In-situ compositional analysis of Advanced Gas-Cooled Reactor (AGR) steam generator tubes (1999)

Overview of application

A lifetime review for the UK's Hunterston 'B' and Hinkley Point 'B' Advanced Gas-Cooled Reactor (AGR) nuclear power stations identified superheater steam tube bifurcation cracking as a commercial threat to the estimated 35-year operation of the boiler plant. Inspection of up to 528 bifurcations in each of four reactors was required in order to identify the components that were at risk of failure prior to the end of station life. The material properties of the bifurcation casts are primary factors in determining the risk of an individual component failing. A survey of the boiler manufacturing case history identified a number of casts having low creep ductility properties leading to an increased risk of the component failing within the remaining operating life of the stations. The location of these low creep ductility casts within the total population of 2112 bifurcations was, unfortunately, not known. It was known that the low creep ductility casts exhibited abnormally high copper content in comparison to other 316H stainless-steel casts. In-vessel measurements of the copper content of the bifurcations could, therefore, be used to quickly identify the components manufactured from this cast allowing further inspection techniques and repair procedures to be targeted only where necessary. A suitably-designed FO-LIBS instrument was selected to perform in-situ compositional analysis of the steam tube bifurcations.

Hunterston B, West Kilbride, Scotland (left) and Hinkley Point B, Somerset, England (right) AGR nuclear power stations

Location:	Superheaters, just below level of circular walkway above reactor core
Inspection task:	Cu content of steam tube bifurcations
Environment:	C3/R4 area Gamma dose-rate: ~ 1.0 mSv/hr Temp: ~60°C
Location of material:	Inside each superheater enclosure, near the top of the steam generators
Access:	Access from pile-cap down 40 ft ladder to circular walkway. Down vertical access ladder between each steam generator

FO-LIBS instrument design

This FO-LIBS instrument was of the compact, single-fibre design described on APL's website. The instrument was to be deployed during a routine reactor outage programme with the LIBS control module housed in a safe area above the pile cap and the probe/umbilical deployed within the reactor pressure vessel via a man-access route. The environment of the vessel is such that the umbilical and probe needed to be able to withstand temperatures of around 60°C, radiation dose rates of up to 2 mSv/hr and be sufficiently rugged to minimise risk of damage from mechanical shock and rough handling.

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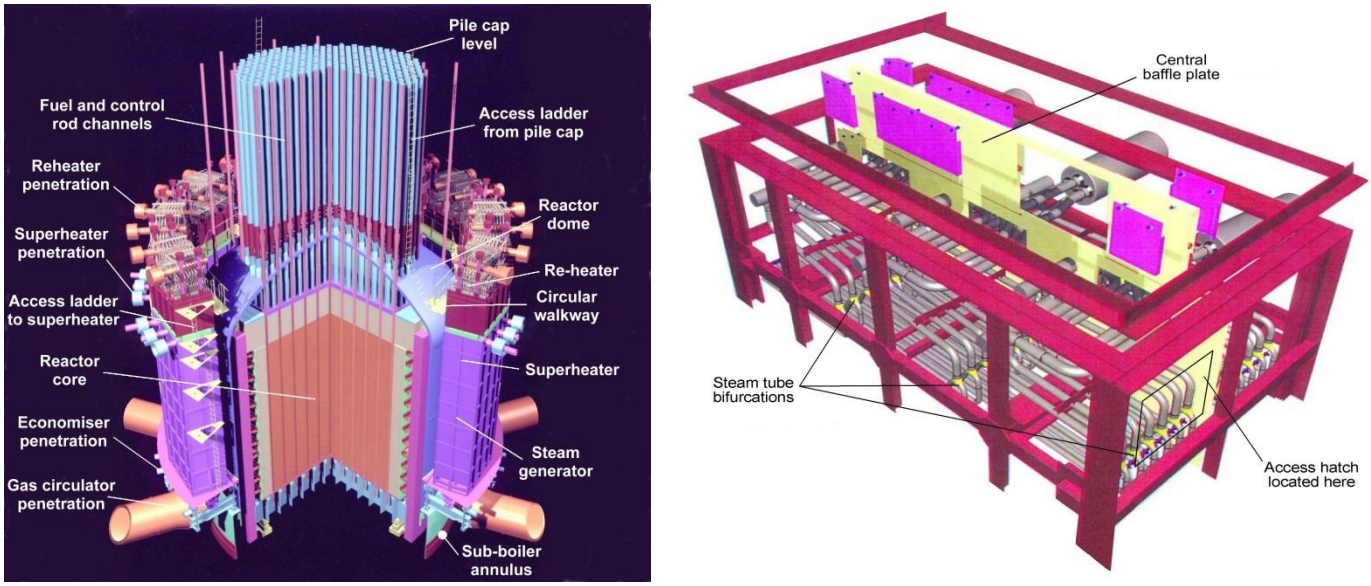
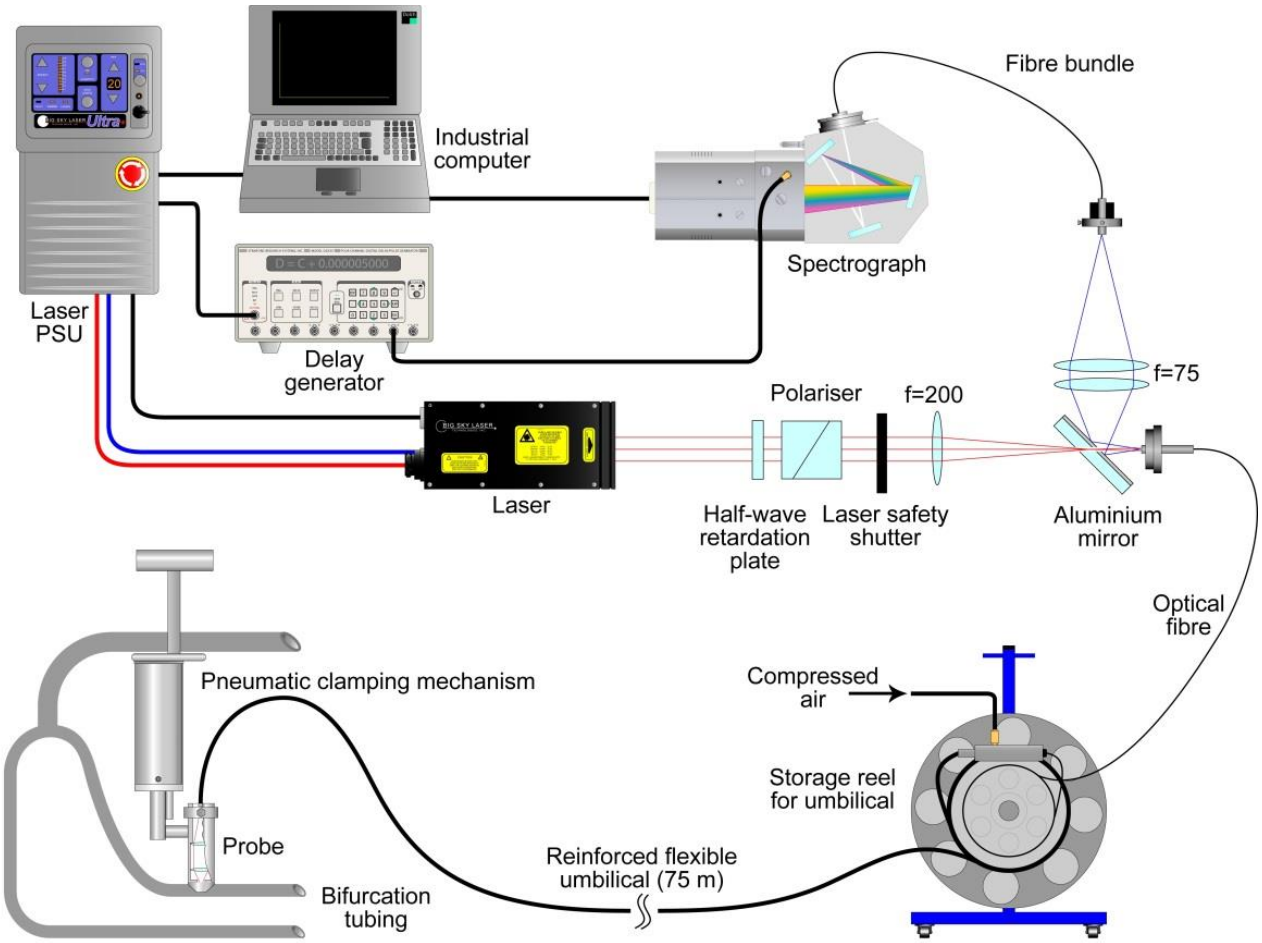


Schematic of an AGR showing the location of the superheaters within the pressure vessel (left) and the steam tube bifurcations within each superheater (right)

In order to access each of the 528 bifurcations in a reactor, a 75 metre long umbilical was required; this length being far in excess of any previously reported industrial application of a fibre-optic LIBS instrument. A single optical-fibre design was used as previous work at our laboratories has demonstrated that this is the most simple, practical and efficient configuration of a FO-LIBS instrument.



Schematic of FO-LIBS instrument used at Hunterston B and Hinkley Point B AGR power stations

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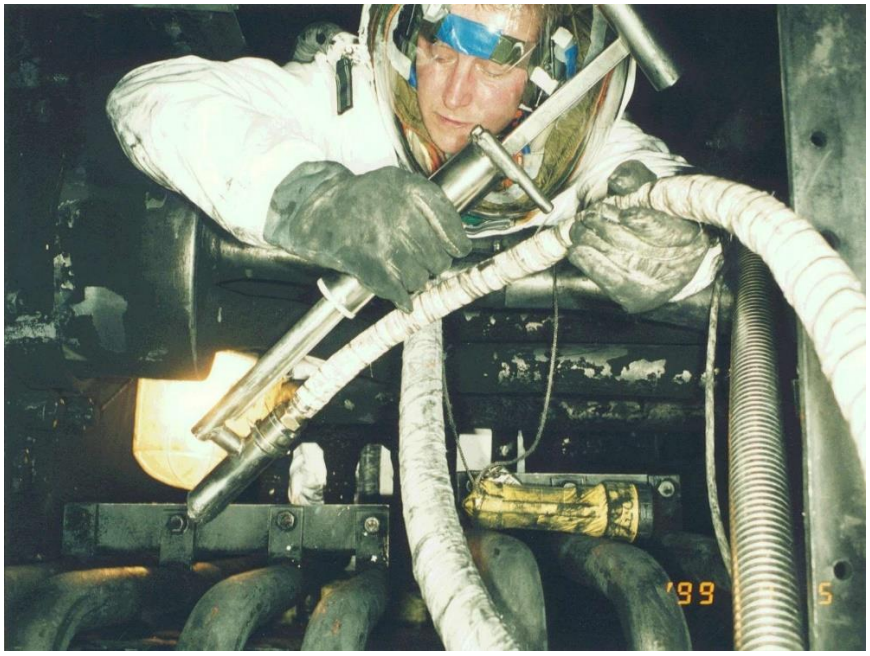
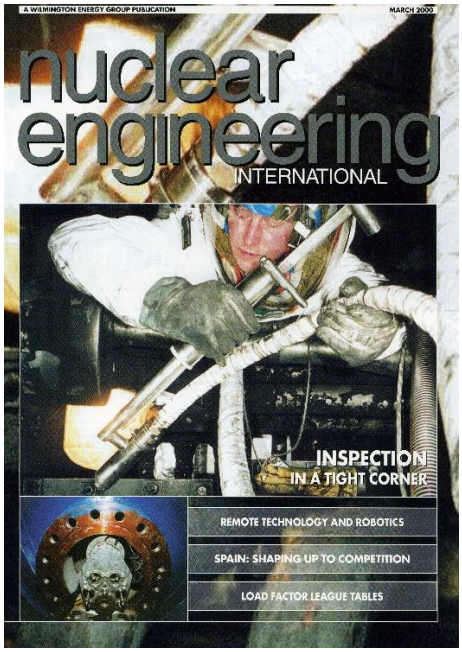




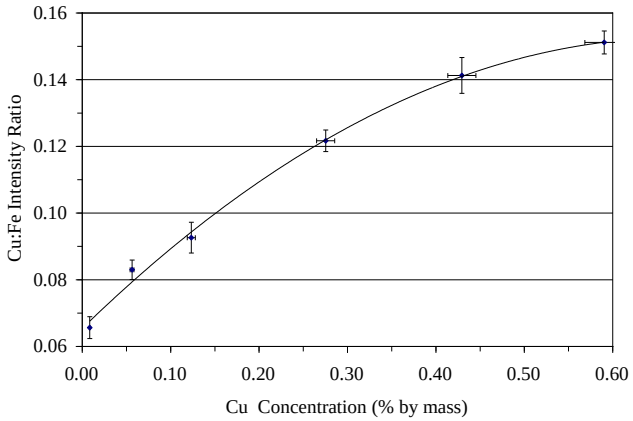
Deploying the FO-LIBS probe inside an AGR superheater at Hinkley Point B (left) and front cover of NEI magazine (right)

Data analysis

The analytical requirements of this application were such that the copper content of each bifurcation needed to be established as being either low (<0.06%), intermediate (0.06%<Cu≤0.2%) or high (>0.4%).

A calibration was derived from laboratory tests on samples of material of known copper content. An iron emission line was used for internal standardisation and the copper to iron peak intensity ratio was plotted against the copper concentration to generate the calibration curve (see figure below).

The LIBS instrument was used during the routine reactor outage programmes for these stations during the summer of 1999 and was able to determine the copper content over the range 0.04% to 0.60% (by mass) of each bifurcation to an accuracy of approximately ±25% and with a measurement time per bifurcation of less than 3 minutes. The analytical performance met the requirements of this application.



LIBS instrument calibration curve for copper in stainless steel

References

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