Pulsed Eddy-Current (PEC) Inspection through Insulation

Method statement of an advanced non-destructive testing technique for inspection through insulation.

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Inspection through insulation opens unexpected opportunities

Shell Global Solutions in Amsterdam has developed an inspection instrument that can measure wall thickness of steel objects like pipes and vessels without contacting the steel surface. The instrument can measure through coatings, insulation materials, weather sheeting and even corrosion products.

Inspection through insulation. Pulsed eddy-current inspection of a steel skirt through fire-proofing material.

The main benefits this offers include:

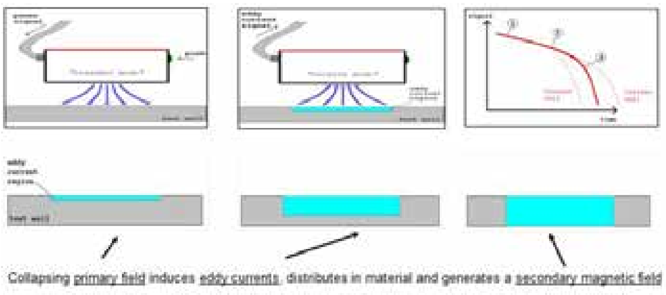
- No production loss: the instrument can inspect while the equipment is in service.
- Ability to monitor the integrity of the plant while in service helps to prevent unplanned shutdowns.
- Reduction of inspection costs: no need to remove insulation materials.
- Significant lower cost for underwater inspections.

The PEC instrument has been applied extensively at Shell refineries, chemical plants and offshore installations. The technology is now being commercialized and available at TÜV Rheinland Sonovation.

The technology is based on pulsed eddy current, or simply PEC. The principle of measuring wall thickness measurements with PEC has been around for many years, but only recent developments have made it a practical method.

Working principle

Pulsed eddy-current is an electromagnetic method to determine wall thickness of electrical conductors. A simplified explanation of the method is illustrated in the figures below. The PEC instrument probe is placed against the metal weather sheeting of an insulated pipe or vessel. A magnetic field is created by an electrical current in the transmitting coil of the probe. This field penetrates through the weather sheeting and magnetizes the pipe wall. The electrical current in the transmission coil is then switched off, causing a sudden drop in the magnetic field. As a result of electromagnetic induction, eddy-currents will be generated in the pipe wall. The eddy-currents diffuse inwards and decrease in strength. The rate of decrease of the eddy-currents is monitored by the PEC probe and is used to determine the wall thickness. The thicker the wall, the longer it takes for the eddy-currents to decay to zero.



PEC has been used to inspect the annular ring of atmospheric storage tanks while in service. The PEC probe was inserted in "rabbit holes" dug underneath the tank bottom to obtain a wall thickness profile of the first 0.7m

In–service inspection of a coated offshore riser.
PEC proved that seemingly innocent damage to the coating was in fact hiding severe corrosion.

Strengths and limitations

All NDT techniques have both strong and weak points. The relevance of these strengths and weaknesses varies greatly from application to application and needs to be considered separately for each application. In order to do so, the extents and limitations of the pulsed eddy-current technique are addressed below.

The main strengths of the pulsed eddy-current technique are:

No need for direct contact.

Wall thickness can be measured through any material not conducting electricity: insulation material, coatings, paint, concrete, bitumen, dirt, sludge and so forth. The layers can be as thick as 200 mm.

PEC can measure through aluminum and stainless weather sheeting. It is in principle also possible to measure through galvanized weather sheeting, but performance is lower.

Very good reproducibility of PEC readings at the same locations, typically ±0.05 mm. This makes PEC very suitable as a corrosion monitoring device.

Wide temperature range: -100ºC to 550ºC (-150ºF to 1000ºF).

Up to 1000 points can be stored in the data logger and downloading of stored data to personal computer is done using an Excel spread sheet.

There is no need for surface preparation. In particular, surface roughness does not affect the PEC readings. Besides it is not required to remove corrosion products, even up to 20mm thick.

The above qualities ensure that the instrument can be applied in-service.

The PEC instrument can be operated by remote control, e.g. for use in Remote Operated Vehicles (ROV's).

Suitable for use in safety zone 2 (i.e., no sparks are generated under normal conditions).

The main weaknesses of the pulsed eddy-current technique are:

Only applicable to carbon steel and low-alloy steel.

PEC integrates over a relatively large foot print. As a result, the smallest defect that can be detected has a diameter of about 50% of the insulation thickness (between 30 and 120 mm insulation thickness). PEC is therefore suitable for general wall loss, but isolated pitting defects cannot be detected.

The PEC wall thickness readings are relative values, showing variations in wall thickness on the object being inspected. Whilst this is sufficient in many applications, absolute readings can only be obtained by a wall thickness calibration at one point of the object.

The PEC readings depend on the electromagnetic properties of the material. Variations in these will influence the PEC wall thickness readings. Such variations have occasionally been observed on vessels. Variations in material properties within one object will result in spurious variations in PEC wall thickness readings, typically at a rate of 10%.

The geometry of the test object should be simple; e.g. straight sections of pipe work. Wall thickness readings are affected by nearby nozzles, welds, internals, and support structures.

Typically, a clearance of 2" is needed. It is not possible to inspect under steam tracing, near supports and in sharp bends. The limitation in geometry is relevant when inspecting for corrosion under insulation.

The pulsed eddy-current instrument

The main characteristics of the pulsed eddy-current instrument are:

- Single operator tool, portable instrument, handheld probe.
- Instrument weighs 6 kg (12 pounds); measures 350 x 200 x 130 mm (13.5 x 8 x 5”).
- Battery operated.
- Suitable for use outdoors: robust design and splash-water tight.
- No computer required during data taking.

Data collection

Is simple and fast (about 5 seconds per reading; still being improved) and can be done by a single Level I operator. The PEC instrument takes point measurements. During the 5-second PEC reading, the probe must be held stationary; the probe may not be moved while collecting data.

Data analysis

The instrument gives an instantaneous estimate of the wall thickness. For some applications this is sufficiently accurate and no further analysis is required.

More demanding applications require more detailed analysis. After the inspection the instrument is connected to a PC and the stored data is downloaded. A Level II or Level III inspector can process data using dedicated software. Off-line processing can be done remotely with data being sent by electronic mail. The Level II or Level III inspector does not need to be on site nor present during data collection.

The separation of data collection and analysis proves to be cost-effective.

Typical performance parameters		
Wall thickness	3 – 35 mm	012″ – 1.4″
Typical accuracy	± 0.5 mm	±0.02″
Same spot reproducibility	± 0.05 mm	±0.002″
Lift-off range	0 – 200 mm	0-8″
Pipe diameter	75 mm – flat plate	3″- flat plate
Material temperature	-100°C to +550°C	-150°F to 1000°F
Defect sensitivity	Diameter larger than 50% of the insulation thickness (at 30 – 120mm lift off)	
Remaining wall thickness of defect	± 1 mm	±0.04″

Applications

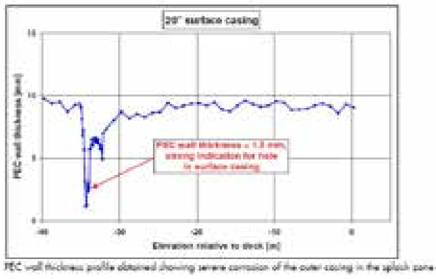
A vast body of experience has been obtained over the past years. The PEC instrument has been tested at over 20 different Shell Operating Companies. Local Shell staff have provided abundant feedback, greatly contributing to the development of the PEC instrument. Several example experiences are presented below.some 250 implanted weld defects.The separation of data collection and analysis proves to be cost-effective.

Corrosion under insulation

A large range of insulated and coated equipment, including pipes, vessels, columns, heat exchanger shells and storage tanks, has been inspected for corrosion under insulation (CUI). Inspections have been carried out on equipment both with and without metal weather sheeting around the insulation.

The inspection involves taking several readings on the equipment and searching for variations in wall thickness. An example of wall loss on a failed pipe is displayed below.

Here, readings were taken along the circumference of the pipe and normalized to 100% at the top of the pipe (12 o'clock). A wall loss of 30% was observed near the bottom of the pipe.



PEC wall thickness profile obtained showing severe corrosion of the outer casing in the splash zone

In-service inspection of a heat exchanger at high temperature. Several readings are taken along the circumference of the shell.

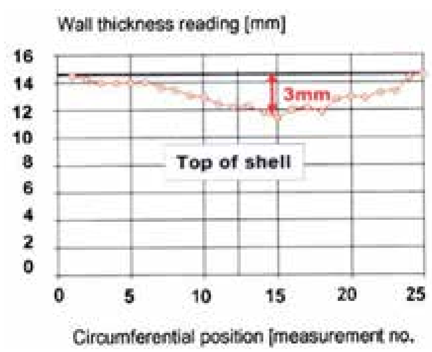
High temperature applications

PEC inspection is also possible at high temperatures. By placing a ceramic block in between probe and hot wall, the probe can be shielded from the heat and readings can be taken as normal. In this way, PEC is able to produce accurate measurement at temperatures up to 550°C.

An example of a high-temperature inspection involved a refinery where two heat exchanger shells had been mistakenly exposed to hydrogen chloride attack, resulting in suspected wall loss at the top of the shells. Insulation material was removed from the heat exchangers to take ultra sound wall thickness readings.

The high temperature of the heat exchangers hampered the ultra sonic measurements and reliable data could only be obtained at a limited number of points. PEC performed more successfully. PEC data,collected along the circumference of the heat exchanger at several points, proved consistent with the ultra sound data at those points producing reliable ultra sound readings.

The worse case of wall loss detected by PEC at the refinery is displayed in the figure opposite, showing about 3 mm wall loss. As this was acceptable from the integrity point of view, the asset owner decided not to replace the shells.

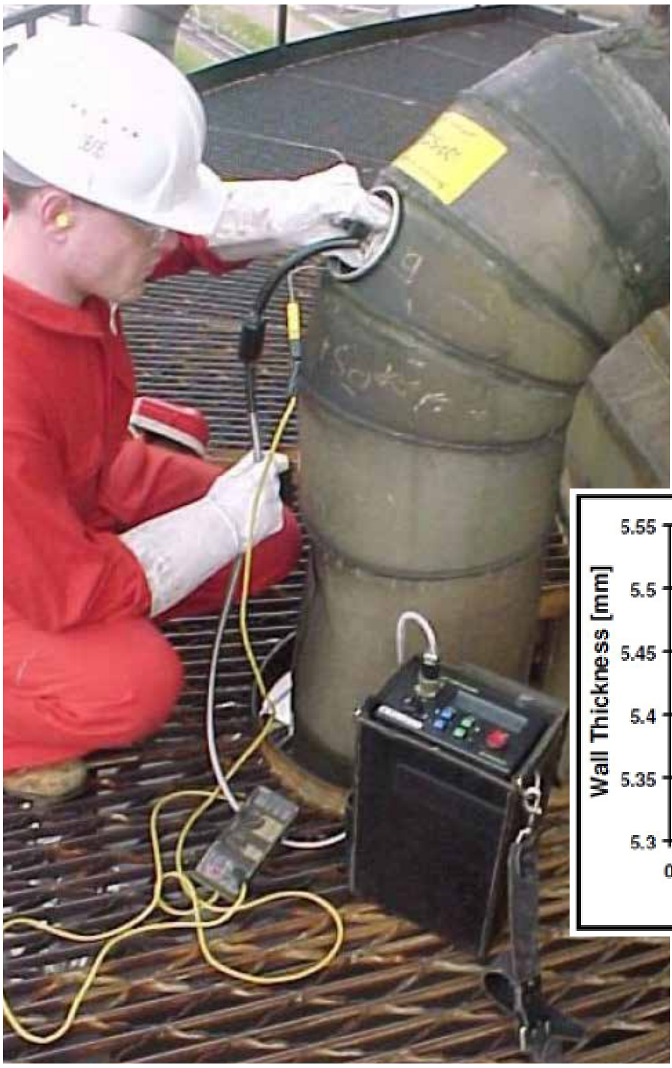


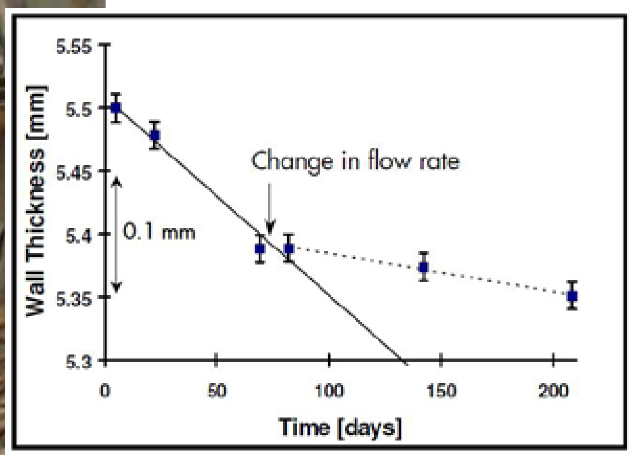
Wall thickness along the circumference of the heat exchanger shell.

In-service corrosion monitoring

Pulsed eddy-current measurements are generally highly repeatable. This makes it well suited for corrosion monitoring purposes. Corrosion rates can be deduced from wall thickness measurements over a time interval at fixed locations. PEC corrosion monitoring was recently put to the test on a refinery furnace outlet operating at 420°C.

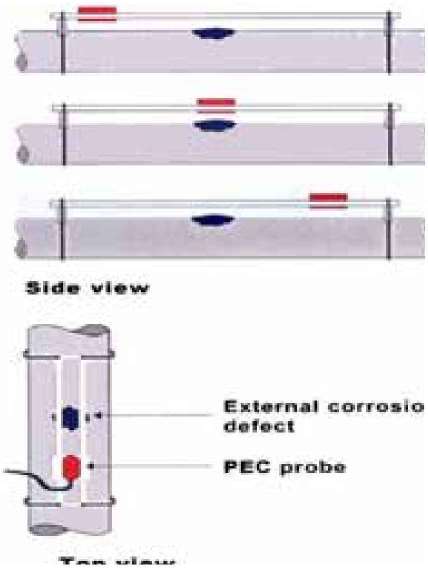
The asset owner discovered that an inappropriate material had been used in the construction of the elbows of the outlet, which led to unacceptable high corrosion rates. Measurements at two-week intervals confirmed the expected corrosion rates. The high reproducibility of PEC readings at one spot allowed the asset owner to quickly and accurately monitor the degradation of the plant over time.





In addition to monitoring the elbows, PEC readings were also taken at appropriately constructed locations where no measurable corrosion rates were expected..

Indeed, the wall thickness at these locations showed a less than 0.04 mm (one standard deviation) difference between readings separated by 5 weeks, confirming the reproducibility of the PEC readings.



Measuring remaining wall thickness through an external defect without removing any corrosion products.

Inspection of heavily corroded equipment

Another application of PEC is in-service assessment of heavily corroded pipes and vessels. Often, safety considerations do not allow the corrosion products to be removed on stream. In this case, PEC has the crucial advantage that it can be applied without disturbing or even touching the corrosion products.

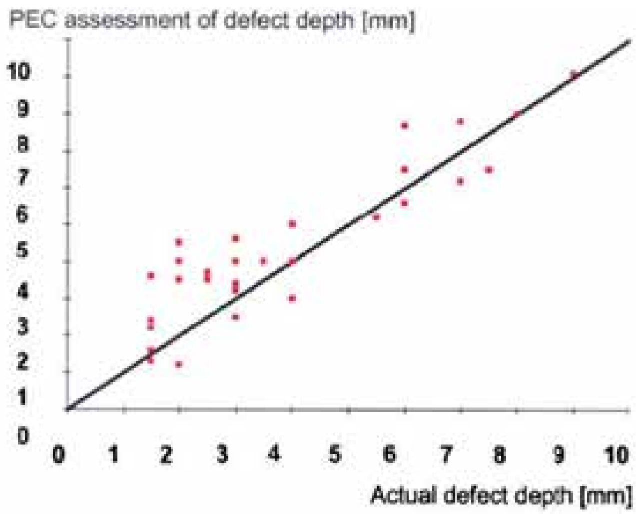
The inspection procedure involves taking reading on the defect and comparing these with readings of the area directly next to it. To this end, a slider was developed to move the probe over the defect area without having to touch the surface of the pipe.

The PEC method was validated on 40 different natural defects on a non-critical water line. PEC was used to measure the remaining wall thickness underneath layers of corrosion products while the equipment was in service.

After the PEC measurements, the corrosion products were removed and the remaining wall thickness was determined by a mechanical profilometer.

The figure shows the correlation between the two methods. Although the correlation is not perfect (standard deviation 1 mm), it shows that PEC can distinguish between serious defects and less severe cases of corrosion.

This information is of great value, as it allows determining how much pipe needs to be replaced and how much can be simply repaired by grit blasting and painting.



Minimal remaining wall thickness of 40 naturally corroded defects

Pulsed eddy-current has been used with much success for underwater inspections of coated risers and caissons. The advantages of using PEC over conventional technologies are that there is no interference with production, it doesn‘t require surface preparation and there is no need to remove coatings.

Inspections were carried out both in the ‚splash zone‘ as well as in deeper water. The splash zone inspections were conducted using abseil techniques, whereby inspectors and the PEC tool remained above the water level.

The PEC probe was moved through the splash zone down to eight meters under water by a jig guiding the probe along the riser or caisson.

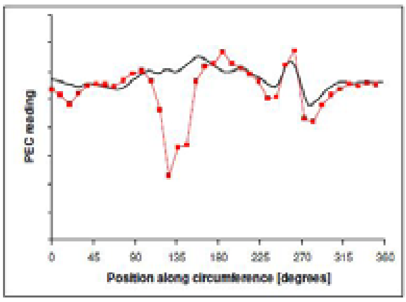
The inspection has been applied at several locations now. In one instance, a defect with only 4 mm remaining wall thickness was detected in a riser with 10 mm nominal wall thickness.

Inspection of a caisson using rope access techniques. The PEC probe (not seen on the picture) is moved along the caisson using a jig.

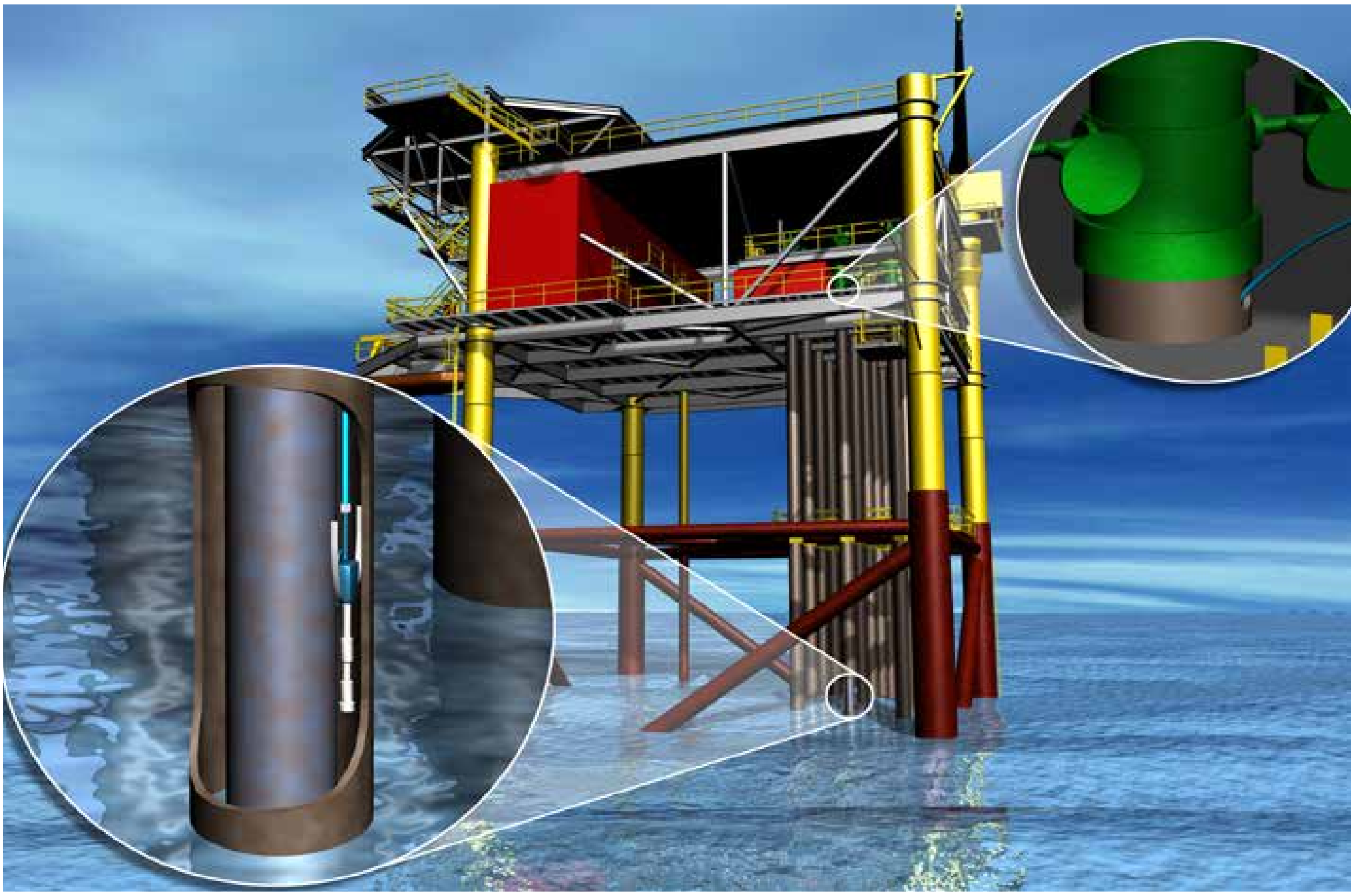
Corrosion of surface casings of offshore wells

Corrosion of surface casings on platforms is normal. Structural integrity includes axial loads, which can lead to well failure. after 15 years of service.

Because many wells are currently at risk, a solution has been designed to measure in specific areas inside the well casings in the splash zone.



Wall thickness variation along circumference. The black curve indicates the expected wall thickness; deviations of the measured curve (red) are due to wall loss.



A PEC probe is lowered on a long lead to inspection the casing in the splash zone.

Did you know?

TÜV Rheinland Sonovation has over twenty years of experience with advanced non-destructive testing. Our inspection team is one of the best resourced in the world. Our involvement is equipment development, inspection solutions and accredited training courses demonstrate our commitment to these techniques.

About TÜV Rheinland:

Founded 140 years ago, TÜV Rheinland is a global leader in independent inspection services, ensuring quality and safety for people, the environment, and technology in nearly all aspects of life.

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