate powerful three-dimensional, color-coded grid files. Some instruments feature on-screen comparison of current thickness readings vs. previous readings, which is ideal for monitoring the degree of wall thinning.

The following general principles apply to all corrosion measurements with dual element transducers, whether used with a thickness gauge or a flaw detector. In all cases, the instrument must be properly calibrated for sound velocity and zero offset in accordance with the procedure found in the instrument's operating manual.

Transducer selection

For any ultrasonic measurement system (transducer plus thickness gauge or flaw detector), there will be a minimum material thickness below which valid measurements will not be possible. Transducers at higher frequencies are capable of measuring thinner parts. In corrosion applications, where minimum remaining wall thickness is normally the parameter to be measured, it is particularly important to be aware of the specified range of the transducer being used. If a dual element transducer is used to measure a test piece that is below its designed minimum range, the gauge may detect invalid echoes and display an incorrectly high thickness reading.

In selecting a transducer for a corrosion application it is also necessary to consider the temperature of the material to be measured. Not all dual element transducers are designed for high-temperature measurements. Using a transducer on a material whose temperature is beyond the unit's specified range can damage or destroy the transducer.

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Surface condition

Loose or flaking scale, rust, corrosion, or dirt on the outside surface of a test piece will interfere with the coupling of sound energy from the transducer into the test material. Thus, any loose debris of this sort should be cleaned from the specimen with a wire brush or file before measurements are attempted. Generally it is possible to make corrosion measurements through thin layers of rust, as long as the rust is smooth and well bonded to the metal below. Some very rough cast or corroded surfaces may have to be filed or sanded smooth in order to insure proper sound coupling.

Severe pitting on the outside surface of a pipe or tank can be a problem. On some rough surfaces, the use of a gel or grease rather than a liquid couplant will help transmit sound energy into the test piece. In extreme cases it will be necessary to file or grind the surface sufficiently flat to permit contact with the face of the transducer. In applications where deep pitting occurs on the outside of a pipe or tank it is usually necessary to measure remaining metal thickness from the base of the pits to the inside wall. There are sophisticated ultrasonic techniques utilizing focused immersion transducers that can measure directly from the base of the pit to the inside wall, but this is generally not practical for field work. The conventional technique is to measure externally unpitted metal thickness ultrasonically, measure pit depth mechanically, and subtract the pit depth from the measured wall thickness. Alternately, one can file or grind the surface down to the base of the pits and measure normally.

Transducer positioning, alignment

For proper sound coupling the transducer must be pressed firmly against the test surface. On small diameter cylindrical surfaces such as pipes, the transducer should be held so the sound barrier material, visible on the probe face, is aligned perpendicular to the center axis of the pipe.

An ultrasonic test measures thickness at only one point within the beam of the transducer, yet wall thickness often varies considerably in corrosion situations. Test procedures usually call for making a number of measurements within a defined area and establishing a minimum and/or average thickness. Ideally, data should be taken at increments no greater than half the diameter of the transducer to insure that no pits or other local variations in wall thickness are missed. It is up to the user to define a pattern of data collection appropriate to the needs of a given application. This is normally not possible; instead a significant statistical sampling of data points is often taken.

High temperature measurements

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Corrosion measurements at elevated temperatures require special consideration. The following points should be considered:

- Check that the surface temperature of the test piece is less than the maximum specified temperature for the transducer and couplant to be used. Some dual element transducers are designed for room temperature measurements only.
- Use a couplant rated for the temperature of the test surface. All high temperature couplants will boil off at some temperature, leaving a hard residue that will not transmit sound energy.
- Make measurements quickly and allow the transducer body to cool between readings. High temperature dual element transducers have delay lines made of thermally tolerant material, but with continuous exposure to very high temperatures the inside of the probe will heat to a point where it eventually will destroy the transducer.
- Both material sound velocity and transducer zero offsets will change with temperature. For maximum accuracy at high temperatures, velocity calibration should be performed using a section of the test bar of known thickness heated to the temperature where measurements are to be performed. Quality thickness gauges have a semi-automatic zero function that can be employed to adjust zero setting at high temperatures.

Gauges and flaw detectors

An ultrasonic corrosion gauge is designed to detect and measure echoes reflected from the inside wall of a test piece. It is possible that material discontinuities such as flaws, cracks, voids, or laminations may produce echoes of sufficient amplitude to trigger the gauge, showing up as unusually thin measurements at particular spots on a test piece.

Corrosion gauges that incorporate waveform displays can be very useful in detecting these conditions. However, a corrosion gauge is not designed for flaw or crack detection, and cannot be relied upon to detect material discontinuities. A proper evaluation of material discontinuities requires an ultrasonic flaw detector used by a properly trained operator. In general, any unexplained readings by a corrosion thickness gauge merit further testing with a flaw detector. **MT**

Information supplied by [Meindert Anderson](#), [Nondestructive Testing Division of Panametrics](#), 211 Crescent St., Waltham, MA 02453; (800) 225-8330

What Is Ultrasound? Sound energy can be generated over a broad frequency spectrum.

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Audible sound, for example, is restricted to a low frequency range with a typical upper limit of 20,000 cycles/sec, or 20 kHz. Ultrasound is sound at frequencies above 20 kHz, too high to be detected by normal human hearing. Corrosion thickness gauges typically operate at much higher frequencies, ranging from 1 MHz to 10 MHz.

Testing?

—because of its short wavelength—has the advantage that it can make very accurate thickness measurements on metals (as well as on plastics, glass, rubber, and other engineering materials). Equally important, measurements are nondestructive and allow an inspector to obtain wall thickness from one side without having to cut the test piece open.

Measurements are repeatable, meaning an inspector has the ability to perform the same inspection at various time intervals and monitor the degree of wall thinning.

Ultrasonic thickness gauges can play a vital role in the predictive or preventive maintenance of pipes, tanks, or other metal structures subject to corrosion, erosion, or pitting.

Through Paint, Echo-To-Echo Thickness Measurements

Recent advances in the design of ultrasonic corrosion thickness gauges utilizing dual element transducers have made it possible to take accurate metal thickness measurements with no need to remove paint or coatings. This feature is often referred to as echo-to-echo thickness measurements.

Traditional ultrasonic corrosion gauges make thickness measurements by determining pulse transit time to the first backwall echo. This technique generally works very well, except for the specialized case where the surface of the pipe or tank is covered with a layer of paint or other coating. In these cases, traditional corrosion gauges will measure the total thickness of both the coating and the metal substrate. Because paint and similar coatings normally have a sound velocity that is much slower than the metal substrate, a coating will usually add two to three times its actual thickness to the total ultrasonic reading. Therefore, inspectors often may have to remove the paint or other coating in order to get true metal thickness readings. This often proves to be very time consuming, and usually the measurement point has to be repainted as well.

Until recently, to avoid this measurement problem without having to remove the coating, inspectors had to rely on flaw detectors to make thickness readings utilizing the multiple backwall echoes that many metal test pieces produce. This technique works well, but requires more operator skill as well as heavier and more expensive equipment. Now inspectors can use handheld thickness gauges for these types of measurements as long as these gauges have the echo-to-echo feature.