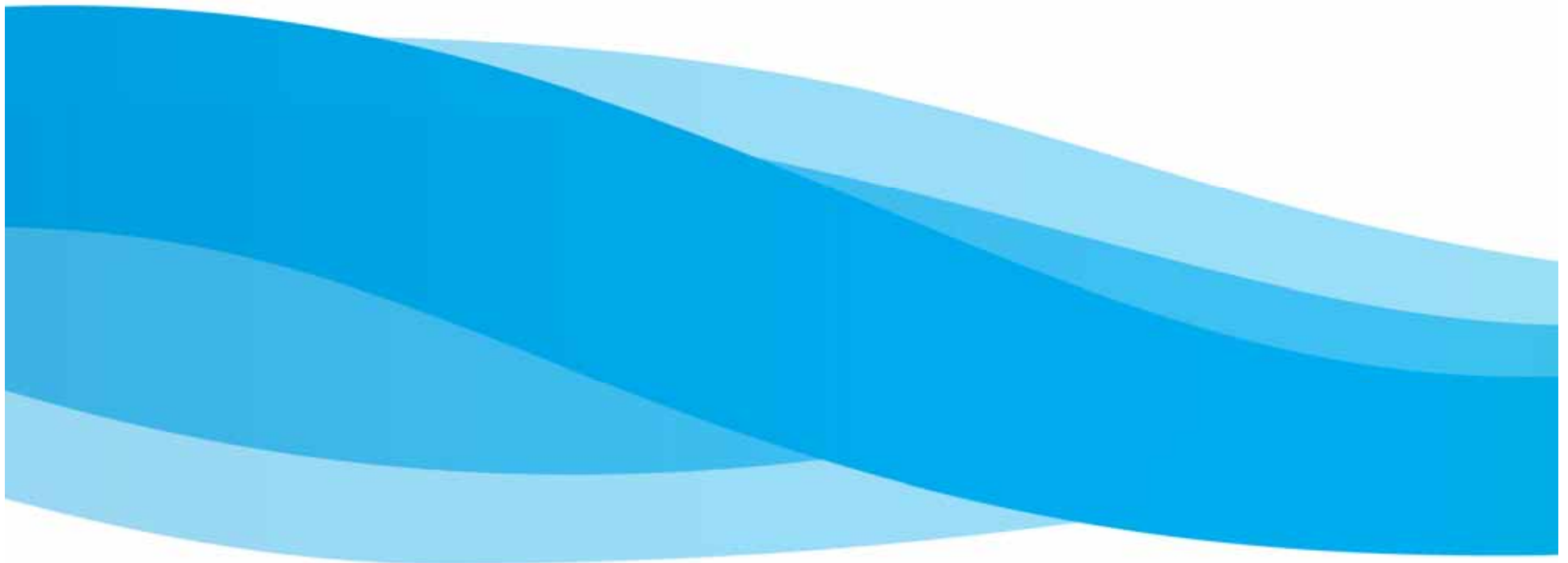


British Energy's Current & Future PIE Needs

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Presentation to Hotlabs 2008, Kendal, UK



- > Introduction to British Energy
- > PWR (Sizewell B nuclear power station)
 - > RPV surveillance
 - > Fuel PIE
- > AGR nuclear power stations
 - > Overview of AGR technology & AGR fuel design
 - > AGR fuel PIE challenges and methods
 - > AGR tiebar
 - > AGR graphite core
- > Summary of PIE requirements



British Energy fleet

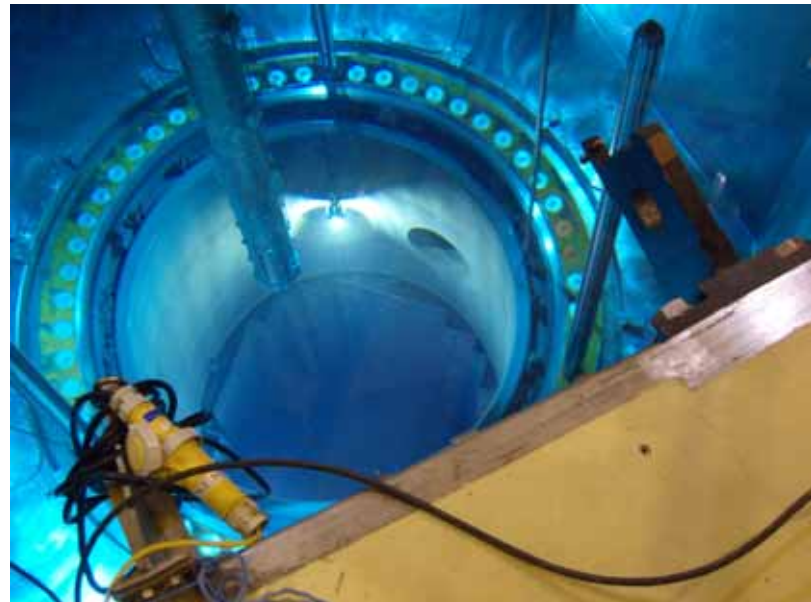
- > 7 twin reactor AGR Power Stations
- > Single PWR (Sizewell B)
- > Commissioned 1976-1995
- > Supplies around one sixth of UK electricity demand
- > 6100 employees
- > Technical support at Barnwood (Gloucester) and East Kilbride (Glasgow)



Sizewell B – PWR



- > Single 1,200MW PWR unit
- > 13 years of electricity production since February 1995

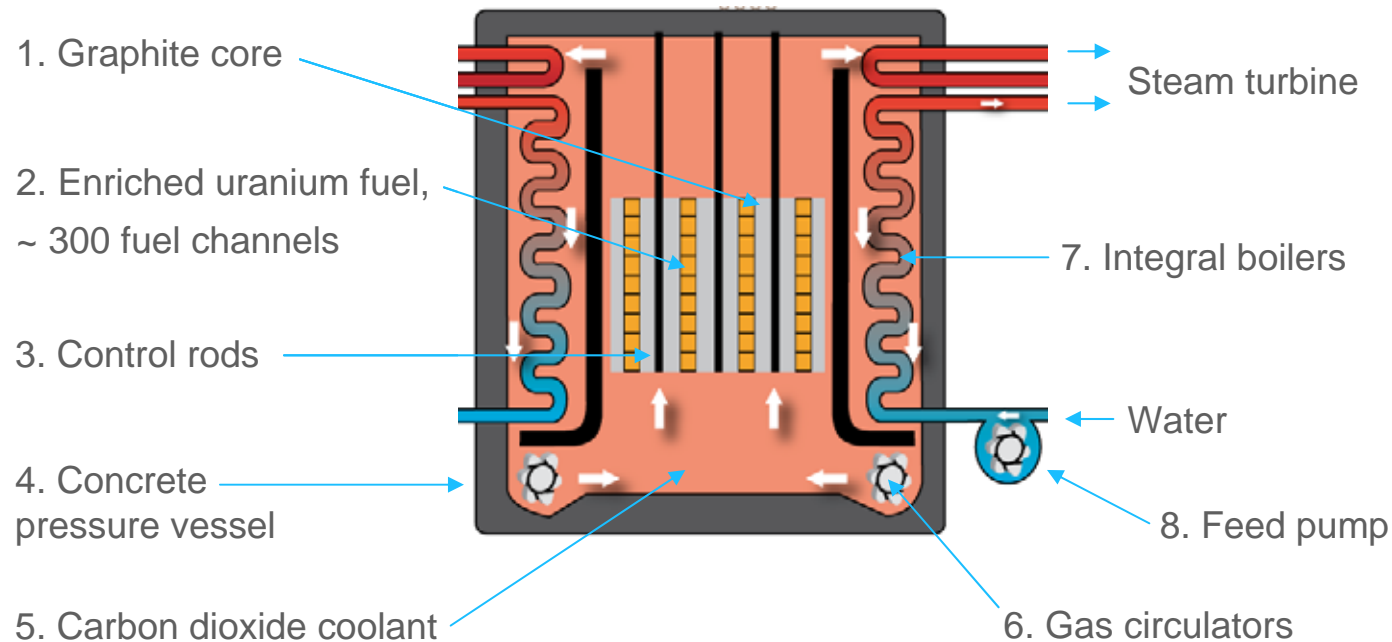


- > PWR reactor pressure vessel (RPV) steels surveillance
 - > Accelerated irradiation of capsules of RPV steel samples in Sizewell B
 - > Dosimetry and mechanical testing PIE programme undertaken
 - > Underwrites the future operation of the plant

- > PWR Fuel PIE
 - > Pond side visual inspections
 - > No Sizewell B specific fuel PIE
 - > Rely on worldwide utility operating experience
 - > Fuel vendor supplied information
 - > Membership of specific international programmes incorporating PIE and irradiation experiments
 - > Areas of active interest include: clad oxidation, PCI, FGR, high burnup fuel performance
 - > Watching brief on MOX, long term fuel storage

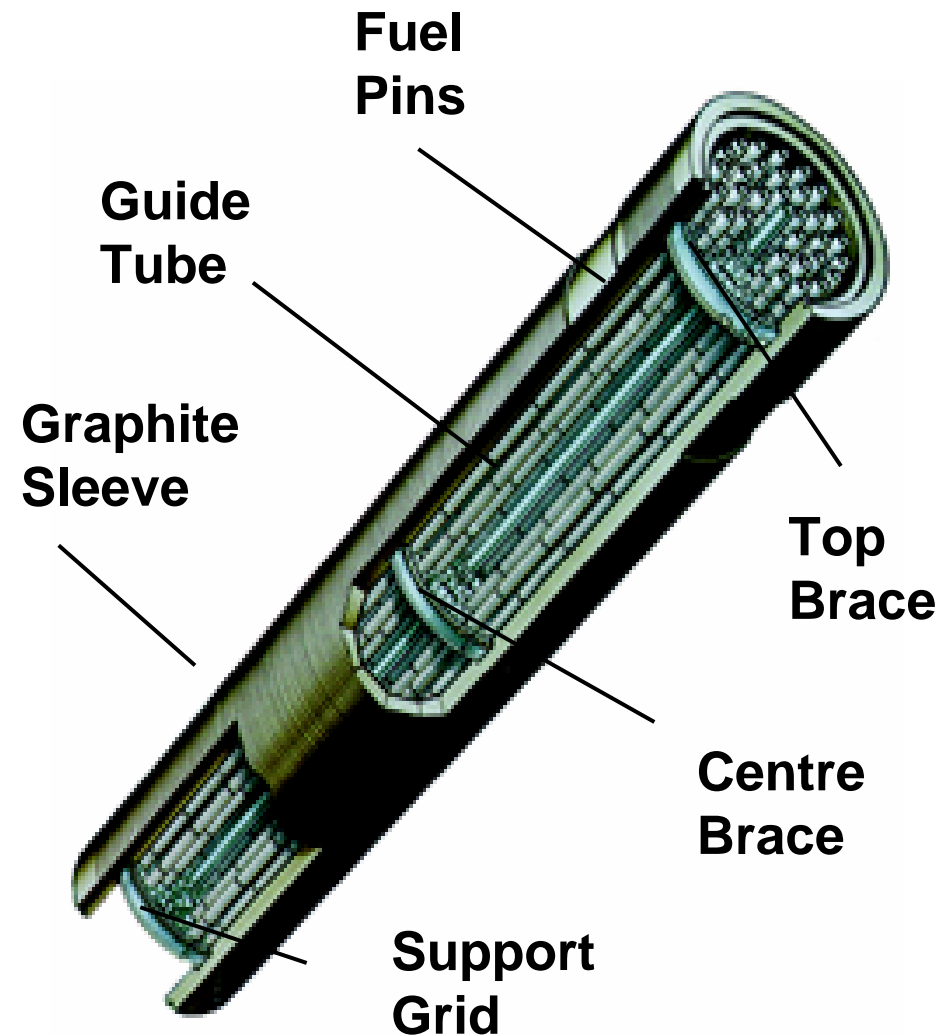
Advanced Gas Cooled Reactors (AGR)

- > 7 twin 600MWe reactor nuclear power stations
- > Unique UK design first commissioned in 1970s



AGR fuel element

- > ~300 fuel channels per reactor
- > 7 or 8 elements per channel (joined by tiebar)
- > Graphite sleeve
- > Stainless steel grid and braces
- > 36 fuel pins per element; ~1m long
- > Stainless steel ribbed cladding
- > ~64 UO₂ hollow fuel pellets
- > ~3.5% enrichment
- > Rating ~20kW/m
- > Burnup ~40GWd/tU
- > ~7 year fuel dwell
- > Clad temperatures ~800°C
- > Fuel centre temperatures ~1200°C



AGR fuel PIE challenges

> AGR fuel condition monitoring

- > Underwrite satisfactory performance under current operating regimes
- > Provide baseline materials and performance database for future changes
- > FGR, PCI, graphite shrinkage & stress, fuel pin thermo-mechanical, high burnup fuel performance

> AGR fuel Integrity

- > PIE of fuel failures & other fuel & clad damaging mechanisms
- > Pin brace interaction, pin rotation, PCI, carbon deposition



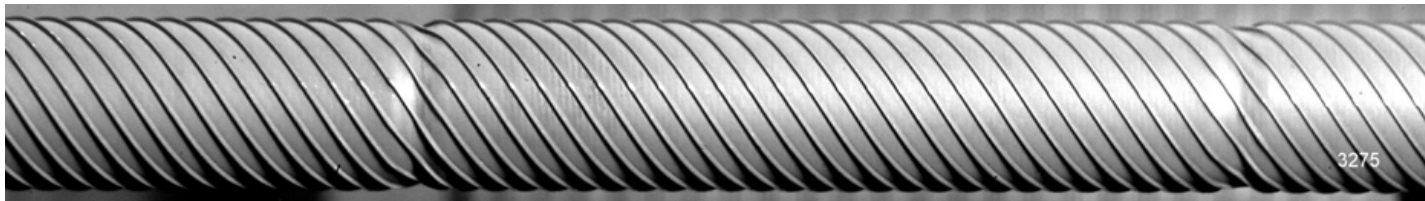
> Design changes or changes in operation

- > Fuel design, material or manufacturing route changes
- > Changes in operating or refuelling regimes
- > Pilot or lead loading or early discharge of fuel

> Code & Model validation

- > Under AGR conditions
- > FGR, high burnup UO_2 performance – overlap with PWR
- > Specific AGR models – reactor physics, fuel & clad performance

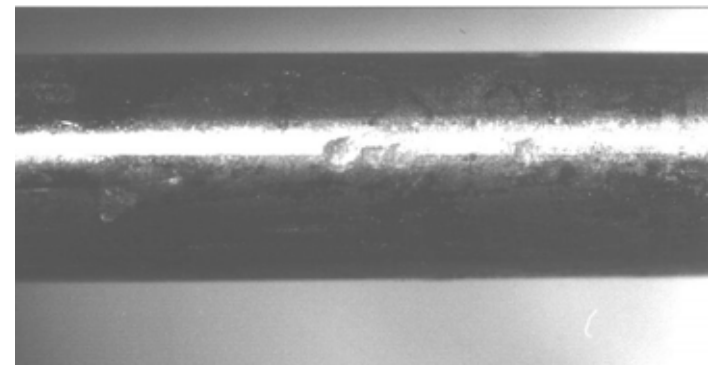
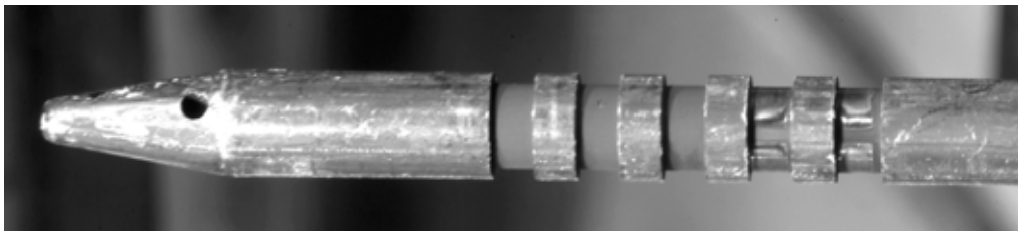
- > AGR fuel pond surveys
 - > Endoscope survey to assess fuel pin carbon deposition
 - > Element top end TV camera inspection – PBI, pin rotation, graphite sleeve damage
- > Shielded PIE of fuel
 - > PIE of fuel failures – determination of failure mechanism and extent of problem
 - > Condition monitoring programme
 - > Proving new designs or operating regimes – lead, pilot, early discharge fuel
 - > Validating pond inspection techniques



- > AGR irradiation experience
 - > Test reactor experiments simulating AGR conditions
 - > Instrumented stringer irradiation in commercial AGR
 - > Complementary PIE programmes
- > Use of international LWR PIE where appropriate – e.g. FGR

AGR tiebar PIE

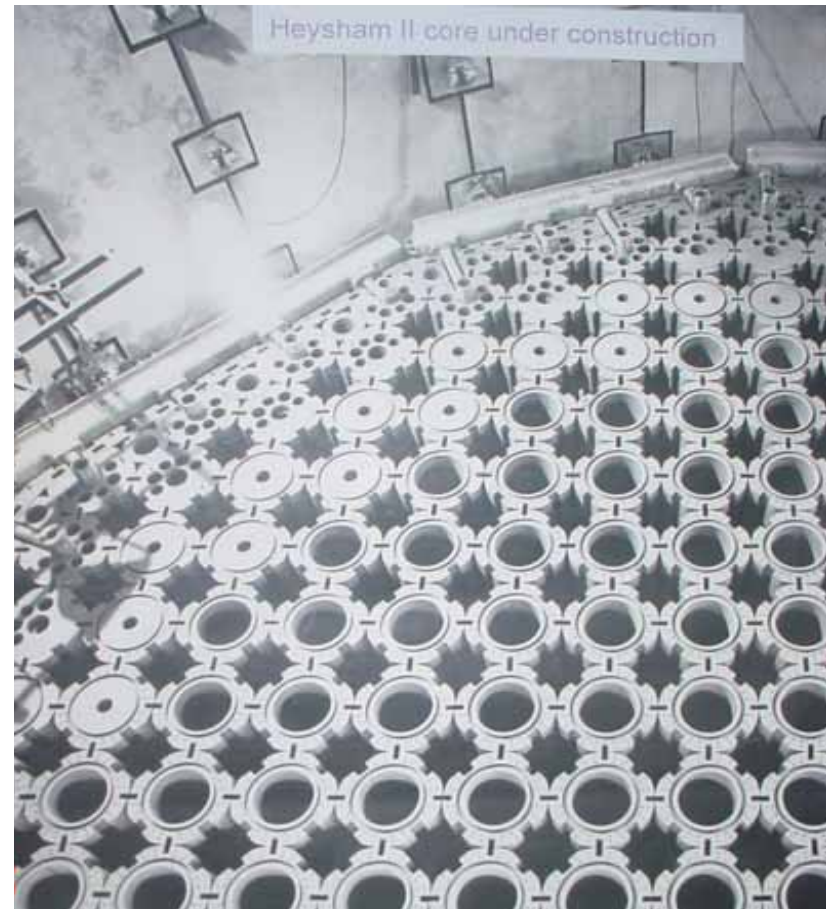
- > Single steel bar which supports the total weight of the fuel stringer during refuelling operations
 - > Non-redundant component
 - > Cannot be inspected whilst in the reactor core
- > PIE, including a programme of mechanical testing required to:
 - > Confirm satisfactory performance as expected
 - > Validate tiebar reliability codes
 - > Support safety case assessments for new manufacturing routes or changes in operating or refuelling strategies



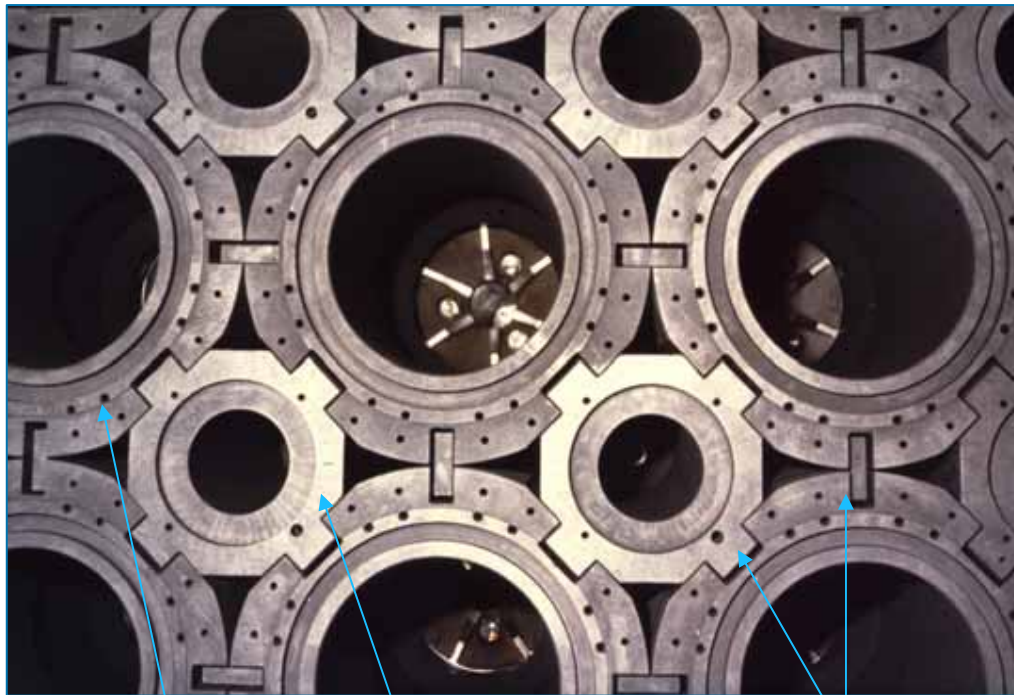
AGR graphite core and function

- > Graphite core
 - > 300+ fuel channels plus 2 surrounding rings of graphite reflector bricks
 - > 10 layers in active core with 2 layers of reflector bricks at top and bottom

- > Fundamental requirements of graphite core
 - > Provide neutron moderation
 - > Unimpeded movement of fuel, and control rods under fault conditions
 - > Adequate cooling of fuel and core



AGR graphite core arrangement and threats



Fuel bricks (forming channels for fuel)

Interstitial bricks (forming channels for control rods)

Keying system which holds structure together

- > Ageing mechanisms
 - > Brick cracking
 - > Core distortion
 - > Graphite weight loss
- > Properties change with time and irradiation
- > Stresses change with time and irradiation
- > Bricks can crack over time
- > Modelling and monitoring programme to mitigate risks

AGR graphite core PIE strategy

- > Programme of remote core inspections
- > Trepanned samples for shielded PIE
 - > Graphite density
 - > Mechanical properties
 - > Coefficient of thermal expansion
- > Materials test reactor irradiation experiments
- > PIE is used to
 - > Understand irradiated material properties
 - > Validate predictions of aging behaviour of the core
 - > Support AGR core lifetime extension assessments



- > Complementary PIE methods
 - > Specific Shielded hotlabs programmes
 - > Pond inspections – AGR & PWR
 - > Membership of international programmes and test reactor programmes
 - > Utility and fuel vendor operating experience
- > British Energy's expectations of a PIE supplier
 - > Reliable and flexible service to meet changing and emergent demands
 - > High quality results, to programme, cost effective
 - > Proactive in maintaining standards, skilled staff capability, developing new techniques
 - > Partnerships and complementary programmes to provide cost effective total solutions

In conclusion PIE has been, and remains, an essential component for British Energy in continuing to support safe and reliable nuclear generation in the UK