In-situ characterisation of AGR pod boiler spine steel using a Fibre-Optic LIBS instrument (2013 – 2015)

In 2013 a possible defect was identified in the spine of a pod boiler at Heysham 1 AGR power station using long-range ultrasonic techniques. There are eight pod boilers per reactor, and the station has two reactors. Each pod boiler is approx. 22 metres high and approx. 3.7 metres in diameter. Each pod boiler weighs approx. 250 tonnes. The nature of the pod boiler design is that they are very compact and so remote inspections of the internal components of the pod boilers are extremely difficult due to very limited physical access.

Location:	Heysham 1 AGR nuclear power station, Lancashire, UK
Inspection task:	In-situ elemental characterisation of pod boiler spine material
Environment:	Pod boiler (8 per reactor)
Location of material:	Circumferential weld located approx. half way down (~10 metres) the boiler spine.
Access:	From top of boiler and via the annular gap (approx. 13 mm width) between the thermal shroud and the boiler spine. Custom-designed miniature fibre-optic LIBS probe (6 mm diameter, 22 mm length) integrated with a steerable guide tube (SGT) of length 12 metres

Physical access can be gained from the top of each boiler via various penetrations but access to the area where the defect was believed to exist was severely limited. The possible defect was detected approximately half way down the boiler spine which is essentially a thick-walled steel tube of diameter approx. 600 mm which runs down the central axis of the boiler and acts as the primary structural component supporting the weight of the boiler. The defect was thought to be associated with a circumferential weld in the spine and so the power station operators wished to perform an in-situ analysis of the composition of the weld and the surrounding (parent) material of the spine.

Heysham 1 nuclear power station, Lancashire, England

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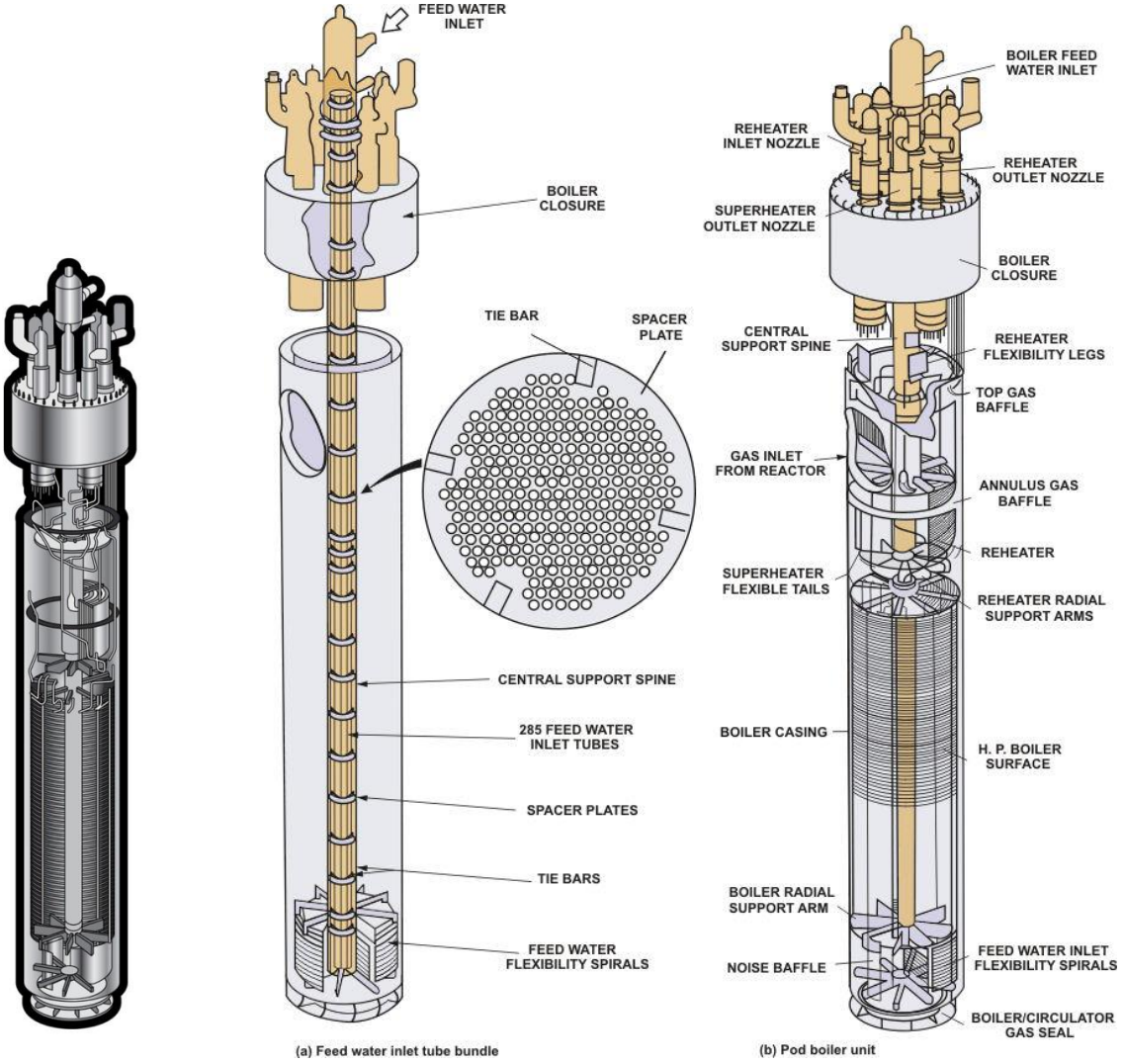
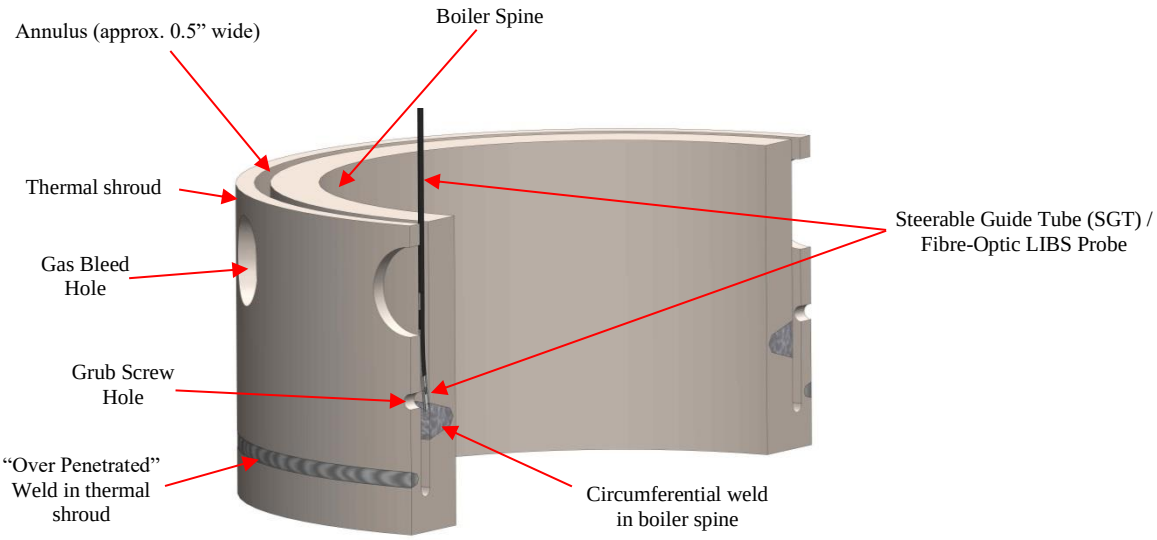


CAD illustrations of the pod boiler



Sectional view showing thermal shroud, annular gap and the circumferential weld in the boiler spine

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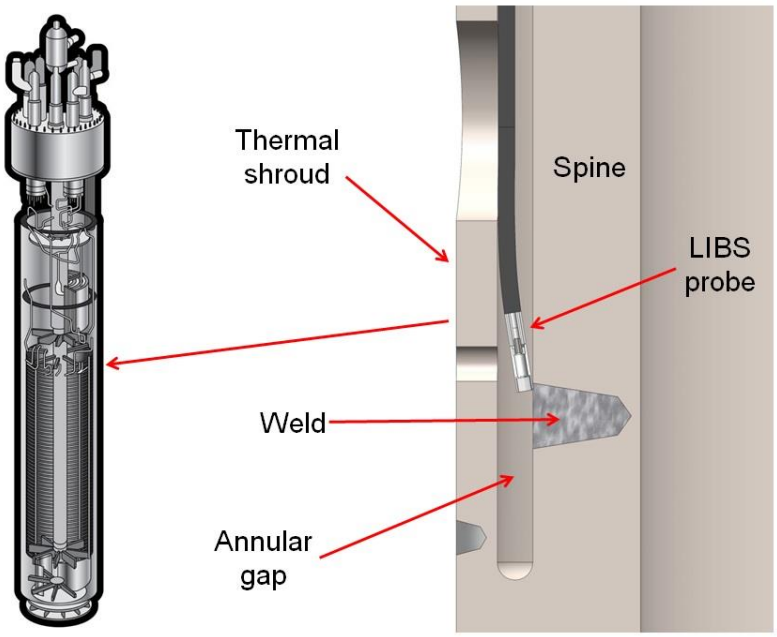
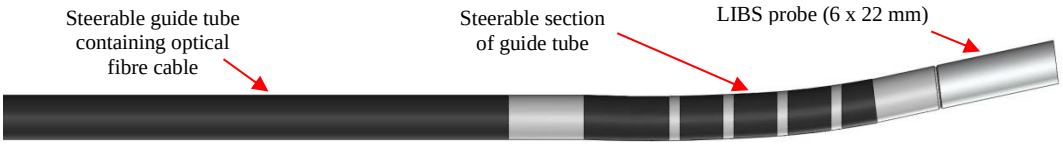
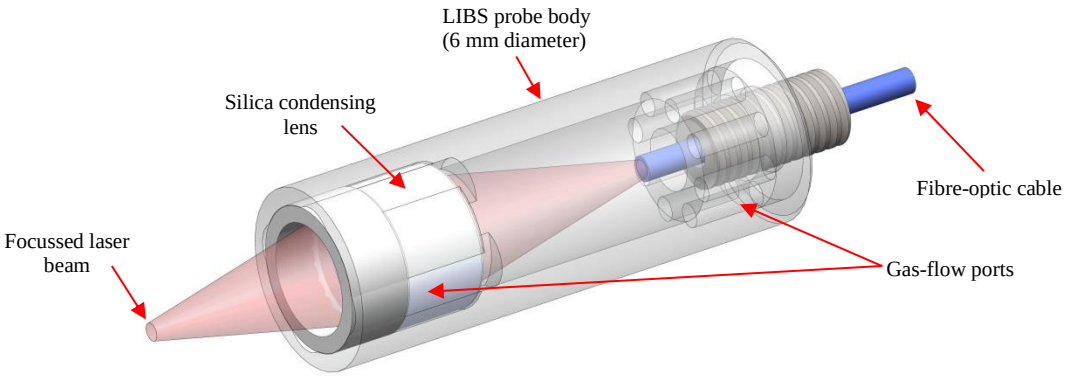


CAD illustration showing the LIBS probe within the annular gap and adjacent to the circumferential weld



CAD illustration of the LIBS probe / steerable guide tube



CAD illustration of the LIBS probe showing the single fibre optic cable, condensing lens and gas-flow ports

The LIBS system used at Heysham 1 Station utilized a fibre-optic probe integrated with a 12-metre long Steerable Guide Tube (SGT) which was deployed within the pod boiler. A video endoscope was used to record video footage of the LIBS probe within the pod boiler. The laser of the LIBS system was also used to perform "laser cleaning" of a specific area of the boiler spine in the vicinity of the circumferential weld. This was conducted to remove the carbon layer (up to 2 mm thick in places) from the surface of the steel. LIBS analysis of the steel was conducted in areas previously cleaned by the laser.

The LIBS spectra were subsequently analysed and interpreted to provide information on the composition of the steel at the positions analysed by the LIBS system. LIBS spectra of three steels of interest (Esshete 1250, Inconel 182 and 316 steel) were recorded using the same LIBS system and comparisons made with the spectra recorded from the pod boiler spine. The three steels may be distinguished by detecting the presence or otherwise of the following elements: Fe, Cr, Ni, Mo, Mn. Of the three steels of interest, only Esshete 1250 contains detectable quantities (by the LIBS system used during this work) of all five of these elements.

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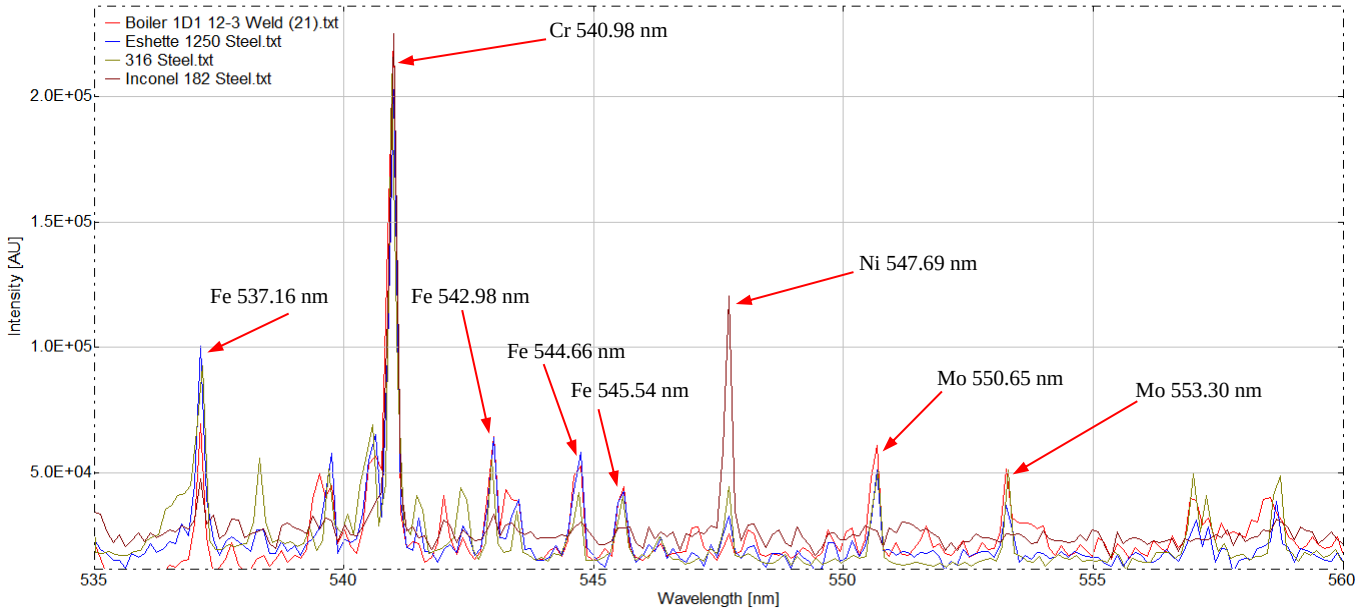
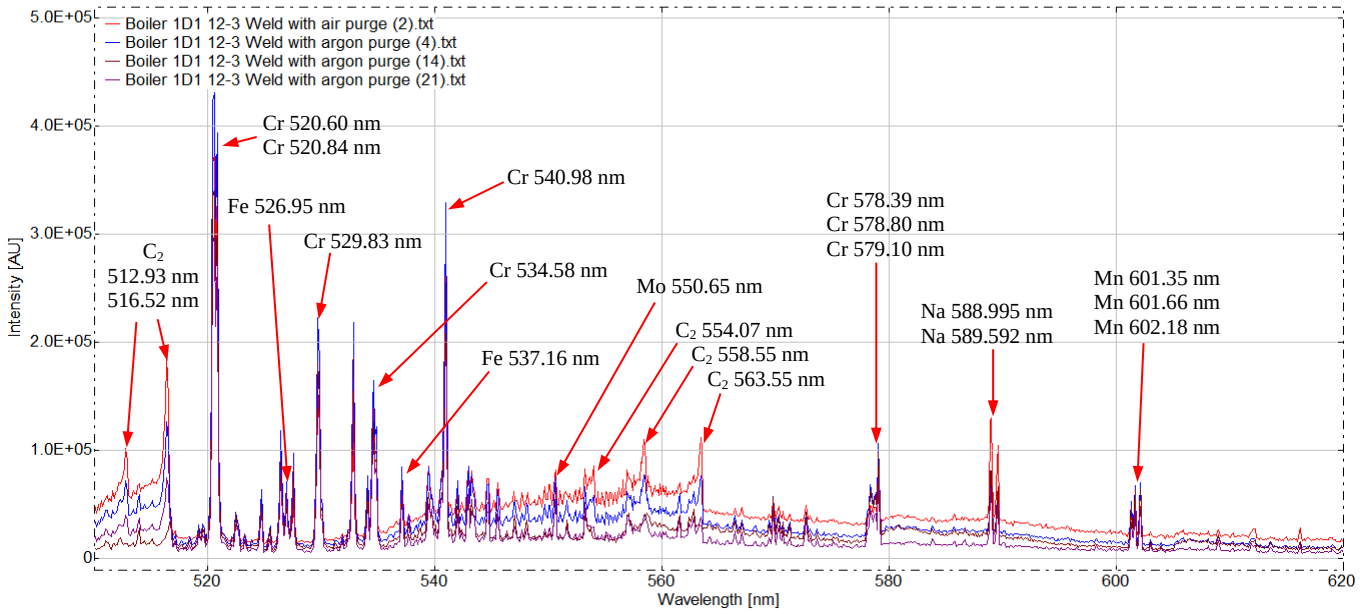
The results show that, within the limitations of the LIBS system used during this work, the recorded LIBS spectra exhibited very similar characteristics and, with the exception of the spectra recorded at positions where the carbon deposit was still present (as evidenced by detecting molecular carbon in the spectra), indicated that the steel was Esshete 1250. None of the recorded spectra exhibited features which are consistent with Inconel 182 or 316 steel and so it was concluded that the positions on the boiler spine analysed by the LIBS system are manufactured from Esshete 1250 steel.



Comparison of boiler spine LIBS spectrum with the three steels of interest (570 – 610 nm)



Comparison of LIBS spectra taken from boiler spine area (510 – 620 nm)

Many of the recorded spectra exhibit poor Signal-to-Noise Ratio (SNR) but spectrum “Boiler 1D1 12-3 Weld with argon purge (19).txt” displays reasonably intense and well-defined emission lines. The same spectral features, however, can be seen in all four spectra which suggests that the area of the boiler spine analysed by the LIBS instrument is manufactured from one type of steel. Some of the spectra exhibit enhanced baseline (continuum) but this is likely to be due to small changes in the measurement conditions (focus, stand-off, etc) and the presence of residual carbon on the surface of the steel.

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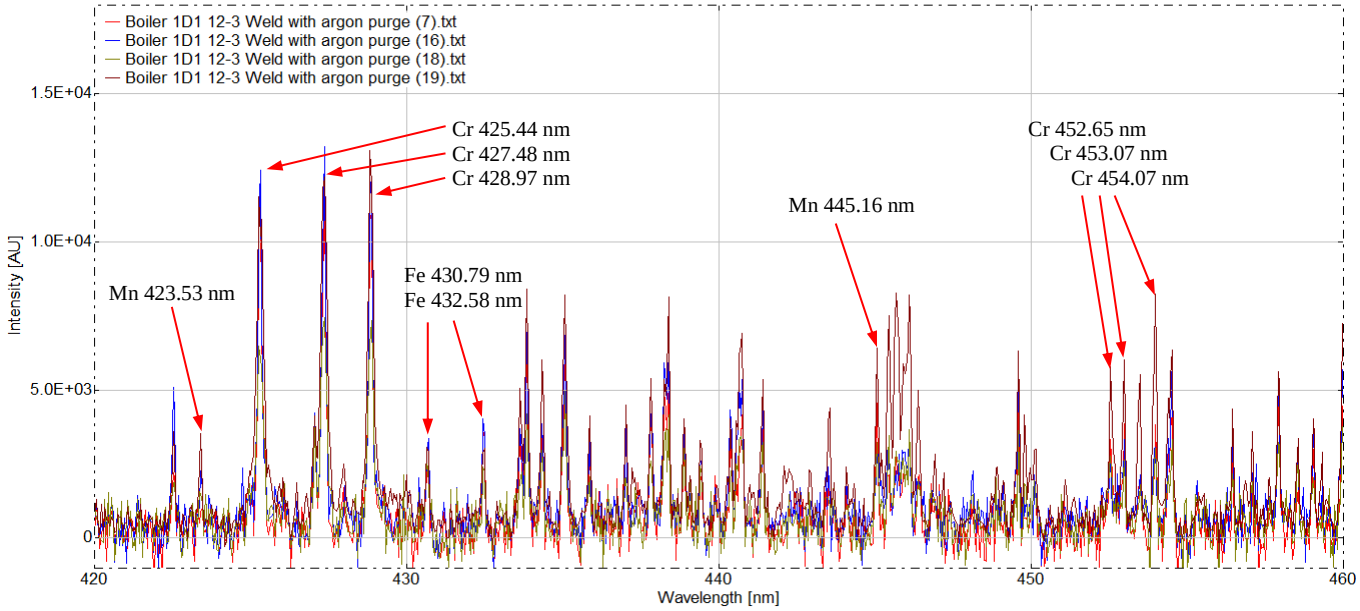
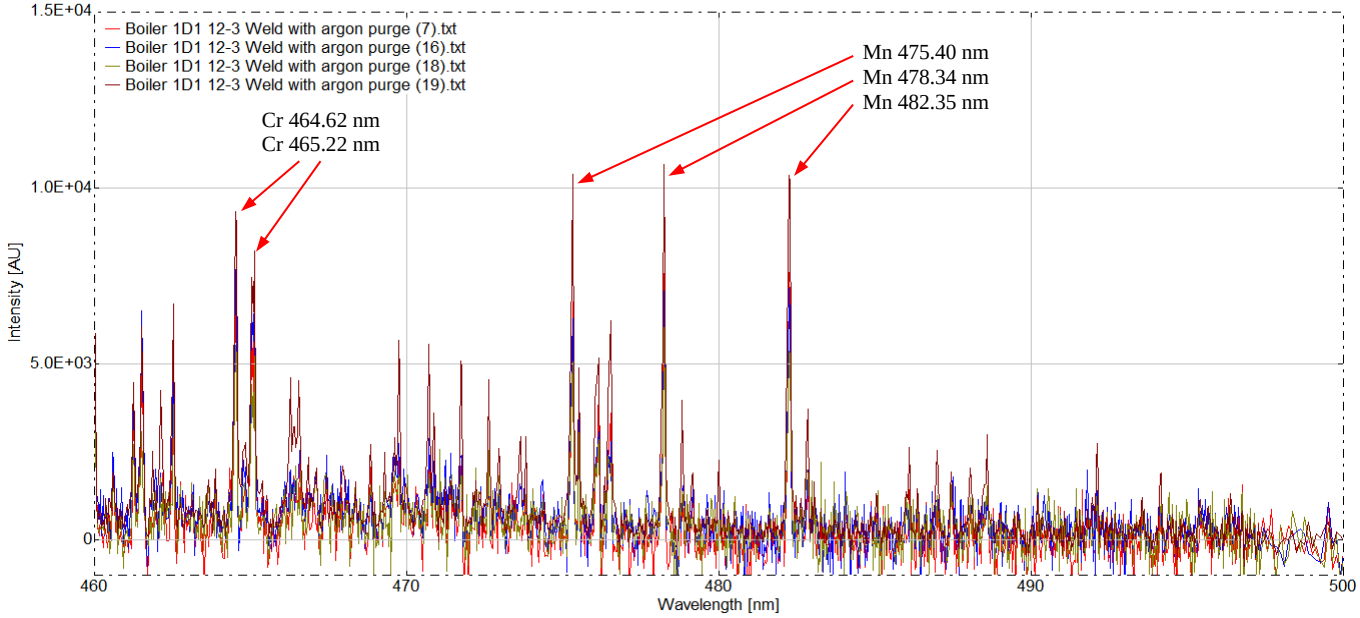


Comparison of LIBS spectra taken from boiler spine area (420 – 460 nm)



Comparison of LIBS spectra taken from boiler spine area (460 – 500 nm)

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