REFORMER TUBES & COMPONENTS

Comprehensive services for testing reformer tubes.

FOERSTER

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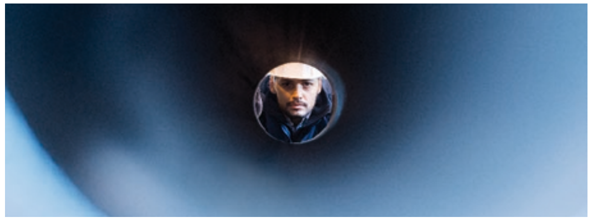


New name, same mission

A critical service for ensuring that petrochemical plants operate safely and efficiently is the non-destructive testing of the materials used – especially centrifugally cast reformer catalyst tubes and their associated components. For many years, the two leaders in this field have been the German company Magnetische Pruefanlagen (MP) and, operating on the other side of the globe, the American company US Thermal Technology (USTT). MP was a fully owned subsidiary and essential part of the FOERSTER Group, a global concern headquartered in Reutlingen, Germany; USTT was MP's long-term partner for tube inspections in the western hemisphere from 1989 until 2020, when it was acquired directly by FOERSTER. In 2021, MP itself was integrated into the Institut Dr. Foerster GmbH & Co. KG. Finally, at the end of 2021 the FOERSTER Group completed the acquisition of Quest Integrity's Syngas business unit. This transaction included the business unit's technical staff and its LOTIS and MANTIS inspection technologies.

Now joined under the FOERSTER umbrella and known as the Business Unit (BU) 'Inspection', these expertise partners together continue the important work that the sector has relied on for well over 30 years. While the names have changed, the mission remains the same: providing comprehensive services for all your reformer tube testing needs.

Making quality visible

The FOERSTER Group develops, manufactures, and distributes instruments and systems for non-destructive material testing using, among other methods, eddy current (EC) technology. FOERSTER also produces highly specialized, customized eddy current probes for detecting cracks and carrying out microstructural testing.

Test results can be markedly improved by employing customized sensors that are designed specifically for the complex geometries of the components under test. For calibrating the testing systems, FOERSTER fabricates artificial test defects that differ in depth, width, and length, together with standard calibration blocks.

El Dorado Chemical Site, El Dorado, Arkansas; part of LSB Industries

FOERSTER
Parent Company of MP and USTT
Owner of LOTIS and MANTIS Technology

Reformer tube testing with LEO-Scan

Reformer tube testing

An important focus of BU Inspection is to provide its customers with comprehensive services around reformer tube testing. This testing is performed in ammonia, methanol, direct reduction iron (DRI) and hydrogen plants all around the world.

The automated testing is conducted by our highly trained, non-destructive testing (NDT) inspectors, who are qualified in accordance with EN ISO 9712. These inspectors are graduate engineers with numerous technical certifications of Level 2 and Level 3 in various disciplines, including eddy current methodologies. Because we design, build and specify the components used, the testing of the reformer catalyst tubes can be reliably executed even under conditions that require technological expertise.

It is recommended that all our customers utilize the complete inspection package of applicable and appropriate techniques offered by FOERSTER to ensure cost-effective and reliable monitoring of the complete asset. This exhaustive approach ensures that the reformer tubes and their components are regularly tested at appropriate intervals throughout their entire service life. When indicated by the inspection results, prompt corrective action can be taken to maximize production, eliminate downtime and provide a safer workplace.

Services include

- Baseline scanning of the reformer tubes (when new, prior to commissioning)
- Regular scanning of centrifugally cast reformer catalyst tubes throughout their service life (every 2 to 4 years)
- Remaining life assessment (RLA) of the reformer tubes using non-destructive methods
- Destructive testing of the reformer tubes using selected sample tubes via third-party laboratories
- Inspection of outlet pigtails for strain and magnetic permeability
- Eddy current ID inspection of the top ends
- Support services on an as-needed basis

External tube inspection (LEO-Scan)

For the purpose of inspecting centrifugally cast reformer catalyst tubes used in steam methane reformers, FOERSTER has developed and built the proprietary `LEO-Scan' system, an inspection carried out from the outside of the tubes, using the Eddy current and Laser technique.

The complete LEO-Scan system is mounted on a unique tube crawler. The special construction of the crawler transports the sensors from the furnace floor – depending on reformer design – all the way up to the roof. This includes the areas below the top of any flue gas collection tunnels, if present. The probes and lasers are mounted near the bottom of the crawler, allowing readings to be taken in the most critical areas of the typical down-flow reformer, since this is considered the hottest portion of the tube. The device is also intended to test reformers with tube-to-tube clearances as narrow as 20 mm (0.79 in). This allows the inspection of furnace designs with very tight clearances from the OD. Other crawler and probe configurations are also available to test up-flow reformers. No cleaning of the tubes is required.

The eddy current system is calibrated on an actual reformer tube 0.4 m (15.75 in) long, split lengthwise, and has an electrical discharge machining (EDM) notch on the ID, which serves as an artificially induced crack. The calibration proves both defect identification and penetration of the full wall thickness.

The LEO-Scan device uses a dual-axis laser system to measure the OD of the tubes over their entire tube length inside the firebox. OD measurement, while not the primary inspection tool, is an important secondary test for identifying creep. The use of lasers for this inspection ensures repeatability and allows the tube diameter to be recorded digitally over the complete tube length inside the reformer.

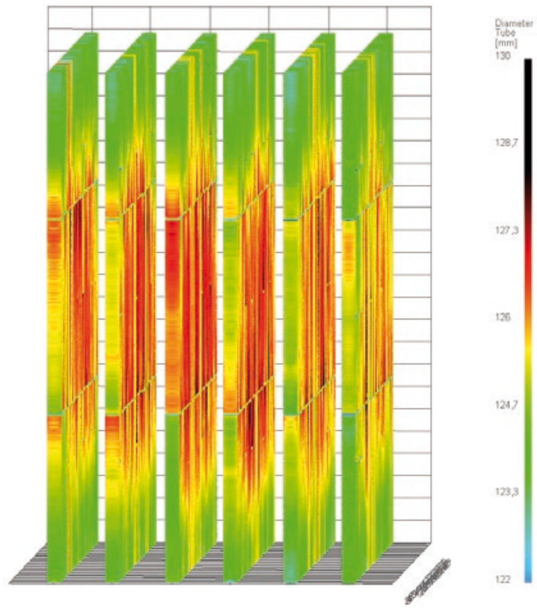


Figure 1: Typical inspection results

This technique can spot trends in the firing profile of the furnace and help isolate areas with catalyst loading problems or issues with the catalyst's condition. Issues with flue gas flow can also be isolated using this data. OD results and EC readings are taken and displayed simultaneously, which facilitates this interpretation.

This is the only proven EC system in use today that penetrates the complete tube wall thickness up to 24 mm (0.95 in). As the crawler ascends the tubes, proprietarily designed EC probes record signals for evaluation. Not only does the system record the variations in magnetic permeability, but more importantly, the system processes and continuously monitors it, thus allowing the EC system to detect cracks and defects within the tube wall and the surfaces of the OD and the ID. Since the system functions electronically, LEO-Scan requires no couplant (e.g. water), which makes the entire examination absolutely repeatable.

Repeatability is a key element for this type of testing. It allows the results from each inspection to be overlaid and compared directly from year to year. Any deviation in the signals can be correlated to damage in the tube wall. This is in stark contrast to ultrasonic testing: variation in the coupling strength eliminates repeatability and the difficulty in penetrating these materials – for example, due to the as-cast roughness and large coarse grain sizes (high dissipation/damping) – make ultrasound a poor choice for centrifugally cast tubes.

Using up to four lasers (depending on tube-to-tube clearances), the LEO-Scan measures the outside diameter at the same time as it conducts the EC testing. The lasers allow for maximum accuracy and repeatability. Tube diameter measurements, taken as a secondary procedure that has the ability to reveal normal creep, can also help point to the probable conditions that caused the damage.

There are three scenarios through which damage can occur in reformer tubes

- It is possible for cracks to form without diametrical growth as a result of operational disturbances, catalyst issues or flame impingement (short-term overheating), flue gas flow distribution issues and thermal shock.
- Diametrical growth can form without cracking (long-term overheating).
- A combination of both.

LEO-Scan

LEO-Scan has the ability to expose such complex defects due to its combination of EC testing and laser measurements, which makes it one of the most thorough and effective systems on the market.

If warranted, based either on the inspection results or the material ageing, a remaining life assessment (non-destructive, strain-based approach) may be recommended. It will provide remaining life calculations based on experience and expert judgment for fitness-for-service (FFS) decisions, replacement strategy, and purchasing support of overall tube life management. The final outcome of this analysis provides our customers with an API-579 Fitness for Service Level II Assessment.

Figure 2 shows the superimposing of several years' worth of inspections done from the outside of the tube. Ideally these charts begin with a baseline inspection, which are then laid over the others with each successive inspection. This makes changes in the OD and EC signals immediately apparent and straightforward to evaluate. This graphic clearly shows the changes (growth) in the OD near the left side of the chart, which represents the bottom of the tube.

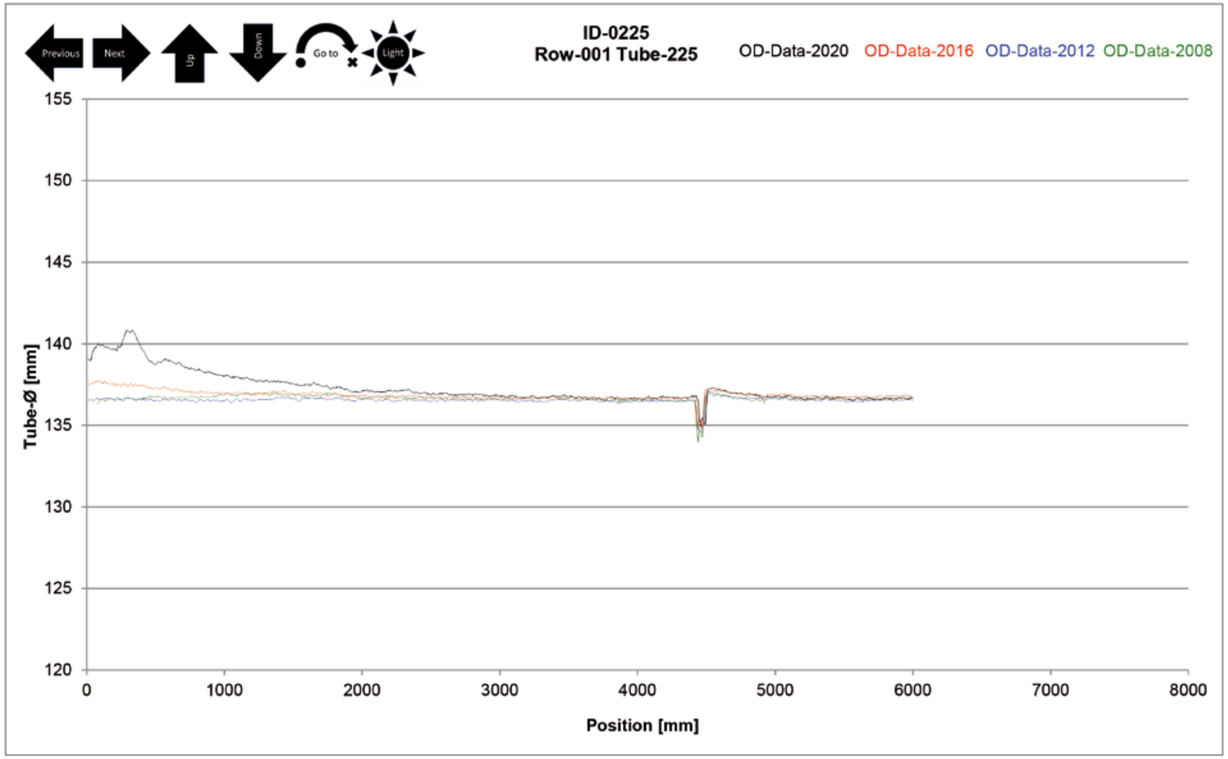


Figure 2: Four inspections of a reformer tube's outside diameter are superimposed to show changes over time (baseline taken in 2008 and inspections in 2012, 2016 and 2020)

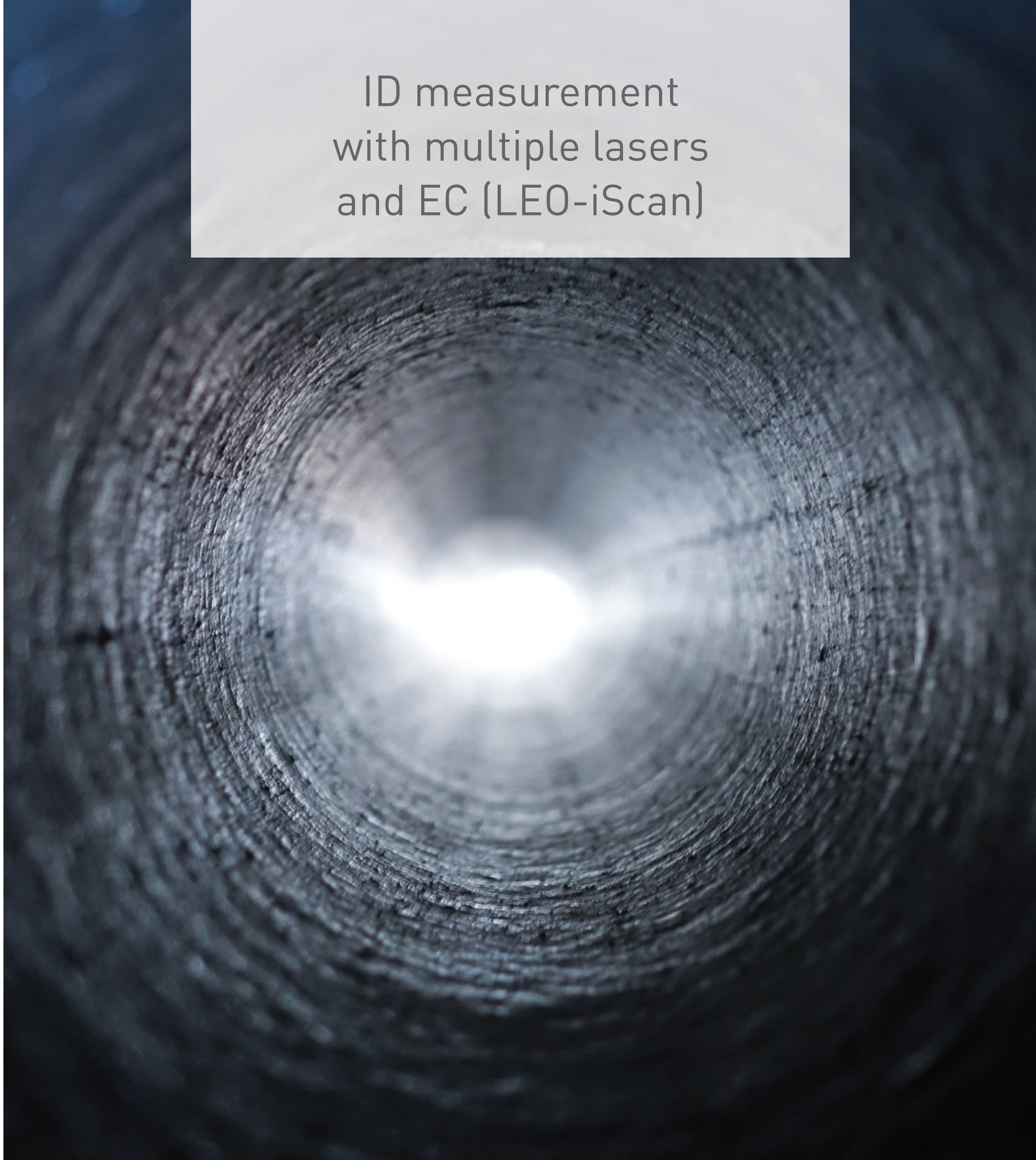
ID measurement with multiple lasers and EC (LEO-iScan)

A sophisticated new device developed by BU Inspection is now available: LEO-iScan. Having proven itself both rugged and reliable in field use, it encompasses a powerful laser unit that very accurately measures the ID combined with an EC system. The inspection is carried out starting at the top of the tube flange and continuing all the way down to the catalyst support grid. This is possible only when the tubes are undergoing catalyst replacement. Since the inside surfaces of the reformer tubes are machined, these readings easily show creep growth even in the absence of previous (baseline) data. The system uses eight lasers configured on four axes to gain a full picture of the tube's ID.

One advantage of using EC to inspect from the inside is the proximity of the probes to the site of potential creep damage, which generally starts approximately 1/3rd from the ID surface.

The system was developed for furnaces that may require monitoring for creep damage below the floor, or for tubes that touch each other due to significant bowing, thus making them inaccessible from the outside. It can also be used as a secondary control to verify a tube's creep condition.

The results show the tube diameter in a 3D, 360° view. This information can be presented for single tubes, single rows or the entire reformer.



Monitoring the condition of outlet pigtails

Wrought outlet pigtails are critical components that need rigorous inspection due to their location and intended function. For the identification and determination of creep, we have developed a unique device for measuring pigtails diametrically from the tube outlet to the manifold.

The measurements are taken on two axes; this configuration enables evaluation of diametrical growth of both the straight pigtail sections and the bends, taking into account the inherent (and normal) differences in diameter due to the bending process. Compared to manual gauge testing, this new system is very fast, reliable and repeatable. It also provides an accurate diameter profile over the complete length of the pigtail, resulting in an assessment of creep in digital form that can be used for future evaluations.

It is also possible to measure the permeability of the outlet pigtail using FOERSTER's MAGNETOSCOP. This is especially important when it comes to nipping of the pigtails in the event of a tube failure: here, it is important to determine that the material is in a suitable condition, i.e. with sufficient ductility, to permit nipping. The procedure can be employed on-line, without requiring a plant shutdown to isolate leaking tubes. Recently, many plants have required a shutdown, or at least a reduction of process flow to steam, just to allow nipping.

Inspection of top ends

The historically accepted standard for examining in-service reformer tubes in steam methane reformers (SMRs) has been to inspect the heated length of the tube within the furnace. However, recent trends have changed that perspective, due to the discovery of internal defects and damage in these heretofore uninspected portions of the tube at the top ends in some plant designs. Defects have been found in two completely different design arrangements: a top-fired, down-flow design; and a bottom-fired, up-flow design. In both, a damage mechanism known as "thermal fatigue" was to blame.

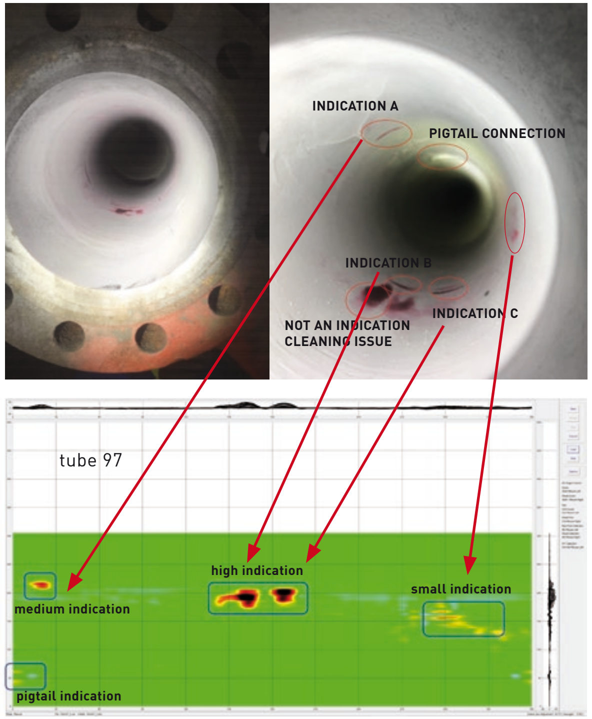


Figure 3: Representative scan of the top end showing defects

Figure 4: Typical top end

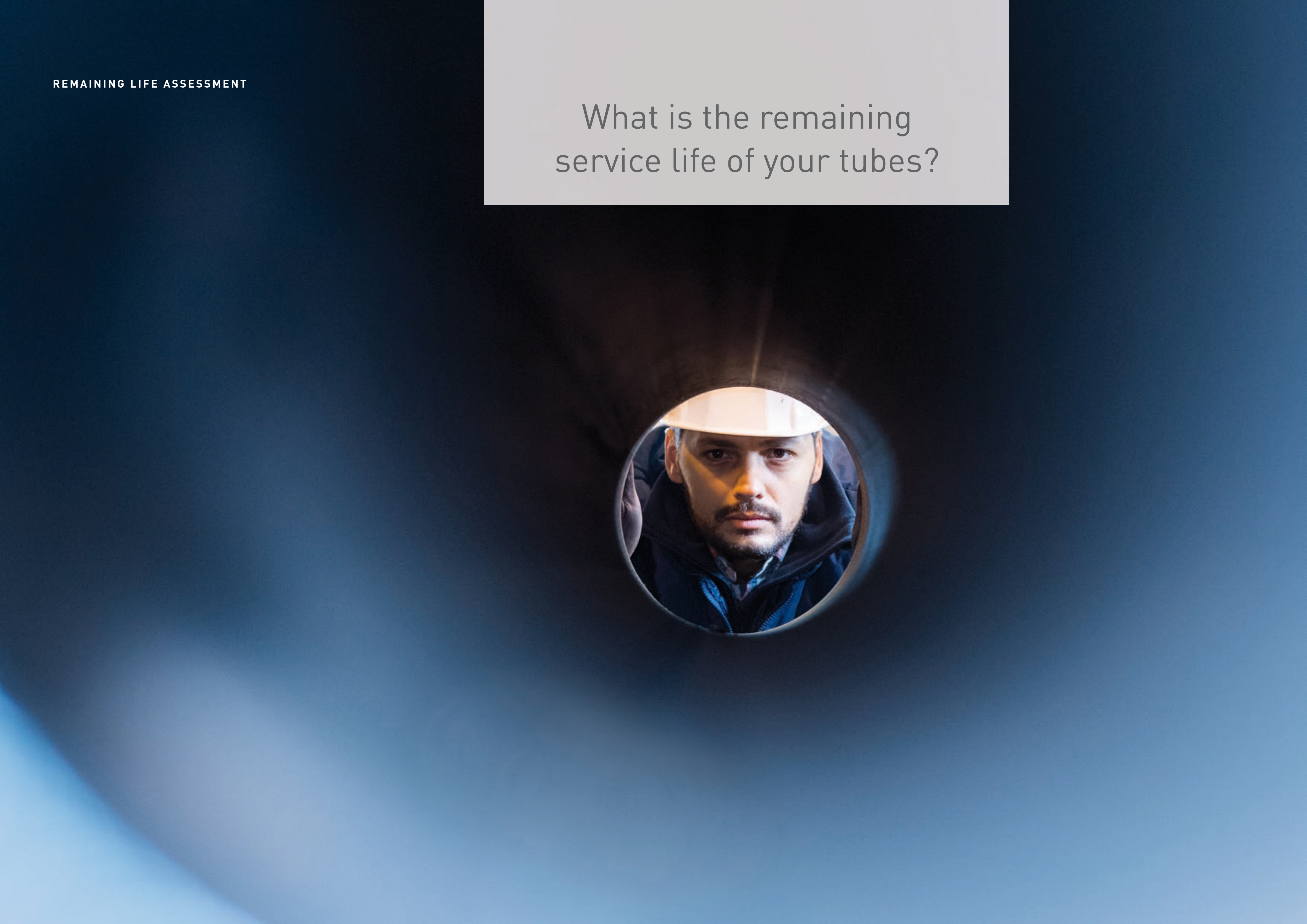
It is necessary to emphasize that these crack defects start on the inside and propagate towards the outside, offering no warning until an unexpected failure interrupts service. It is also important to know that these cracks typically show no measurable creep. Therefore, an effective inspection of the top ends must detect cracks rather than creep damage.

When failures of this type occur, they can cause catastrophic property damage, production outages and safety breaches. This is because a fire in the top ends of the reformer tubes, occurring in an area not frequently visited, can burn undiscovered for quite a while. Adjacent tube tops, inlet pigtails and structural steel can become overheated, setting off a cascade of further failures.

The BU Inspection has developed a reliable technique and a specialized device for checking these upper areas of the tubes to avert such disasters. A purpose-built eddy current probe scans the top ends for cracks and other signs of thermal fatigue. Timely identification of these flaws contributes to the safe and dependable operation of the reformer and can prevent fires that may result in significant losses.

Figure 3 displays a typical scan of the top end of the reformer tube, showing cracks in the tube wall that radiate outward from the inside surface. The customer verified the cracks with penetrant testing (PT). Prompt detection of such defects can increase the reliability and protect the value of the asset while ensuring safety.

What is the remaining service life of your tubes?



A proprietary software developed in a collaborative effort, TubeLife was created expressly to stop the gap in assessing the remaining service life of reformer tubes: before, there were no publicly available codes or practices that formally addressed the complexity of reformer tube life behavior. TubeLife achieves this by integrating strain and crack size data into its proprietary model.

In the past, estimates of this important quantity were based on the principles and elements of post-construction standards such as API 571, API 579, R5 and/or BS7910. However, the application of these standards is less than ideal, as they do not directly reflect the complexity of the damage mechanisms that affect the longevity of reformer tubes. A modified Dyson model incorporated into TubeLife assesses the strain accumulated over a given time period as a means of projecting material degradation and calculating the remaining service life. Furthermore, the analysis weights any eddy current measurements that indicate wall damage, since cracks usually initiate tube failure mode.

The software also draws on laser diametrical data for the strain measurement, along with process information and shutdown history.

The model calls on several degradation mechanisms that are known to occur in reformer tubes. These include thermal ageing/softening, strain softening, coarsening of the grain structure (especially secondary carbides) and increases in mobile dislocation density, creep void formation/cavitation and growth. The integration of multiple degradation types allows for realistic estimates of remaining life based on strain accumulation over the lifetime of the tube, coupled with accurate assessment of crack formation via the EC signals.

This assessment technique has been successfully executed for many companies worldwide.

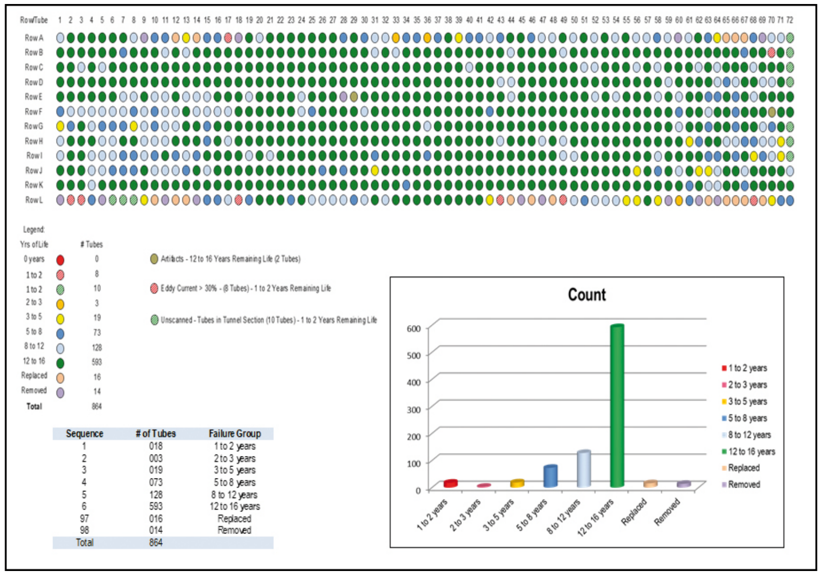


Figure 5: Typical output for the Remaining Life Assessment

Crack testing with eddy current

Non-destructive testing using the eddy current method

The keen attention paid to quality these days – not to mention the risks associated with product liability – increasingly necessitates 100% inspections. The EC method according to DIN EN ISO 15549 is a non-destructive, non-contact method for material testing. It reveals material defects such as cracks, pores, cavities and material artefacts, and it works quickly, reliably and economically – without requiring the use of coupling liquids.

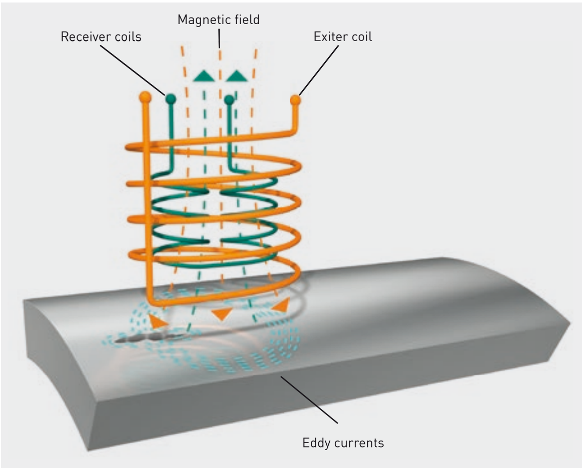


Figure 6: The principle behind eddy current testing

A magnetic field is generated by an excitation coil, which induces high-frequency eddy currents in the material. The resulting signal is usually recorded with a differential measuring coil. This received signal is evaluated against the amplitude and phase shift relative to the exciter signal, exposing even the smallest defects in the material.

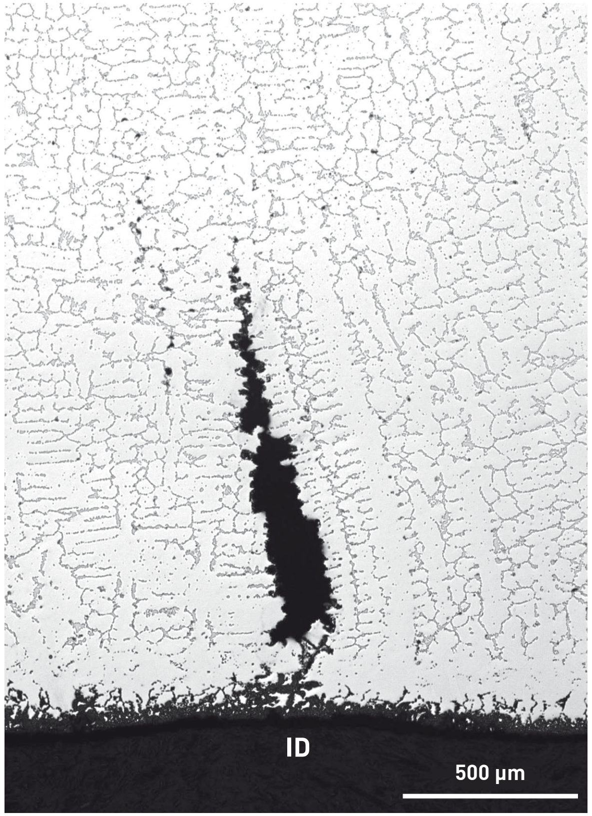
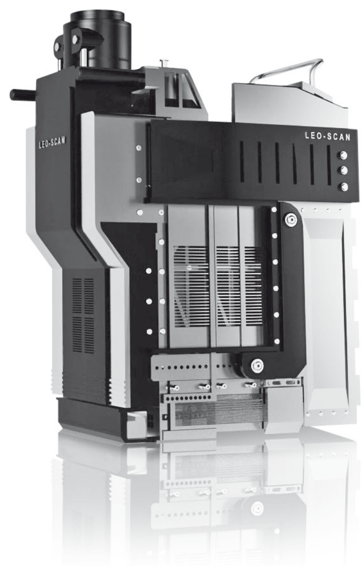


Figure 7: Higher magnification photomicrograph of creep fissure

Testing for cracks

For crack detection, the eddy current probe is moved along the length of a stationary sample. As long as there is no damage in the material, the eddy currents flow through evenly, because the electrical resistance is homogeneous. But wherever there is a crack, the eddy current density shows up as different from that of an undamaged part. This change is recorded and displayed as an error signal. The penetration depends on the frequencies in use: while higher frequencies concentrate closer to the surface, lower frequencies penetrate deeper into the material. Probe type, probe size and test frequency are chosen based on the type of testing desired and the material under test.



LEO-Scan

The FOERSTER test tower – Our true-to-life test facility for putting test equipment through its paces

The newly installed test tower, which contains several tubes in their original vertical extension (including the top flange), is a perfect representation of a catalyst tube row in a steam methane reformer. This configuration allows for realistic scanning conditions to trial new developments or optimize prototypes and modifications; it is now available for experiments with automated external (OD) and internal (ID) scanning systems. Furthermore, it is ideal for testing the software side in terms of applying control and data-collection programs in real time when using advanced EC mobile instrumentation.

At home around the world – rooted in Reutlingen, Germany

Operating worldwide – anytime, anywhere.

From the very start, the FOERSTER Group has worked to build out its worldwide network of experts to operate efficiently and prudently in global markets. Wherever in the world a need for reformer tube testing arises – our BU Inspection is there for you, ready to respond to your needs and requirements.

Headquarters

- Institut Dr. Foerster GmbH & Co. KG, Germany

Subsidiaries

- FOERSTER Instruments Inc., Americas
- FOERSTER (LOTIS & MANTIS), Americas
- US Thermal Technology Inc. (USTT), Americas
- FOERSTER (Shanghai) NDT Instruments Co., Ltd., China
- FOERSTER Japan Ltd., Japan
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- Calibre Petrochem SDN. BHD., Malaysia
- Leap Engineering Solutions, Pakistan
- Marant Polska SP z o.o., Poland
- Arsenal Group Co. Ltd, Russia
- Safetech Co., Ltd., South Korea
- Pipeline Supply Company LLC. (PSC), Sultanate of Oman

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