Background

Cokebusters was contracted by a facility in Texas to carry out an In-Line Inspection (ILI) of a Reactor Charge Heater, as part of a scheduled maintenance turnaround.

The inspection was carried out, using the patented Cokebusters' Smart Pig, to obtain accurate geometric assessment of both convection and radiant coils in four separate passes.

Prior to inspection, the process coils were thoroughly decoked and cleaned internally, using Cokebusters mechanical pigs.

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

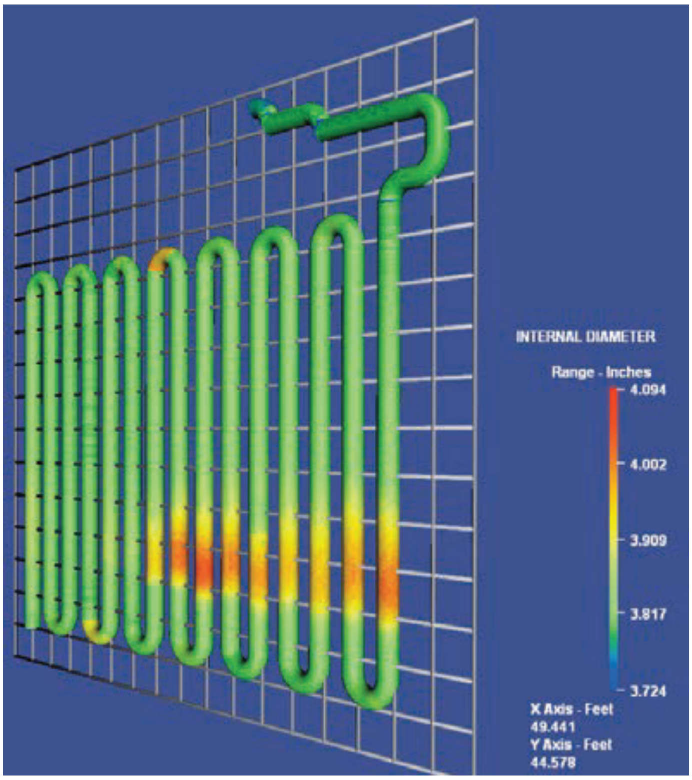
Significant diametric abnormalities were identified within the radiant coils of passes 1, 2 and 3.

These abnormalities were more abundant in Pass 2, with diametric growth up to 4.7% (Pass 2, Tube 7) observed. This phenomenon was clearly visible in the 3D C-Scan and accompanying graphical plots (Figures 2, 4(a) & 4(b)).

The diametric anomalies were considered to be "irregular" due to the consistent swelling around the full circumference of the tubes, as opposed to ovality or localized bulging on the fire side of the pipe-work.

The tube wall thickness was seen to be constant throughout the radiant tubing, with minimal deviation from the nominal value. This can be seen in the graphical plot shown in Figures 3 and 4(c).

Figure 2: Pass 2 Internal Diameter 3D C-Scan showing diametric growth in Radiant Coil 2



Failure Mechanism

Following the inspection, a full Level III Fitness for Service assessment was carried out in accordance with API 579-1/ASME FFS-1. Visual examination, microstructural analysis and micro-hardness measurements were conducted on the heat affected areas.

Scanning Electron and Optical microscopy confirmed the presence of ferrite and martensite in the heat affected areas, indicating that the tubes were exposed to skin temperatures in excess of 750°C, with a high rate of cooling experienced. The micro-hardness measurements obtained in these areas further confirmed exposure to excessive temperatures and were attributed to strain hardening resulting from plastic deformation from exposure to elevated operating temperatures and pressures. Overheating reduced the tube strength sufficiently that the internal stresses exceeded the yield strength of the tubes, which ultimately led to diametric swelling.

Upon discussion with the client, it was concluded that the radiant tubes were subjected to short-term overheating during operational shutdown, which ultimately led to the tube bulging and diametric deformation within the radiant tubing. Long-term creep damage was ruled out due to the uniform concentric swelling, accurate burner alignment and known historic operating temperatures outside of the creep regime.

Figure 4: Graphical plots showing (a) Diametric increase in Radiant Tubes 5-9 (Inclusive), (b) Average diametric growth in radiant tube 5 and (c) Wall thickness profile along radiant tube 5

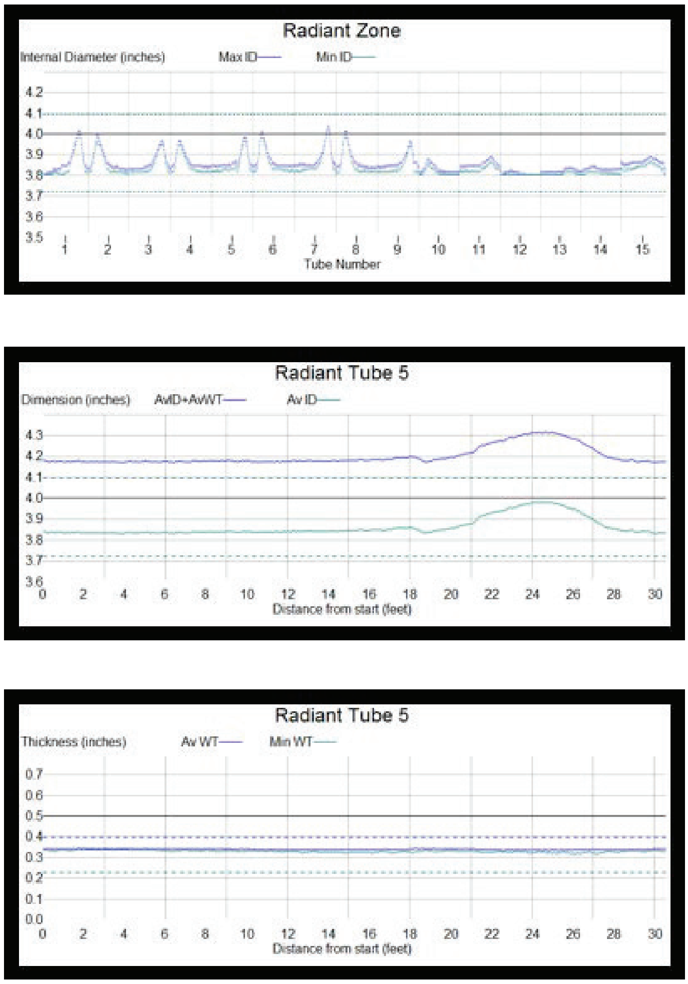
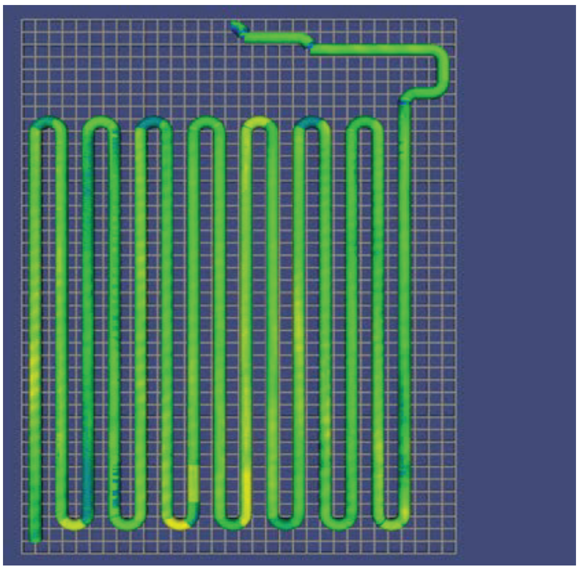


Figure 3: Pass 2 Wall Thickness C-Scan



Conclusions

Following the inspection, the tubes that were identified as damaged were removed upon Cokebusters' advice. All defect quantification and location was confirmed by the client, who commented that this damage would almost certainly have gone undetected using conventional NDT methodologies.

Annual mechanical decoking and smart pigging operations have since been introduced into all of the future turnaround schedules for this heater.

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