



**RTD - INCOTEST<sup>®</sup> - FOR THE DETECTION OF CORROSION  
UNDER INSULATION**

by

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**ABSTRACT**

Inspection for insulated pipe/vessel wall thinning may be expensive because the traditional non-destructive examination (NDE) method, Ultrasonic Testing (UT) requires the removal and reinstallation of the insulation over what may be many metres of the piping/vessel system.



*Figure 1 - Typical Insulated Components*

The UT method can generally only be performed during scheduled outages, which in some cases are now being extended to as much as four and five years.

A technique capable of being used “on stream” is the RTD Incotest<sup>®</sup>, which measures the average remaining wall thickness of ferro-magnetic material through an insulation layer.

The system is based on the principle of Pulsed Eddy currents, and was first derived in the United States in the late 1980's. A brief history and an overview

of the theory of operation of the RTD Incotest<sup>®</sup> follows.

**Introduction**

The measurements are based on the phenomena that in a conductor within a variable magnetic field Eddy-Currents are induced.

If the conductor has magnetic properties the induced Eddy-currents are much stronger.

The magnetic field used for the measurements with RTD - Incotest<sup>®</sup> is generated by means of a (transmitter) induction coil powered by the RTD - Incotest<sup>®</sup> system.

The coil is placed directly onto the surface of the insulation sheeting at the location to be measured.

During a defined time a DC-current is sent through the coil causing a stable magnetic field in the pipe or vessel wall. After switching off the current the magnetic field drops rapidly to zero, generating Eddy-currents within the material under examination.

The duration of the Eddy-currents, within the enclosed magnetic field, is directly related to the thickness of the material.

The strength of the magnetic field and the Eddy-currents have no influence on the duration of the Eddy-currents.

The strength and the measurable duration of the Eddy-currents depend on the strength of the magnetic field as well as the conductivity and permeability of the material. These properties are all being monitored and measured by the RTD - Incotest<sup>®</sup> system.

**If the strength and duration are measured, the average wall thickness can be calculated.**

The common name for this method is:  
Pulsed Eddy Current (PEC)

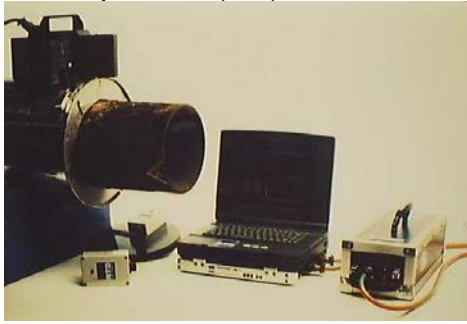


Figure 2 - RTD Incotest® an overview

### The history of PEC

The basic principle has been known for some time, but was first applied for wall thickness measurements by ARCO under the name “TEMP”



Figure 3 - ARCO TEMP an overview

ARCO is an American oil company who had the need for wall thickness measurements through insulation, and as such developed the method. After a successful application in Alaska for their own purposes they did not feel the need for further developments.

Although ARCO had no interest in further development, they had patented the principle. ARCO still believed that this method could be of interest for the other industry and/or NDT company's, and were looking for interested licensees.

A number of companies were selected and all were given a system for trials, RTD was one of these companies.

RTD received, after preliminary investigation on the applicability, the worldwide exclusive license for further development and application of the TEMP.

Three years of further developments from RTD on the basic method, signal processing, improving coil constructions and software, resulting in the current system, with all further improvements of RTD patented also.

Due to the fact that many customers were confused by the name “TEMP”, thinking that it has something to do with temperature measurements, RTD decided to change the name into “**RTD - INCOTEST®**”.

### THEORY OF OPERATION

To understand the mechanism of the examination, a few basic principles need to be explained.

#### The Magnetic Field

To be able to handle the signals, containing amplitude, and duration of the Eddy-current uniformly, it is essential to work with a defined magnetic field. At the point of contact between this magnetic field and the component being inspected there becomes an effective “footprint” that represents the area that is encompassed for the calculation of average remaining wall thickness, refer to figure 4. The smaller magnetised spot at the surface results in a higher resolution.

Various probe arrays are available that allow for the variations and combinations in material wall thickness and probe standoff.

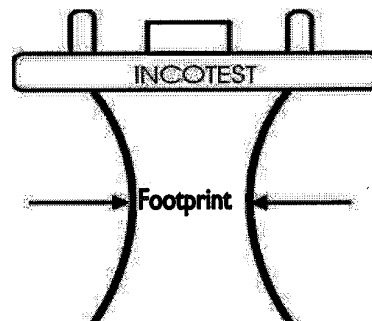


Figure 4 - Magnetic Field / Footprint relationship

For this reason the magnetic field is generated by means of DC current with an exactly defined duration. The strength of the current is defined by the coil resistance and battery voltage, the duration of this current is determined by the program and depends on the wall thickness to be measured.

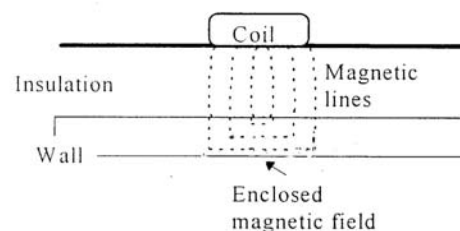


Figure 5 - Magnetic Field

After switching on the current through the coil, it takes a specific time before the magnetic field in the pipe or vessel wall is stabilised, this is caused by the induction of the coil and initial Eddy-currents in the material.

These stabilisation times depend on the wall thickness, so for larger wall thickness the pulse time is much longer than for thin wall thicknesses.

Typical values are: 200 msec for 6mm, and 2 sec. for 40mm wall thickness.

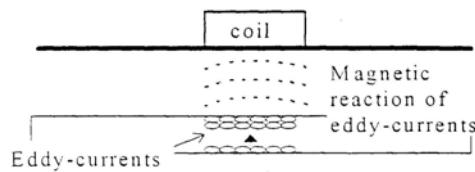


Figure 6 - Eddy Current Duration

The used field strength is far below the magnetic saturation point of normal steel, and no relevant residual magnetism is induced by several coils configured to one package, a combined magnetic field is generated with a special shape (focused beam) resulting in a small magnetised area.

### The Signal Amplitude

The strength (amplitude) of the Eddy-currents is measured on a distance (lift off / insulation thickness) by measuring the magnetic reaction field, picked up by the receiver coil.

The signal amplitudes of the Eddy-currents are inversely proportional with the square of distance between pick-up coil and the material surface.

$$S = \frac{C}{LO^2}$$

Where: S = signal strength (amplitude)  
C = coil constant  
LO = lift-off

The result of this relation is, that the signal amplitude rapidly decays at increasing lift-off.

Under normal circumstances the maximum lift-off is restricted to 1500mm (6 inches).

### The duration time of the Eddy-currents

The duration of the Eddy-currents is expressed by the symbol  $\tau$  (**tau**) and is proportional to the thickness to the material.

$$\tau = \mu_r \mu_0 \sigma d^2$$

*In this formula you find the typical material properties, permeability and conductivity.*

*Permeability stands for the relative ease of the magnetic domains to align themselves.*

*Conductivity indicates the number of electrons passing through the material in a certain time.*

### The pulse length

After activating the transmitter coil magnetic field rapidly build up.

However in the ferritic material of the pipe, it takes some time before the magnetic domains are aligned, and the magnetic field becomes stable.

Also during build up of the magnetic field, Eddy-currents do occur, but these Eddy-currents are not used.

For this reason the duration of the electrical pulse need to be adapted to the material thickness, to be sure that the measurements are performed on base of stable magnetic field. The time interval between the pulses will have the same duration as the pulse.

The measurements are performed during this time interval between pulses; the duration of the Eddy-current to be measured depends on the thickness.

To compensate for the influence of remaining residual and other magnetic fields, one measuring cycle consist of one positive and one negative polarised magnetic field.

The measured Eddy-current signals are subtracted and averaged, thus some effects on the signal amplitude are compensated for.

The numbers of cycles are programmable resulting in a higher accuracy, but this in turn results in a longer measuring time. As standard, 2 cycles are used.

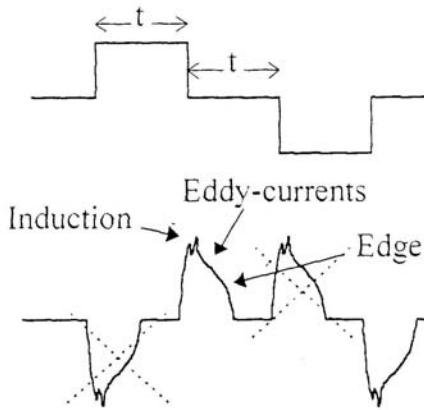


Figure 7 - Positive and negative Polarised Magnetic field.

### Measurement of the amplitude and duration of the Eddy-currents

The signal strength of the Eddy-currents propagating out of the material is very low, in the order of  $0.01\mu\text{Volts}$ . This is the same strength as broadcast, radio signals. Due to this very low voltage output electrical noise (electric motors) may interfere with the signal.

To measure the amplitude and duration of the Eddy-currents a high sensitive pick-up coil (receiver) is essential.

This is achieved by using a receiver coil with a large number of turns.

In the receiver the signals are amplified and digitised. The digital signals are transferred to the computer for further processing.

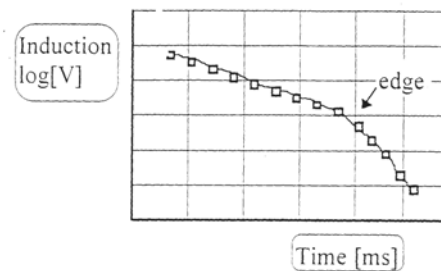


Figure 8 - Induction / Time relationship of useable field

The fact that these signals are very low in strength would imply the sensitivity might be affected due to external noise.

For this reason the coils are carefully constructed with certain compensations and the received signals are processed with filtering algorithms.

During measurements the coil needs to be kept very stable to the surface to avoid disturbances to these weak signals.

### The reference measurements (learning process)

To determine the combined influences of the actual material properties (permeability, conductivity and sheeting signals, if present) as function of the signal strength at the applicable lift-off, a reference measurement must be performed.

This measurement is performed automatically in several steps. The results of these steps are (partly) presented at the screen, (for acceptance by the operator) and stored by the program for further processing during measurements.



Figure 9 - Screen Presentation of Reference Reading.

If the results of this reference measurement are rejected by the operator, parameter changes can be made by the operator and a new reference measurement must be made.

If no applicable parameter setting is available or the selected setting is not optimal, a measurement showing the raw signals can be performed and displayed. By means of this signal and the present scale, the operator can select the most optimal parameter setting.

### Shape and Strength of the Magnetic Field

Although the shape and the field strength can be roughly determined by a calculation, for practical reason it is more efficient to perform a reference measurement with a coil optimised for application at the applicable wall thickness and present insulation thickness. In that case the signals incorporate all variables like shape and strength of the magnetic field, permeability, conductivity and lift-off.

The practical dimensions of the magnetic field at the material surface (the footprint) are determined by the construction of the coil. A combination of more coils within the construction enables modelling of the magnetic field and is called focusing. This focusing effect is used for reduction of the footprint.

Each coil type is designed for a specific wall thickness range and a specific lift off range. However for each coil type, the footprint will increase at larger lift off, this results in a reduced resolution, and weaker signals. This means that the dimensions of detectable local wall thickness reductions are of the same order as the footprint. Eg. there is a strong relationship between, lift off and resolution "footprint".

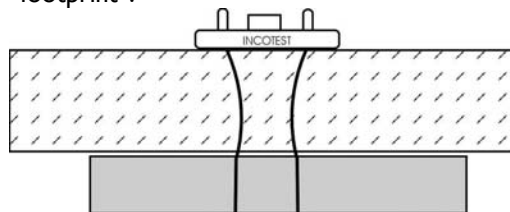


Figure 10 - Area of averaging – footprint

Also the geometry has an influence on the shape of the magnetic field. This means that a strongly curved surface results in different footprint dimensions, measured in axial and radial directions.

In general you can conclude that a large probe is not suitable for small diameter piping, but small probes can be used for small piping and plane surfaces and visa versa.

### **Influence of Insulating Materials**

All commonly used insulating materials like; glass, wool, rock wool, asbestos, PU foam, scales of silicate, concrete and all kinds of fire proofing, have no influence on the magnetic field and induced Eddy-currents.

However the binding ties or band, fitting supports, fixing materials and composition of the weatherproofing has influences on the examination.

To be able to compensate for these influences the parameters of the RTD Incotest® settings need to be adapted.

The material of the weatherproofing can be painted linen tape, plastic, stainless steel, aluminium, zinc, or (galvanised) steel plate.

The metal weatherproofing is in common called sheeting.

Bandage is mostly combined with chicken wire (as reinforcement) has no or very little influence on the examination results.

Metal sheeting will influence the examination results, however in most cases they can be compensated for. Multiple layers of metal sheeting can strongly affect the results and in some cases a useful signal cannot be obtained.

### **Stainless Steel Sheetting**

Common stainless steels used for sheetting are non-magnetic and the conductivity is less than normal steel, so the influences on the signals are very low, this means, low amplitude Eddy-currents. The sheetting does not influence the magnetic field and no corrections need to be made and the footprints remain unchanged.

### **Sheet of aluminium, zinc or alloys**

Aluminium and zinc have no relevant magnetic properties but the conductivity causes strong Eddy-currents. Due to the fact that the coil is located direct on the sheetting the Eddy-currents appear directly at the beginning of the signals and cannot be eliminated properly. For this reason the presence of aluminium or zinc sheetting need to be programmed in the RTD Incotest®. Aluminium or zinc has no influence on the shape of the magnetic field, so the footprint remains unchanged.

### **Sheetting of Steel Plate or Galvanised Steel Plate**

Steel plate has strong magnetic properties and a good conductivity. As a result of this, the magnetic field is strongly influenced and relatively strong Eddy-currents are generated. The distortion of the magnetic field results in less focusing thus a larger footprint. The diameter of the footprints will increase by about a factor of two. Providing the wall thickness of the steel plate / galvanised sheetting is at or below 1.0mm the eddy-currents generated in the sheetting are compensated and have no influence on the results of the measurements. The signals from the wall may be weaker than with other sheetting types or without sheetting.

### **Generating Eddy-currents**

The magnetic field necessary for generating Eddy-currents is built up by means of a transmitter coil or coils activated with a DC-current. This current has rectangular shape and consists of a positive and negative pulse. Both pulses are equal in time and have the same amplitude. The time between the pulses is exactly as long as the pulse.

The times are programmed and controlled by the RTD Incotest® and depend on the material thickness (time window). The coils are powered with 20 to 24 Volts from the battery. The current depends on the construction of the coil(s), but are practically the same for a specific coil type.

One cycle (stack) consist always of one positive and one negative pulse. The operator can define the number of stacks.

An increasing number of stacks improves the accuracy but generates more heat in the coil and takes more time for a measurement.

Eddy-currents are generated during each variation of the magnetic field. This means, with one stack, four lots of Eddy-current are generated in the material. No measurements are performed during the initial induction of the pulses.

The measurements are performed immediately after switching off the current, this time frame being the same time as the length of the pulse.

### **Receiving the Eddy-currents**

The Eddy-currents to be measured are picked-up by means of the receiving coil(s).

The signal strength of the Eddy-currents coming from the back wall are in the 0.01  $\mu$  Volt range. So in each turn of the coil this voltage is induced. The receiver coil has many turns so the summarised signal is n-times stronger (where n is the number of turns). These signals have amplitude of 0.001 Volt to 0.1 Volt and are connected to the amplifier by means of shielded cables. The frequency band (bandwidth) of the Eddy-currents is 0.2 Hz to 1000 Hz.

The receiver coil shall also detect and measure the signals from the self-induction of the coil system. These signals are very strong and will mask a part of the Eddy-currents to be measured. The effect takes place at the beginning of the time to be measured, so the

self-induction has influence on the minimum thickness that can be measured. The duration and strength of these self-induction signals depend mainly on the construction on the coil system.

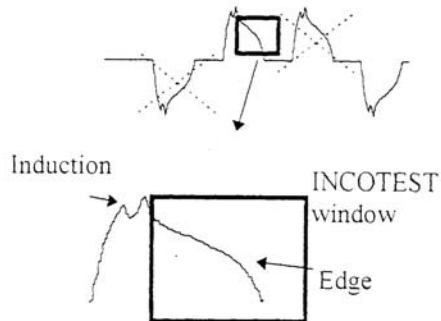


Figure 11 - Full measurement curve showing self-induction as well as a useable window.

### **Conditioning of the Signals**

In the RTD Incotest® the signals are amplified and filtered (for the eventual present main signals of 50 or 60 Hz). The amplification factor ranges from 100 to 100000 times and is controlled by the RTD Incotest® program eg. selected by the operator or automatically by the selected operation mode.

### **Digitising of the Signals**

After amplification and filtering of the signals, they are fed through a sampler into an analog/digital converter.

### **Statistical Processing of the Digital Signals**

The first processing of the signals is immediately performed in the PC. From all incoming signals, the mean value of each subsequent (increasing) number of sample is determined and stored over a time equal to the activating time of the transmitter coil with a maximum of 65 mean values.

This storage takes place in a cell corresponding the position in a matrix as defined by the operator (measuring location). With these 65 mean values, a (statistical) reliable curve can be determined.

Depending on the number of stacks (cycles) these mean values from all the positive and negative pulses are added and give a new mean value of all pulses. With these summarised mean values, the shape of the curve is more precisely determined.

### **Temporary Storage of the Settings Calibration and Received Signals.**

All temporary storage is performed on the hard-disc and ensures that in case of a power interrupt, the setting and data are still available.

### **Validation of the signals**

The shape of the calibration curve will be fixed and stored at the moment of the operators' acceptance of the calibration. During measurements the new curve based on the received signals is compared with the calibration curve (indicated in yellow at the screen). The statistical coincidence between both curves is indicated by the statistical factor "CHI<sup>2</sup>".

A factor of 1 indicates a perfect fitting of both curves. The value of the factor CHI<sup>2</sup> is displayed on the screen during each measurement and give the operator the opportunity to validate the measurement or to reject the results and perform a new measurement.

The curves do not need to have the same vertical position at the screen. A measuring curve lower than the calibration curve indicates weaker signals generally associated with a larger lift off. Measuring curves higher than the calibration curve mostly indicates a lower lift off. The fitting of the curves (coincidence in shape) is statistical and not influenced by the positions of both curves. A horizontal shift of measured curve indicates differences in the material properties. Little deviations are acceptable; large deviations may required a new calibration (reference measurement).

*If the signals are good comparable with the reference signals, without too much noise, the practical accuracy of the system will be  $\pm 0.5\text{mm}$  ( $\pm 0.02$  inch). The reproducibility at good documented measuring locations will be  $\pm 0.2\text{mm}$  (0.008 inch).*

### **Practical Applications for the use of RTD Incotest®**



Figure 12

In figure 12 an operator can be seen utilising the RTD Incotest® for the measurement of an 8" insulated pipe clad with stainless steel weather sheeting



Figure 13

Figure 13 shows an operator utilising the RTD Incotest® for the measurement of an insulated ammonia storage vessel with aluminium weather sheeting.



Figure 14

Figure 14 - shows utilisation of the RTD Incotest®, via rope access, for the measurement of an insulated LPG storage tank with non-metallic weather coating.



Figure 15

Figure 15 shows an RTD Incotest<sup>®</sup> probe in position taking readings on an offshore caisson through the coating and marine growth.



Figure 16

Figure 16 shows an RTD Incotest<sup>®</sup> Contact probe in position taking readings through 5mm of coating, this probe provides an area of averaging of as little as 25mm.



Figure 17



Figure 18

Figure 17 and 18 shows an RTD Incotest<sup>®</sup> Contact probe in position taking readings for internal corrosion at the junction point of a nozzle to pipe.

## Conclusion

RTD Incotest<sup>®</sup> has now been utilised at numerous facilities throughout Australia and overseas with more than satisfactory results being obtained. Locations of reduced wall thickness that have been detected via the RTD Incotest<sup>®</sup> have had the results confirmed via Ultrasonic and or Radiographic examinations.

In all instances extensive savings have been made by the companies concerned with regards reduced plant down times and the exclusion of the necessity to remove the insulation when information on average remaining wall thickness is required.

New applications for this technology are continually being made to further the advantages of the system. Among these are the use of a surface contact probes for wall thickness measurements through painted, corroded / scaled and marine growth effected areas.

## References

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Cohn, M., and J. A. de Raad, "Nonintrusive Inspection for Flow-Accelerated Corrosion Detection" ASME 1997 PVP-Vol. 359, Fitness for Adverse Environments in Petroleum and Power Equipment, pp 185-195 (July 1997)