

Background

Cokebusters was requested by a European refinery to carry out an In-Line Inspection (ILI) of three separate sections of 6-inch furnace tube. The three sections of tubing had been removed from the furnace due to the presence of severe internal pitting corrosion.

The aim of the investigation was to assess the competence of the Cokebusters' Smart Pig at detecting and resolving these defects. The sections of tubing were sent to the Cokebusters Technology Centre (UK), where the tests were conducted.

Cokebusters Smart Pig

The Cokebusters' Mark IV Smart Pig is a single bodied un-tethered device, which employs a series of ultrasonic transducers to measure wall thickness and internal radius, circumferentially, along the full length of the heater coil, effectively scanning the process tubes for geometric abnormalities or defects.

The Smart Pig records and stores the received data to its on-board memory, which is later uploaded, via USB, for analysis and post processing.

Reporting formats include tabulated data, graphical plots and a customizable 3D reader version of the entire heater coil (C-scan).

Figure 1 – Example Cokebusters' Smart Pigs



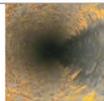
Testing

The three tube sections (C28, C29 and A27) to be tested were classified as described in Table 1.

An initial visual examination showed clear evidence of internal pitting within each tube. The pitting was seemingly more severe on Section C29, albeit it was only possible to see the end sections of the tubes.

The three tube sections were fitted with temporary flanges at either end to accommodate pig launchers/receivers. Each tube was then connected to a Cokebusters pumping unit to create a closed loop thus facilitating the movement of the Smart Pig bi-directionally.

Table 1: Classification of Tube Sections

| Tube Reference | Composition | Visual Defects | |
|----------------|-----------------------------------|---|--|
| C28 | A-106, T _{ном} 11.0mm |  | Severe Internal Pitting |
| C29 | A-106, T _{ном} 11.0mm |  | Severe Internal Pitting (More observable at end) |
| A27 | A-106, T _{ном} 11.0mm |  | Severe Internal Pitting |

A series of four separate inspection runs were carried out bi-directionally on each test section for validation of data. Two further inspections were also carried out on each tube using a different Smart Pig, for comparison purposes.

The data obtained from each inspection was collated and analysed using standard procedures.

Results

Evidence of wall loss through internal pitting corrosion was clearly apparent from the geometric tube data obtained from the inspection operations. Where an internal pit is present, a reduction in tube wall thickness, corresponding to an increase in internal diameter would be expected.

Figure 2 shows the resulting wall thickness and internal radius C-scans obtained.

The corresponding linear graphical plots illustrated a pattern, consistent with internal pitting. The wall thickness and internal diameter data obtained within said areas showed a high standard deviation from the nominal values, indicating a variety of pit depths.

Figure 3 shows the typical graphical plots obtained from the three tube sections.

Section C29 showed the most severe pitting of the three sections tested. The damage was distributed throughout the full length of tubing, with a minimum wall thickness of 3.0mm measured. Data tables summarising the wall thickness and internal diameter measurements obtained can be seen in Tables 2 and 3.

In areas where the pitting was very dense, i.e. a high amount of pits per internal surface area, significant amounts of ultrasonic scatter were observed.

The result of the scattering effect show as a loss in wall thickness data at these locations. This can be seen as the grey shaded areas in the C-scans shown in Figure 2.

Figure 2: C-Scan images displaying Wall Thickness (WT) and Internal Radius (IR) measurements

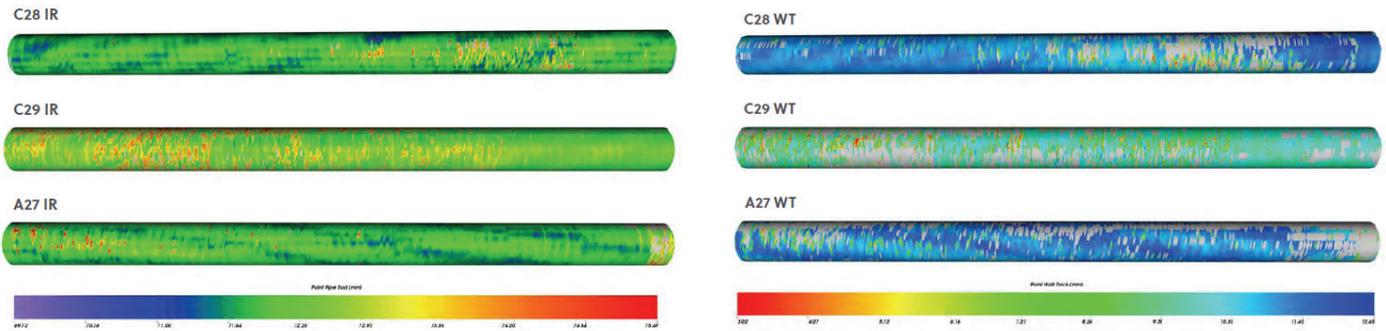


Figure 3: Linear graphical plots showing average/minimum wall thickness & maximum ID with respect to tube length

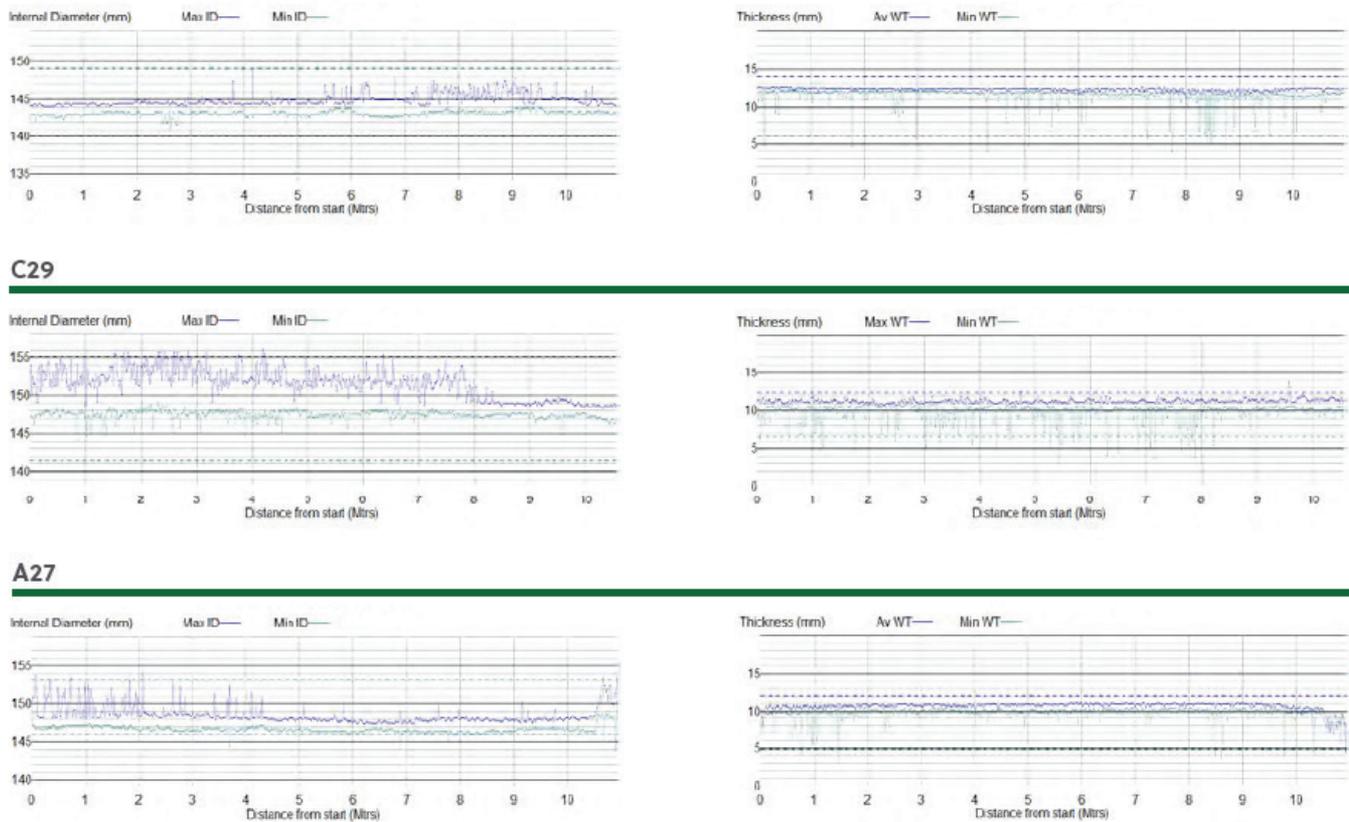
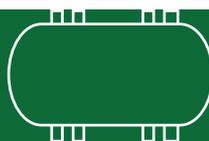
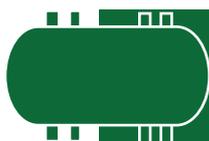


Table 2: Wall Thickness Data

| Tube Reference | Average Wall Thickness | Minimum Wall Thickness | Minimum WT Axial Location | Maximum Wall Loss |
|----------------|------------------------|------------------------|---------------------------|-------------------|
| | mm | mm | mm | mm |
| C28 | 12.4 | 3.8 | 7.6 | 7.2 |
| C29 | 10.4 | 3.0 | 5.4 | 7.9 |
| A27 | 10.7 | 3.1 | 1.4 | 7.9 |

Table 3: Internal Diameter Data

| Tube Reference | Average Internal Diameter | Minimum Internal Diameter | Minimum ID Axial Location | Maximum Internal Diameter | Maximum ID Axial Location |
|----------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| | mm | mm | mm | mm | mm |
| C28 | 144.1 | 141.3 | 2.6 | 149.1 | 4.1 |
| C29 | 147.2 | 142.7 | 10.5 | 155.0 | 1.5 |
| A27 | 147.6 | 143.9 | 10.9 | 155.6 | 10.9 |



Discussion

The Cokebusters Mark IV Smart Pig detected and resolved areas of internal pitting corrosion, found within the three tube samples supplied by the client. The areas of the pitting were accurately located both along the tube length and circumferentially around the tube.

Figure 4 shows an example of the pitting detail observed in Section C29.

Ultrasonic Scatter

Credible wall thickness measurements, obtained by the Smart Pig, are dependent on a regular surface profiles.

As surface condition deteriorates, such as the unevenness created by heavy pitting, the ultrasound signal can be deflected, often manifesting as a compromise in data integrity.

With knowledge of the inspection circumstances and objectives, this type of scatter can be interpreted. In this particular instance the loss in wall thickness data was determined to be proportional to the pit density within the tube.

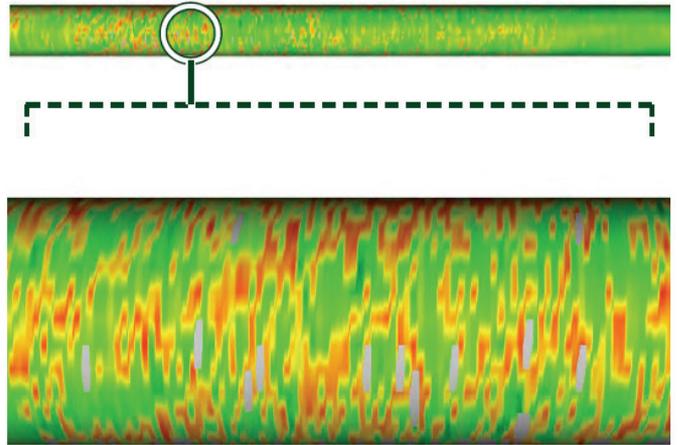
Detection and Resolution

Detection and definition of defects depends on many factors, including:

- tooling design
- configuration of parameters
- competence of the software and of operator
- inspection procedure
- frequency and morphology of defects

The Mark IV Smart Pig employs ultrasonic immersion transducers, configured to provide the best overall response to wall thickness measurements, representative of most inspection scenarios.

Figure 4: C-scan identifying an area of dense internal pitting in Section C29



Conclusions

Inspection of three separate tube sections was carried out using standard operating procedures with the Cokebusters Mark IV Smart Pig.

- Analysis of the IR and WT data identified areas within each of the three tube sections, which was consistent with internal pitting
- Each data measurement was accurately mapped to its correct axial and circumferential location within the tube
- The minimum measured wall thickness was 3.0mm (Section C29), relating to a maximum pit depth in the region of 8mm

The first generation Mark IV Smart Pig was deployed in 2012. In 2021 it remains an incredibly stable and successful inspection platform, having completed some 700 individual jobs worldwide. Each job can range from 500m to 20km.

Maintaining the successful formula, the Mark V Smart Pig was released in 2020, providing an effective doubling of radial capability. A broader range of this tooling is also now available.

The key objective to using the Smart Pig system is to quickly and accurately locate and resolve anomalies. By definition the inspection is highly dynamic, and so if a greater level of non-intrusive investigation is subsequently required, these anomalies can then be further investigated / assessed using alternative methodologies such as handheld UT measurement and other corrosion mapping techniques.

Such a deployment technique is highly cost effective when screening for corrosion under insulation or under pipe supports.

