Western Instruments Inc.
Established 1965

December 18, 2003

# Reference Indications

## for the Verification of Ultrasonic Testing Systems used on Welded Tube and Pipe.

By Mark Palynchuk
Vice-President
Western Instruments

## Introduction

*Reference Indications*, holes or notches, for Ultrasonic Testing are used to create a standardized method for the detection of Anomalies such as cracks, inclusions or laminations, based on the known physical properties of these indications. When a defect is detected by an Ultrasonic Testing System, the operator can evaluate it's size or severity by comparing it's A-Scan reflection (amplitude, width, and duration) to that of the *Reflective Area* of the Reference indication.

Reference Indications are normally outlined in Industry Specifications such as API (5L or 5CT), ASTM (A53, A273, & A513), etc. Large End Users of Tubular Products often have their own *Supplementary Specifications*, which ARE often formatted as addendum's to an Industry Specification they are based on, but more specific in scope.

Reference Indications are machined into *Calibration Standards*, which are the same diameter (shape), wall thickness, and grade of steel as the Tubular Product to be tested. The Systems performance is *Standardized* (or Calibrated) against the Calibration Standard in two ways. Statically, so the Transducers can be positioned and Ultrasonic Instrumentation adjusted to the Reference Indications. Dynamically, so the Calibration Standard can be moved by the Transducers to simulate the Testing Speed, ensuring that all appropriate Reference Indications are detected and alarmed.

## Weld Testing

Weld Testing Reference Indications are typically 1/8" (3mm) Drilled Holes and/or Longitudinal Notches 5 to 10% of the Wall Thickness. Drilled holes are easily made and very reproducible, however care must be taken to ensure holes are normal to the surface, located on an Artificial Weld Centerline, in both the longitudinal and transverse planes. Notches are expensive to make, and very difficult to reproduce along the artificial Weld Centerline of the Calibration Standard, with respect to consistency in parallelism (straightness) and depth.

Holes more typically represent short and small weld interface defects, while the use of the notch has been misunderstood for many years. Notches were originally introduced

to the Tubular Products Industry as a way to ensure transducers were aimed perpendicular to the weld, and have been misinterpreted as Reference Indications. These problematic reference indications should only be used on very thin wall thickness material, as it is in the range of 0.060” (1.5mm) wall thicknesses where the reflective area is close to being that of a hole. Secondly, notches are acceptable for their original intent of ensuring Perpendicular Wave Propagation to the Weld Centerline

*Reference Indication Gauge*, equipped with a Special Dial Indicator, easily measures the depth of indications (Holes or Notches). The Gauge’s contact blade is equipped with a “V” edge, and magnetic hold downs, to sit normal on a curved surface of various diameters. The elevation of the Dial Indicator is readily adjustable for zeroing the contact point to the surface of the calibration standard.

This Calibration Standard (3 ½”OD x 0.410”wt) was ‘commercially’ EDM Machined, however the 2” long N10 Notch (10%wt) was made 0.045” deep at one end and 0.052” deep at the opposite end. This calibration standard was in use for several years before the inaccuracies were properly measured.

If a smaller reflective area of a Reference Indication is used, smaller defects can be detected in the weld. The reflective area of an indication can easily be changed, when drilled holes are used, by reducing the diameter of the drill. When a 1/16” (1.6mm) Drill is used, instead of a standard 1/8” (3mm), the reflective area is reduced proportionately. Only the segment of the drilled hole that is at right angles (tangent) to the sound propagation is actually reflective or approximately 25% of the cross sectional area of the hole.

The Reflective area of Drilled Holes can be further reduced by only drilling in half the wall thickness, thus reducing the area by 50%. These *Half Holes* can be placed on the OD and/or ID surfaces of the Calibration Standard. However the bottom of the hole must be made flat, either with a small end mill, or with a specially flattened tip drill. These *Half Holes* are beneficial on heavier wall thicknesses, above 0.250” (6.4mm), where differentiation between ID and OD defects is very beneficial. Furthermore, on wall thickness above 0.500” (12.7mm), attention must also be paid to the Calibration Verification of Mid- Wall Defects.

Mid-Wall Reference Indications are easily made with Drilled Holes, by simply drilling a longitudinal hole on an end of the Calibration Standard in the middle of the Artificial Weld Centerline. Appropriate Ultrasonic Probes/Transducers should be able to test within 60% of the Transducer Diameter (or length) from the end of the Calibration Standard, so the hole should be in the order of 1” (25mm) deep, but depends on the Probe design. The addition to this Mid-Wall Reference Indication ensures the inspector can reliably verify an Ultrasonic Weld Inspection on the full thickness (OD, ID, & Mid-Wall) of the weld.


In many Supplementary Specifications for Submerged Arc Welded Pipe, Reference Indications are called for that are not on the Weld Centerline. Here the inspector must be concerned with the Industry Specification for Longitudinal and Transverse Weld Centerline defects, but also the Weld Reinforcement and defects in the large Heat Affected Zone. On Spirally Welded Pipe, a notch is very necessary to ensure the Transducers are at Right Angles to the area of the weld targeted.

These Supplementary Reference Indications include ID and OD Half Holes outside the Weld Reinforcement, on both sides of the Weld Centerline, to ensure *Automatic Alarm Gates* are set to detect defects that extend outside the weld area. Notches, Through Holes, and Half Holes are placed at the Toe of the weld (in all 4 quadrants) to simulate Toe Crack Reference Indications, and to set Automatic Alarm Gates so the Toe Area transitions with the Weld Reinforcement do not cause erroneous alarms.

## Lamination Testing

Ultrasonic Lamination Testing is normally only outlined in Supplementary Specifications for Heavy Wall Pipe and Mechanical Tubing. Laminations are simulated by Flat Bottom Holes, 5 to 10mm in Diameter, that have a depth of 50% of the Wall Thickness. However, some stringent Supplementary Specifications have called for depths of 25, 50, and 75%.

Lamination Testing can be performed on Strip or Plate, prior to forming, but is best done after Forming. Laminations are caused during forming when the high shear forces meet areas of inclusions or segregation. Laminations will often not be “open” when the steel is in its unformed state. Laminations most often occur on the Strip or Plate edges adjacent to the weld, secondly 180 degrees from the weld on Single Width (non-Slit) material, and finally in the body of the Tube or Pipe.

100% Full Body Lamination Testing is expensive and can be time consuming, so most Supplementary Specification call for a Percent Coverage or Minimum Sizes or Areas to

be tested. Edges of the Strip or Plate are often inspected 100% for 25 to 50mm, so any lamination 5mm or larger in diameter will be detected and alarmed in that target area. Therefore if testing for laminations is performed, the edges are inherently 100% covered for the specified width.

Body Lamination Testing with 100 percent coverage, that is, detecting a 5mm diameter defect anywhere in the body, can be cost prohibitive on Strip or Plate. Therefore minimum areas are often specified and are in the order of 200 square millimeters or 20mm by 100mm in the longitudinal axis. Therefore Transducers, capable of detecting a 5mm Reference Indication (16mm Dual Element Transducer), are placed on 20 mm transverse spacing, while the strip or plate is moved longitudinally, to ensure approximately 30% of the body is inspected. Conversely, if the pipe produced were placed on a spiraling conveyer with a 100mm Transducer Spacing, the same 30% Coverage can be performed with fewer channels being required. Furthermore, if the advancement per revolution of the spiraling conveyer is adjusted, 100% coverage can be achieved to meet the most stringent Supplementary Specifications.

Some Industry Specifications, such as API 5L, refer to End Lamination Inspection to the *Cut or Beveled End* of the Pipe, but do not specify the Method of Inspection. Supplementary Specifications most always require Ultrasonic Lamination Testing, in a similar fashion to the Edges of the Weld (25 to 50 mm). This inspection is quite straightforward on lengths of Pipe, but is time consuming and complicated on Plate, and impractical on Strip/Coil. The most stringent API Supplementary Specification calls for Ultrasonic Inspection, from the inside surface, if it is performed after Beveling.

## Body Defects

By definition, Body Defects do not typically include Laminations, but are longitudinal, transverse, or volumetric in nature and are detected with Shear Wave Transducers. Here again, percent coverage in not typically well defined in Industry Specification. Most Specifications call for either a Hole or Notches. A hole we know as a reproducible and well-sized indication that can be placed through the wall and/or with ID/OD half holes, for Inside/outside orientation. Notches representing transverse and longitudinal defects are placed on both the inside and outside surfaces (4 total) to ensure sensitivity and differentiation of defects with Inside/outside orientations. The use of Notches makes it difficult to verify sensitivity to Mid-Wall Defects, whereas holes can have a comparative amplitude done between ID or OD Half Holes and the Through Hole.

During Static Systems Verification (calibration), Transducers are easily aimed at Reference Indications. It is during Dynamic Calibrations that the Percent Coverage is truly determined. If 1” to 2 “ (25 to 50mm) notches are used while the test head (or workpiece) is rotated then less than 20% of the total volume is covered as the length of the notch or advancement per revolution becomes the governing factor. Whereas if a hole is used, 100% coverage is required to detect hole(s) anywhere in the Volume of the body, as it relates to length.

## Conclusion

Depending on the type of naturally occurring defect to be detected, Ultrasonics may not be the most applicable or cost effective method of testing. On Heat Treated product, such as API and their N80 Strength Specification, OD Surface Quench Cracks are best detected by Electromagnetic (Eddy Current) Methods, while ID Quench Cracks are best suited to Ultrasonic Testing, which reinforces the fact that Inspection Techniques are primarily complementary and not interchangeable.

This Complementary aspect must also be taken into account with respect to Reference Indications. Ultrasonic Testing detects Reflections to waves, while Electromagnetic Testing detects changes to current flow, so the type (and size) of Reference Indication is not interchangeable. Ultrasonic Inspection is most appropriate for defects below the outside surface, while Electromagnetic Inspection is most appropriate for defects on the outside surface - Complementary and not Interchangeable.