NDT OF STORAGE TANKS

“THE TRUTH ABOUT MAGNETIC FLUX LEAKAGE AS APPLIED TO TANK FLOOR INSPECTIONS”

Introduction

Magnetic Flux Leakage Inspection techniques have been widely used in the Oil field Inspection Industry for over a quarter of a century for the examination of pipe, tubing and casing both new and used. It is only in the last ten years that this inspection technique has been applied to Above Ground Storage Tank Floors in an attempt to provide a reliable indication of the overall floor condition within an economical time frame. In most cases these inspections are being carried out by Industrial Inspection NDT Companies who do not have the depth of experience in the technique that most of the Oil field Tubular Inspection Companies have.
At the same time this relatively new application of Magnetic Flux Leakage brings with it some additional problems not evident in the inspection of tubulars where certain parameters can be quite closely controlled. Probably the greatest of these is that tank floors are never flat, whereas tubulars are generally always round. The ability to obtain any reasonably consistent quantitative information is seriously impacted by this general unevenness of most tank floors. The application of rigid accept/reject criteria based on signal amplitude thresholds has proved to be absolutely unreliable as regards truly quantitative information. A more realistic approach is required in the application of this inspection technique and in the design of the inspection equipment to ensure that there are fewer incidences of significant defects being missed.
The following paper outlines some of the major considerations that need to be addressed in order to achieve reliable, fast and economical inspections of Above Ground Storage Tank Floors.

Magnetic Flux Leakage

In order to understand some of the problems associated with this particular application of Magnetic Flux Leakage it is necessary to understand the basic principles of the technique. Everybody is familiar with the ability of a magnet to “stick” to a carbon steel plate. This is due to the fact that magnetic lines of force (flux) much prefer to travel in the carbon steel plate than in the surrounding air. In fact this flux is very reluctant to travel in air unless it is forced to do so by the lack of another suitable medium. For the purposes of this particular application a magnetic bridge is used to introduce as near a saturation of flux as is possible in the inspection material between the poles of the bridge. Any significant reduction in the thickness of the plate will result in some of the magnetic flux being forced into the air around the area of reduction. Sensors which can detect these flux leakages are placed between the poles of the bridge. Figure 1. Graphically illustrates this phenomenon.

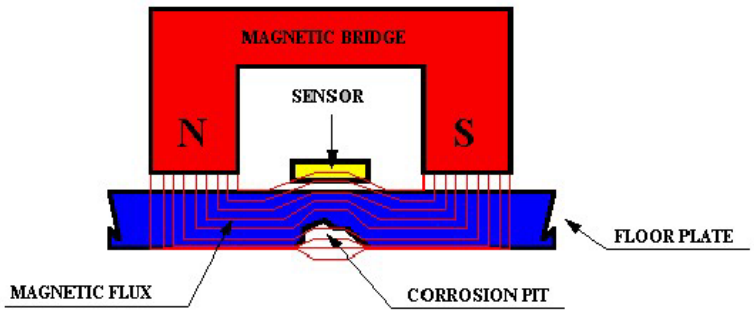

Fig. 1.

The Inspection Environment

In order to optimize the effectiveness of the inspection it is necessary to consider the environment and address the physical restrictions imposed by the actual conditions found when examining the majority of tank floors.

Climatic Conditions

Invariably the range of temperature and humidity conditions will vary enormously world wide. The effect on both operator and equipment must be taken into consideration. Human beings do not function well in extremes of temperature. Use of the equipment should not place too great a burden on them from either a physical or mental point of view. In other words the simpler, more reliable and easy to use the equipment is made the more reliable will be the results of the inspection.

Cleanliness

By their very nature the majority of Above Ground Storage Tanks are dirty and sometimes dusty places to work. The Conditions in this regard vary widely and are dependent upon how much effort the tank owner/operator is willing to expend in cleaning the floors in preparation for Magnetic Flux Leakage Scanning. As an absolute minimum a good water blast is necessary and all loose debris and scale removed from the inspection surface. The surface does not necessarily have to be dry but puddles of standing water need to be removed. The cleaner the floor can be made the better the inspection that can be achieved.

Surface Condition

Significant top surface corrosion and/or buckling of the floor plates represent a serious limitation to both the achievable coverage in the areas concerned and also the achievable sensitivity. Whilst it is understood that very little can be done to improve this situation prior to inspection it must be considered in the design of the equipment and its effect on the sensitivity of the inspection appreciated by both the owner/operator of the tank as well as the person conducting the examination. Any physical disturbance of the scanning system as it traverses the floor will result in the generation of noise. The rougher the surface the greater the noise and hence a significant reduction in achievable sensitivity.

Equipment Design Considerations

It is vital that Magnetic Flux Leakage equipment produced for this particular application is designed to handle the environmental and practical problems which are always present. A piece of equipment designed in a laboratory and proved in ideal conditions invariably has significant short comings in the real world application. Some of the major considerations are discussed in the following paragraphs.

Electromagnets/Permanent Magnets

Powerful rare earth magnets are now available and are ideally suited to this application. They are more than capable of introducing the required flux levels into the material under test. Electromagnets by comparison are excessively bulky and heavy. They do have an advantage in that the magnetic flux levels can be easily adjusted and “turned off” if necessary for cleaning purposes. Permanent magnet heights can be adjusted to alter flux levels but the bridge requires regular cleaning to remove ferritic debris. The build up of debris can have a significant impact on system sensitivity.

Sensor Types

There are basically two types of sensors currently in use. Coils and Hall Effect Sensors. They are both capable of detecting the flux leakage fields caused by corrosion on tank floors. There is a fundamental difference, however, in the way that they respond to leakage fields and generate a response.

Coils

Coils are passive devices and follow Faradays Law in the presence of a magnetic field. As a coil is passed through a magnetic field a voltage is generated in the coil and the level of this voltage is dependent on the number of turns in the coil and the rate of change of the flux leakage. From this it can be seen that speed will have some influence on the signals obtained from this type of sensor

Hall Effect Sensors

Hall effect sensors are solid state devices which form part of an electrical circuit and, when passed through a magnetic field, the value of the voltage in the circuit varies dependent on the absolute value of the flux density. It is necessary to carry out some cross referencing and canceling with this type of sensor so that true signals can be separated from other causes of large variations in voltage levels generated by the inspection process.

There is much disagreement within the industry as to which is the best type of sensor to use in this application. Hall Effect Sensors are undeniably more sensitive than coils. However, in this application coils are more than adequately sensitive and are more stable and reliable. If one draws from the experience of the Tubular Inspection Industry it will be seen that, for the inspection of used tubing, the preferred sensor is still the humble coil. Hall effect sensors prove to be too sensitive when surface conditions are less than perfect which results in an unreliable inspection and the generation of significant false calls.

Technique Application Considerations

Coverage Limitations

It is virtually impossible to achieve 100% coverage using this technique due to the limitations of physical access. The equipment should be designed so that it can scan as close as possible to the lap joint and shell. There are obviously compromises to be made as the wheel base of the scanner is an important consideration on floors that are not perfectly flat. Smaller scanning heads can be used in confined spaces to increase coverage.

Topside/Bottom Side Differentiation

Magnetic Flux Leakage can not differentiate between the response from topside and bottom side indications. Some attempt has been made to use the eddy current signals from topside defects for the purposes of differentiation based on frequency discrimination. This is unreliable on real tank floors due to the uneven nature and lack of cleanliness of the inspection surface. In most cases visual techniques are perfectly adequate for this purpose. Contrary to what is expected the Flux Leakage response from a topside indication is significantly lower in amplitude than that from an equivalent bottom side indication. This means that, to some degree, the influence of the top side indications can be “tuned out” to allow a reliable assessment of the under floor condition.

Quantitative Assessment of Indications

Magnetic Flux Leakage is a qualitative not quantitative inspection tool and is a reliable detector of corrosion on tank floors. Due to the environmental and physical restrictions encountered during real inspections no reliable quantification of indications is possible. Amplitude alone is an unreliable indication of remaining wall thickness as it is more dependent on actual volume loss. Defects exhibiting various combinations of volume loss and through wall dimension can give the same amplitude signal. Couple to this the continually changing spatial relationship of magnets, sensor and inspection surface and it is absolutely clear that an accurate assessment of remaining wall thickness is virtually impossible. Truly quantitative results can only be obtained using a combination of Ultrasonics and Flux Leakage.

The Single Level Threshold

Commercial expediency has brought about the implementation of accept/reject criteria using a single level threshold approach. MFE Enterprises as manufacturers of Flux Leakage equipment do not support this approach. As previously stated the amplitude of signals alone is not a reliable indicator of remaining wall thickness. Significant indications can be completely missed especially in cases where the equipment does not incorporate some form of real time on line display. In order to carry out a reliable inspection the operator must have as much information as possible available to him in the form of an easy to interpret real time display. The use of a blind single threshold is absolutely indefensible in this application.

Computerized Mapping of Flux Leakage Signals

It is obvious from my previous comments that the mapping of flux leakage signals has limited value in this application as it can only reliably be used to offer qualitative and not quantitative information. There is some value in a system that allows the selective mapping of areas with the ability to manipulate the data in order to correlate the output with the accurate information obtained by Ultrasonics. This would allow the generation of selective graphical information for reporting purposes should hard copy presentation of the data be required. The limited advantages of this type of equipment must be weighed against the risk associated with the use of computer equipment in this environment.

Operator Training and Qualification Requirements

Currently there is limited training available to users of the equipment in regard to this application. MFE Enterprises Inc. recognize this fact and offer initial basic training in flux leakage and the use of the equipment on delivery of the scanner. This is obviously geared to our equipment and is quite specific. The ultrasonic prove up necessary must be carried out by personnel who are adequately trained and qualified. It must be remembered that this is not just “thickness measurement” but rather corrosion evaluation and the technician must have a full understanding of the technique that should be applied. This is not a subject that can be covered within the limits of this paper. It will, however, be the subject of the next in a series of papers regarding the NDT of Storage Tanks.

Conclusions

Certain conclusions can be drawn from the above if one agrees with the facts and opinions that have been expressed.

1. Throwing technology at any given inspection problem does not always reap the expected rewards.

2. The environment and physical restrictions must be addressed in the design of the equipment.

3. Despite the undeniable greater sensitivity of Hall Effect Sensors it is apparent that coils are more reliable for this particular application.

4. Flux leakage is a reliable fast and economical method of providing a qualitative assessment of the overall floor condition.

5. Truly quantitative information is only possible by applying ultrasonics to the areas detected by flux leakage.

6. The amplitude of a Flux Leakage signal is an unreliable indicator of remaining wall thickness.

7. The industry needs to address the training, qualification and certification of personnel carrying out Flux Leakage Inspections of Storage Tanks.