# Problems associated with the strict application of Thresh-holding techniques to the MFL inspection of Tank Floors

For nearly two decades it has been acceptable to many in the tank inspection business to use Magnetic Flux Leakage techniques for the inspection of tank floor plates and, at the same time, apply rigid accept/reject criteria based on signal amplitude. In some cases, it has also been claimed that it is possible to rely on the MFL data, alone, to determining the remaining wall thickness of tank floors.  This has proved to be a critically flawed approach to this application of MFL because it fails to address the underlying limitations of the technique.
In order to apply thresh-holds and expect reliable results there are certain assumptions to be made and variables to be controlled for this approach to be valid.

1. Signal amplitude is relative to remaining wall thickness.
2. Saturation levels in parent material remain constant.
3. Material magnetic properties remain constant.
4. Type and shape of corrosion is uniform.
5. No variation in corrosion product dispersal.
6. All MFL signals are from corrosion.

1. MFL as applied to the detection of underside corrosion is a volumetric inspection. ie. The signal generated from any flaw is dependant upon the overall volume loss associated with the flaw and not just the minimum remaining wall thickness. It follows, therefore, that flaws with essentially the same remaining wall thickness dimension can exhibit  large variations in amplitude dependant upon the overall volume loss of that flaw. It also follows that flaws with essentially the same volume loss can, in fact, exhibit significant variations in remaining wall thickness. Bottom line is that it is unreliable to associate signal amplitude with remaining wall thickness.

2. Saturation levels in the parent material can vary dramatically due to variations in the contour of the plate, which is seldom perfectly flat. This leads to changes in lift off of both the magnetic bridge and the sensors resulting in significant variations in amplitude from identical flaws at different locations. This can and does lead to both under and over assessment of indications. This limitation can have an exponential effect on the signal amplitudes displayed. Systems that incorporate sensors measuring absolute values of flux density eg. Hall sensors,  can be affected by residual fields or build up of ferritic debris around the sensor head. This can result in under assessment in the first case and over assessment in the second.

3. It has been noted that the amplitude associated with a given flaw can vary dependant upon the direction of scanning. This can be due to the method and direction of rolling of the original plate. Material properties, which affect the permeability of the material, eg. Hydrogen embrittlement, stress, cold working, welding etc. can also affect the amplitude of the signal from any given flaw, although these effects are not thoroughly understood at this time.

4. Corrosion appears in all conceivable shapes and sizes but can be categorized in three main forms

   a. <u>Lake Type Corrosion</u>

      This is a general corrosion over large areas of the plate and is generally easy to detect and quantify owing to the large volume losses associated with this form of corrosion

   b. <u>Localized Pitting corrosion</u>

      These are isolated pits surrounded by nominal plate thickness. The smaller the volume loss the more difficult they are to detect. Ultrasonic prove up can be extremely difficult due to the overall shape of this type of flaw.

   c. <u>Bacteriological attack</u>

      This type of corrosion takes the shape of a wormhole type of corrosion and can be difficult to detect due to the small volume loss associated with this type of flaw. These generally appear in clusters and are easier to prove up as the top of the defect is much flatter than that of the isolated pit.

   **The application of a single threshold to the dynamic range of signals associated with these different forms of corrosion cannot be encompassed in one inspection. Sensitivity to one form of corrosion will not be valid for the others.**

5. Corrosion product takes up much more space than the parent material. This means that there can be large variations in amplitude from identical flaws dependent upon the dispersion of the corrosion product within the pit and the surrounding area. Tightly compacted corrosion product within the depth of the pit will result in much lower signal amplitudes than that from a pit where the corrosion product has been widely dispersed. This does not normally effect the Ultrasonic evaluation of indications.

6. Not all signals detected during an MFL inspection are from corrosion flaws. Any localized change in permeability due to, but not limited to, rust, scale, arc strikes, puddle welding etc. will result in signals. In some cases, variations in lift off can result in spurious indications from the sensors. The combined effects of the above can be extremely prevalent during the inspection process, depending upon the surface condition of the floor plates being inspected. Most thresh-holding equipment has no real time display and cannot differentiate between real and spurious signals on the fly. This can lead to many false calls. Automated mapping systems suffer from their inability to differentiatebetween real and spurious indications on the fly and therefore record an inordinate amount of unreliable data. It is extremely difficult to separate the real from the false data offline.

It goes without saying that due to the influence of any or all of the above on signal amplitude it is quite likely that some recordable indications will go undetected by thresh-holding equipment when the preset sensitivity is adversely affected.

In order to carry out the most reliable and accurate inspection of the tank floor it is necessary to locate and evaluate all areas that are highlighted during the inspection process, regardless of amplitude. Ultrasonics is currently the only method that can accurately assess the through wall dimension of indications.

It is in the tank owner's interest to know about all the detectable corrosion on his tank floor in order to accurately assess the remaining life of that floor in line with the requirements of API 653. If a threshold is set by the equipment at some arbitrary level, it must be assumed, in the absence of any other data, that the balance of the floor is corroded to a level just below that set by the equipment. The calculated life of the floor could be extended considerably if all the corrosion is located, quantified and repaired selectively.

This begs the question as to why the Industry still accepts this flawed approach to this application. There is a strong movement within the NDT Industry to remove the technician from the decision making process and apply automated techniques that are computer controlled and rely on data algorithms to assess the severity of indications rather than the judgment of an operator. There are many techniques and applications in NDT that are perfectly suited to this approach but the MFL Inspection of Tank Floors is not one of them. The purpose of any NDT is to provide accurate and reliable information in the most efficient way possible, not to make the job easier for the technician at the expense of the validity of the inspection. This application of MFL, with all it's limitations, requires that the technician is included in the decision making process and must have all the information necessary at his disposal to accurately assess the severity of any indications detected. A real time display that shows all the information above the background noise is vital to this process and is no more difficult an exercise for the technician than that of a manual ultrasonic examination where the required concentration levels can be much higher.

# Computer Mapping of MFL Signals

Some customers are not comfortable with a generated report of results which detail only the indications detected and evaluated, but rather prefer a hard copy report of all the areas tested in the form of a computer-generated map. The map has a very limited value for the following reasons and is actually counterproductive in this application.

A computer map is generated from the base data as a series of color coded signal amplitude levels and suffers from the same limitations as the single level thresh-hold technique described above. The manufacturers of this type of equipment are aware of the limitations of this approach and claim that they apply data analysis algorithms to determine the remaining wall thickness no matter what the shape or base size of the indication. This would only be possible if the following applied.

**1.**

**The leakage field has the same shape and size as the actual defect**.

**NOT TRUE** . The actual leakage field is much larger than the defect that it represents and it's profile is somewhat smoothed compared to the actual shape of the defect. (Analogy - No matter what the shape of a rock in a fast flowing shallow canal, the profile at the surface will be effectively smoothed and over a much larger area than the size of the rock.)

**2.**

**MFL is a high-resolution inspection tool.**

**NOT TRUE** MFL point detectors are not currently available, and even if they were it would be a pointless exercise to profile the leakage fields for the reasons outlined in 1. above. The lack of resolution associated with the technique means that it is almost impossible to separate individual indications that are close to each other. Applying an algorithm to establish remaining wall thickness based on a combination of signal amplitude and number of channels affected is extremely unreliable, especially in the case of localized pitting corrosion and through holes. The highest spatial resolution claimed by mapping scanners is generally no less than 15mm. This dimension is larger than the base size of pitting that can extend all the way through a 6mm thick plate

**All recorded indications are as a result of corrosion pitting**

**NOT TRUE** Except on new, very flat, smooth and clean plate, a large number of spurious signals are generated during the inspection process. These can be caused by, but not limited to variations in lift off, scanner grounding, arc strikes, puddle welding surface condition and under-floor anomalies. It is almost impossible to filter out or annotate these anomalies on the fly when scanning and mapping is conducted at the speed of the current crop of scanners. Circa 0.5 meter/sec. The resulting map is a mixture of true MFL signals and spurious signals with no method available to differentiate the two other than a comprehensive ultrasonic evaluation.

Both the single level thresh-holding and mapping techniques result in way too many false calls and can lead to unnecessary repairs being carried out on perfectly good plate. It is necessary to reduce false calls in order to ensure that the technician conducting the Ultrasonic prove up does not become so complacent that he does not expend the necessary effort in locating and quantifying the true MFL corrosion signals, bearing in mind that localized pitting is sometimes very difficult to detect and measure using compression wave ultrasonics techniques.

A lot of the problems detailed above regarding the limitations of both the single level thresh-hold and mapping approach are not immediately apparent in laboratory conditions or during trials conducted using new plate and man made defects. Corrosion is, by nature, extremely irregular in shape and conforms to no real pattern. To represent it in a test or trial using man made conical pits introduced with a drill bit or slots and smooth shallow areas made by grinding is a poor method of evaluating how equipment performs in the real world environment. Examples of real corrosion on real tank floors are a much better test of the capability of MFL scanners.

There are many claims made regarding the supposedly High-Tec approach of mapping scanners to the MFL Inspection of Tank Floors. In truth, there have been very few real advances in sensor or magnetizing technology that have had a significant impact on this application. The High-Tec part is in the adoption of computers to juggle the data and produce impressive graphical reports. Very little effort has been expended on the improved gathering of the raw data. The old adage of “Garbage In – Garbage Out” still applies. Even a small improvement in data gathering can have a significant impact on the reliability of inspections. This cannot be said for improvements in data presentation brought about by computer manipulation of the raw data.