Although it may seem simple at first, detecting and correctly classifying internal corrosion has proven to be quite a complex skill to acquire and master, even to the most experienced of technicians. Time and resources are used to re-inspect false calls. The problem lies when the NDT technician detects a reduction in wall thickness on the vessel or piping and is unable to supplement the finding with an alternative method or technique such as radiographic or visual testing. Using two or more methods/techniques to confirm an indication is good engineering practice.

Since most false calls are attributed to laminations and inclusions, we will look at ways of differentiating laminations and inclusions from internal corrosion. These laminations and inclusions existed in the component from the initial manufacturing stage so are not necessarily detrimental to the component’s service life.

In this first part of a two-part series, we will look at the basic outline of corrosion detection theory and what practical options are available to an ultrasonic technician working in the field.

Overview of Corrosion Detection
The inherent difficulties of extracting oil and gas from subsea reserves are numerous. One of the most notable is the vast amount of seawater that is pumped up together with the crude oil. The seawater acts as the perfect electrolyte to initiate and sustain internal corrosion in associated piping and vessels. As stated in the text *Corrosion for Science and Engineering*, “sodium chloride (NaCl) in water is an extremely aggressive corrosion medium. Corrosion is the degradation of a metal by an electrochemical reaction with its environment” (Trethewey and Chamberlain 1995, pp. 28 and 30).

There are many mechanisms of corrosion that may cause wall loss: for example, galvanic, crevice, pitting, or intergranular...
corrosion. Flow-induced erosion corrosion is expected in oil extraction systems, due to high flow rates pumping out of the subsea oil reserves together with solids such as sand. Knowing which type of corrosion to expect may help the NDT technician in determining which areas are of more concern to test, meaning when flow-induced erosion corrosion is suspected, then bends and reducers are typical areas of interest due to impingement of particles on the inner wall.

As stated in the text *Corrosion for Science and Engineering*, “a sudden change in inner diameter or a change in direction of pipe will result in turbulence and therefore an increase in likelihood of flow-induced erosion corrosion” (Trethewey and Chamberlain 1995, p.192).

Compression (longitudinal) waves are used extensively in the oil and gas industry for the detection of internal corrosion in process piping and pressure vessels. It has proven to be a successful technique when performed by competent technicians.

Ultrasonic waves are high-frequency mechanical vibrations transmitted by the probe, which travel through the test part, bounce back off the opposite surface or anything in between (discontinuities), and are then detected again by the probe. It is similar to striking a ball off a flat surface and then catching the ball on the rebound. Corrosion detection, on the other hand, may be compared to bouncing a ball off a bumpy surface; the ball (here, the signal) could possibly rebound in any direction. Low corrosion signal or even no corrosion detection at all would result.

The ideal reflector (discontinuity) would be parallel to the outside scanning surface and have a smooth contour. But internal corrosion is much more difficult to detect due to its irregular profile (Drury 1997).

Note in Figure 1 the corrosion echo is lower in amplitude and more “rounded”

![Figure 1](https://example.com/figure1.png)

*Figure 1. How compression waves are used for corrosion detection: (a) process; (b) normal first and second backwall echoes; (c) corrosion echo.*
testing, where basically only the surface radiographic testing (RT) are considered of the vessel. Ultrasonic (UT) and to determine the remaining thickness alternate on-stream inspection, which inspection may be substituted with an frames (for example, 5 or 10 years).

In-service inspection is much favored by the client compared to internal visual inspection since the latter would require stopping the production process to allow entry into the vessel. The costs and labor hours can raise quite considerably—for example, to allow for labor to open up flanges, high pressure cleaning for internal inspection, and pressure tests upon completion—not to mention any delays in production will result in a loss of revenue for the oil producer.

Most training schools and international certification bodies, such as ASNT and BINDT, have set guidelines on the training and certification of UT technicians. Certification is further subdivided into smaller categories for which the technician may seek competence (for example, butt welds in plate, pipe or nozzle welds, and the like). The training and examination samples have discontinuities similar to those found in new fabrications, such as lack of fusion, lack of penetration, and slag inclusions. But rarely do we find samples have discontinuities similar to those found in new fabrications, such as lack of fusion, lack of penetration, and slag inclusions. But rarely do we find, the training and certification of UT technicians. Certification is further subdivided into smaller categories for which the technician may seek competence (for example, butt welds in plate, pipe or nozzle welds, and the like). The training and examination samples have discontinuities similar to those found in new fabrications, such as lack of fusion, lack of penetration, and slag inclusions. But rarely do we find samples have discontinuities similar to those found in new fabrications, such as lack of fusion, lack of penetration, and slag inclusions. But rarely do we find, the training and certification of UT technicians. Certification is further subdivided into smaller categories for which the technician may seek competence (for example, butt welds in plate, pipe or nozzle welds, and the like). The training and examination samples have discontinuities similar to those found in new fabrications, such as lack of fusion, lack of penetration, and slag inclusions. But rarely do we find samples have discontinuities similar to those found in new fabrications, such as lack of fusion, lack of penetration, and slag inclusions. But rarely do we find samples have discontinuities similar to those found in new fabrications, such as lack of fusion, lack of penetration, and slag inclusions. But rarely do we find samples have discontinuities similar to those found in new fabrications, such as lack of fusion, lack of penetration, and slag inclusions. But rarely do we find samples have discontinuities similar to those found in new fabrications, such as lack of fusion, lack of penetration, and slag inclusions. But rarely do we find samples have discontinuities similar to those found in new fabrications, such as lack of fusion, lack of penetration, and slag inclusions. But rarely do we find samples have discontinuities similar to those found in new fabrications, such as lack of fusion, lack of penetration, and slag inclusions. But rarely do we find.

Careful consideration should be given by the technician during corrosion testing due the fact that the only indication of internal corrosion is a loss of repeat backwall echoes. Suspected areas must be interrogated and other possible causes for the loss of signal eliminated (for example, insufficient couplant, loose cable connections, or an irregular or rough outer surface). Codes that regulate the industry, such as API 510 (American Petroleum Institute), require vessels to be visually inspected internally within specified time frames (for example, 5 or 10 years).

Under certain conditions the internal inspection may be substituted with an alternate on-stream inspection, which uses ultrasonic or radiographic testing to determine the remaining thickness of the vessel. Ultrasonic (UT) and radiographic testing (RT) are considered volumetric NDT methods, meaning the full through thickness of the test part is tested as compared to magnetic particle testing, where basically only the surface is inspected. When an indication that may hinder the service life of the vessel is detected with UT or RT, then the responsible inspector may shorten the inspection time periods (for example, six months).

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Some shortfalls that may be encountered with regard to this include the following scenarios:

- The Level III technologist might be based in a different area/country other than where testing is carried out by Level I and II technicians
- No clear transfer of knowledge from mentor (Level II technician) to trainees or Level I technicians, meaning trainees have to rely solely on company procedures to acquire skills for corrosion detection
- Trainees not taking the initiative to seek knowledge themselves or ask questions related to their field
- In-house or client competency checks may not be adequate enough to simulate real corrosion conditions found in the field (meaning the examination sample is fabricated from scratch and not an actual in-service corrosion failure sample)

Due to the nature of internal corrosion it is well suited for detection with UT and RT from the outside of the vessel, but the basic forms of liquid penetrant, magnetic particle, magnetic flux leakage, laser profilometry, and eddy current techniques cannot detect this in-service degradation from the outside surface (ASNT 2007, p. 437). Some possible alternatives to complement corrosion testing are:

- Phased array – zero-degree
- Phased array – dual array
- Tangential radiographic testing (digital or conventional film)
- Visual testing (a last resort since this requires equipment to be shut down to allow for internal inspection)

“Phased array dual transducers are an improvement in ultrasonic detection and characterization of internal corrosion compared to conventional transducers” (Pellegrino and Nugent 2015). Phased array is possibly one of the best alternatives to confirm corrosion detected with conventional UT, since access to only the external side of the vessel is needed (unlike visual testing), and it does not matter if the vessel is full of seawater or oil, which may hinder radiographic testing. The drawback is the client is going to have to cover the additional costs involved with phased array, which may require more specialized technicians, purchase of new equipment, and probes.

Another option is profile radiography. Tangential radiography is popular for corrosion detection (ASNT 2002, p. 519).
Due to the large source-to-film distances needed, this technique is not practical for large-diameter vessels; however, tangential radiography is practical for small- to medium-diameter piping.

As stated in the Nondestructive Testing Handbook, third edition: Vol. 4, Radiographic Testing, radiography does not work very well for in-service examinations as the vessel is likely to contain water or product of some type, which would attenuate the radiation beam and cause an unsatisfactory radiographic image.

Random spot thickness readings on a vessel are not enough to detect internal corrosion on a vessel. The vessel should be scanned in 300 mm × 300 mm (12 in. × 12 in.) grids at areas where internal corrosion is suspected.

Also, each grid should not be scanned slowly but rather with a fast back-and-forth motion (while ensuring probe overlap), since we humans are much better at detecting a change in pattern when it happens sharply. According to research by Drury, this fast “windshield wiper action” is quite efficient at detecting small diameter pitting due to a sudden drop in the echo pattern (Drury 1997).

Ultrasonic angle beam examinations are more suitable in most instances because they need access to one side only, and the water in the vessel would not pose a problem (ASNT 2002, pp. 526–527).

Angle beam inspection would be suitable to detect an in-service discontinuity such as fatigue cracks but as illustrated in Figure 2, angle beam inspection is not a very reliable technique for corrosion testing (ASNT 2007, p. 220). The corrosion indication gives a very low signal response or even no echo at all (ball bouncing off bumpy surface).

In Part 2 of this article series, we will try and develop a solution to have fewer false calls of detected indications using conventional UT alone with compression waves and also analyze two cases where wall loss was reported initially as internal corrosion but later was reviewed as either inclusions or laminations after numerous follow-up inspections by various technicians. For the client, to send out different technicians to retest components multiple times is a very costly expense (requiring helicopters, boats, accommodation, and so on), so it is imperative that during the initial inspection the technician classifies any detected indications correctly, thus avoiding any unnecessary follow-up visits.

REFERENCES