

## Detecting discontinuities through weld inspection Matching the inspection method to the welding process

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Discontinuities, or flaws, can often occur in the welds used to manufacture welded tubular products. The likelihood of discontinuities occurring depends on a number of factors, including the welding process, type of weld, material, and working conditions.

Ensuring tubing quality depends in part on the tube producer's ability to locate and identify discontinuities. Weld inspection is performed to meet industry specifications or customer requirements and aims to identify products that do not meet acceptance criteria. The results of weld inspection are valuable to mills for monitoring their manufacturing process and determining which tubular products meet their quality requirements. This information also is valuable to consumers of tubular products who need to verify the quality of their materials to ensure the safety and performance of the products they manufacture.



High-speed immersion ultrasonic inspection is an efficient method for detecting internal flaws in tubing and pipe.

### Discontinuities Found in Welds

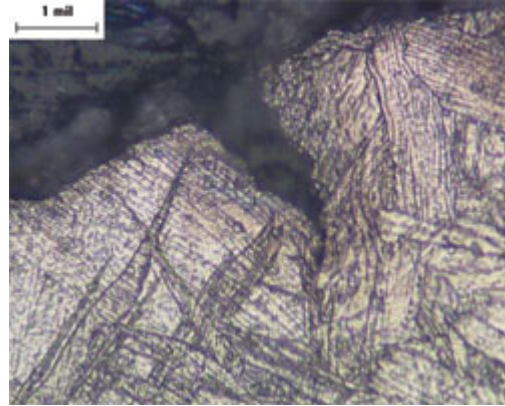
Some of the more common types of discontinuities found in welded tubular products are:

- Cold weld—inadequate or brittle bonding with no apparent discontinuity in the fracture
- Contact marks (electrode burns)—intermittent imperfections near the weld line
- Hook cracks—separations within the base metal that are parallel to the surface and turn toward the outside or inside surface
- Weld-area cracks—cracks that are not caused by upturned fibers (see **Figure 1**)
- Pinholes—tiny holes located in the weld line
- Stitching—a pattern of light and dark areas where the weld has broken in the weld line
- Incomplete fusion—incomplete union of the base metal with the filler metal
- Incomplete penetration—a weld that does not continue through the full thickness of the joint
- Porosity—surface or subsurface voids
- Slag inclusions—trapped nonmetallic solid material

## Selecting an Inspection Method

In general, nondestructive inspection methods are preferred over destructive inspection methods because the product is not permanently altered in the process. Destructive testing is performed on a sample of the product, so the results may not accurately reflect the quality of the joints that are not inspected.

The basic factors that affect the method of nondestructive inspection chosen are product diameter, length, and wall thickness; fabrication method; type and location of potential discontinuities; specification requirements; and extraneous variables such as a scratch, which might cause a rejectable indication even though the product is acceptable.



**Figure 1**  
Polishing and etching a weld cross section reveals a crack.

The most widely used nondestructive testing techniques for weld inspection of tubular products are ultrasonic, eddy current, magnetic flux leakage, radiographic, liquid penetrant, and magnetic particle. The first four are reliable for identifying internal flaws, whereas the last two are most reliable for detecting surface flaws. Each of these techniques has specific advantages and limitations.

**Ultrasonic Inspection.** In ultrasonic inspection, a transducer transmits an ultrasonic pulse into the material under test. The transducer detects flaws by measuring the amount of reflected energy that returns to it.

Ultrasonic inspection can be applied to the entire tube or just the weld, and can be performed by immersion in water or by contact. The immersion method relies on water as a couplant to conduct the signal from the transducer to the tube or pipe. This method is more efficient for smaller-diameter, lighter-wall material because of the ability to use focused transducers and manipulate the transducer to equalize the ID and OD notches to maximum sensitivity. The contact method relies on a couplant with a fitted, contoured shoe that makes physical contact with the tube or pipe and is usually better-suited for larger material with a heavier wall.

Automated immersion inspection can be performed at high speeds, but the speed ultimately depends on the predetermined rejection size of the flaw, along with the physical factors of the material and equipment used. Larger products are inspected by contact ultrasonic testing, but this method is slower than immersion. Tubular products must be clean, straight, round, and have uniform dimensions for ultrasonic inspection by either method.

A disadvantage of the ultrasonic method in tube inspection is its high sensitivity to minor scratches and to the material's dimensional characteristics. Inspection of tube ends can be a problem for some ultrasonic inspection equipment. If inspection of the tube ends is essential, supplementary testing may be required.

**Eddy Current Inspection.** Eddy current testing induces an electromagnetic field into the tube or pipe. Variations in the tube or pipe cause changes in the current flow, which are reflected into a nearby coil or probe that detects and measures discontinuities.

Most eddy current tests use differential systems that detect changes by comparing the variation in induced currents. They are most sensitive to flaws that involve a marked change in normal electrical characteristics. Eddy current instruments have the advantages of speed in testing and convenience in operating, marking, and sorting. This method can inspect the entire tube or just the weld, but is not able to inspect completely to the ends of the tube. If the inspection must include the tube ends, steps can be taken to minimize the error, or a second procedure can be used.



**Figure 2**

Although useful for finding the precise locations of flaws, the magnetic particle inspection method generates subjective results because it relies on the operator's vision and judgment.

**Magnetic Flux Leakage Inspection.** Magnetic flux leakage equipment induces a magnetic field and detects magnetic flux lines that "leak" or change because of a discontinuity in the magnetized area. An inductive coil sensor or a Hall-effect sensor detects the leakage. The flux leakage (or magnetic field perturbation) inspection process is similar to eddy current inspection, except it requires magnetization of the tube; therefore, it is limited to ferromagnetic materials.

The flux leakage method usually detects flaws that run lengthwise and are at or near the surface. Flaws that have minimal longitudinal dimensions, such as pinholes, and subsurface flaws are difficult to detect with this method. Sensitivity to subsurface flaws drops rapidly as the flaws are located farther from the surface.

Tube diameter is not a limitation for the flux leakage process, but the wall thickness that can be tested is limited by the ability of the magnetic flux to penetrate the wall and the ability of the sensor to detect flaws at a distance from the wall. Production speed depends on dimensions, the maximum tolerable flaw length, and the magnetization process. Mechanical conditions, such as tube shape, variations in linear speed, and transverse movement of the tube, may have adverse effects on the test results and must be controlled. As in the eddy current technique, inspecting the ends requires special processing.

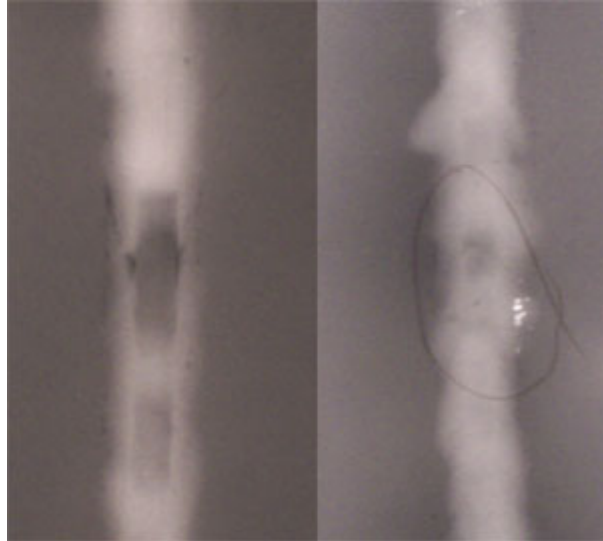
**Magnetic Particle Inspection.** In magnetic particle inspection, magnetic particles are sprayed or spread on the surface of magnetic parts to reveal surface cracks. The most common method uses finely divided iron or magnetic iron oxide particles in a liquid. This liquid can be colored or fluorescent. An older, less frequently used method utilizes a dry powder. In both cases, the inspector applies an external magnetic force that attracts magnetic particles to the defect and makes it visible.

This method, whether dry visible or wet fluorescent, can be used to determine the precise location of flaws detected by other inspection methods. The limitations of magnetic particle inspection are its inability to detect significant subsurface flaws, even when the magnetic particles are covered with a fluorescent coating, and its dependence on human vision and judgment (see **Figure 2**).

**Liquid Penetrant Inspection.** In this method, a penetrating dye or fluorescent liquid is used to coat the surface of the material or part. After capillary action draws the dye or liquid into the discontinuity, the inspector removes the excess penetrant and applies a developer, which draws the dye or fluorescent liquid from the discontinuity, making it visible.

Liquid penetrant inspection is capable of detecting discontinuities open to the surface in welds made of either ferromagnetic or nonferromagnetic alloys, even when the flaws generally are not visible to the unaided eye. This technique usually supplements other methods because testing speeds are slow.

**Radiographic Inspection.** Radiography relies on X-rays to detect subsurface discontinuities and those that are open to the surface (see **Figure 3**). Radiography provides a permanent film record of the location and type of discontinuity, but is labor-intensive and time-consuming.



**Figure 3**

Radiography can detect a variety of subsurface defects such as porosity (the dark spots near the middle of the weld, left photo) and a tungsten inclusion (the bright spot near the middle of the weld, right photo).

### Matching the Test Method to the Welding Process

The common welding processes used to make tubing and pipe are resistance welding of steel tube; double submerged arc welding of steel pipe; arc welding of nonmagnetic, ferrous tubular products; and continuous butt welding of steel pipe and spiral welded steel pipe. The key to successful weld flaw detection is matching the test method to the welding process used. The most reliable test methods for each welded product are:

- Resistance welded steel tubing—ultrasonic and eddy current
- Double submerged arc welded steel pipe—ultrasonic and radiography
- Arc welded nonmagnetic, ferrous tubular product—ultrasonic, eddy current, and liquid penetrant
- Continuous butt welded steel pipe—eddy current
- Resistance welded steel pipe (spiral welded)—ultrasonic and eddy current
- Submerged arc welded pipe (spiral welded)—ultrasonic and radiography

### Making the Choice

Each nondestructive testing method has unique capabilities to determine the quality and reliability of welds in tubular products. Before performing any inspection, it is crucial to choose the method that is best-suited to the flaws associated with the welding process. The most frequently used methods are ultrasonic and eddy current for their speed and ability to detect subsurface flaws.

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