BRITISH ENERGY’S CURRENT AND FUTURE PIE NEEDS

D P S COCKERILL & A S MILLS
Engineering, British Energy
Barnett Way, Barnwood, Gloucester, GL4 3RS, UK
www.british-energy.com
doug.cockerill@british-energy.com
tony.mills@british-energy.com

ABSTRACT

British Energy relies on post irradiation examination (PIE) to support the current and future operations of its AGR fleet and single PWR. A PIE programme, carried out in a shielded facility, must complement other methods of acquiring relevant materials data and should be focused on issues relevant to the utility. New fuel designs, changes to the operational envelope, lifetime extensions, and other emergent issues can all be supported by PIE. Equally, an up to date database of irradiated material properties must be maintained to underwrite the current modes of operation. An efficient, reliable and flexible PIE service that is able to provide high quality, timely and cost effective solutions across a range of issues, is essential in supporting the delivery of British Energy’s objectives of providing safe and reliable nuclear generation to the UK.

Key Words – Post Irradiation Examination, AGR, PWR, Fuel, Graphite

Introduction

British Energy is the largest generator of electricity in the UK supplying approximately one sixth of total demand. It operates 7 Advanced Gas Cooled Reactor (AGR) Power Stations, each with two nominally 600MWe reactors, and a single 1200MWe Pressurised Water Reactor (PWR).

British Energy is a prudent operator of Nuclear Power Plants. Post Irradiation Examination (PIE) provides a vital leg in supporting ongoing operations, understanding emergent issues, underwriting future operating regimes and deploying future design changes, as well as supporting lifetime extensions for the AGR fleet and PWR.

The two different reactor design types operated by British Energy each offer their own particular technical challenges and therefore require the support of different PIE programmes.

PWR PIE Requirements

As the operator of a single PWR unit (Sizewell B) British Energy aims to achieve world class operation of the asset within a global PWR fleet in the most cost effective manner. As such it relies heavily on fuel vendor supplied information, as well as information provided by international utility operating experience. It also subscribes to membership of specific international programmes tailored towards the PWR involving both in-pile test reactor experiments, and hotlab (shielded) examinations, which are complemented by associated analysis and theoretical work. Nevertheless, some plant-specific PIE is necessary.

PWR RPV Surveillance

One specific area where hotlab measurements are required in direct support to Sizewell B is the surveillance testing of irradiated reactor pressure vessel (RPV) steel samples. In common with many utilities British Energy undertakes a programme of accelerated irradiation of a capsule of RPV steel samples in Sizewell B and conducts a dosimetry and mechanical testing programme in hotlabs in order to underwrite the future operation of the plant.

PWR Fuel PIE

No specific hotlab PIE has been undertaken on fuel from Sizewell B. The original plant design intent was to use tried and tested fuel designs and operating regimes and to date, this strategy has been sufficiently closely followed that hot cell examinations have not been deemed necessary. However, this strategy is only viable if sufficient hot cell examinations of fuel from other, similar PWRs have been performed.

A number of simple visual inspections are carried out in the Sizewell B ponds in order to directly confirm the satisfactory operation of the fuel. In addition, the capability to deploy other techniques, e.g. poolside fuel failure inspections, is available. In the future it is expected that deployment of more advanced in-pond PIE techniques may provide an alternative method of obtaining useful data that should complement, but will not replace, the international programme of detailed hot-cell measurements.

Finally British Energy uses fuel vendor supplied information, worldwide utility operating experience, and membership of specific international programmes. These sources are complementary and ensure that British Energy retains adequate knowledge of current PWR operating issues, developments in relevant fields such as fuel cycle development and modelling, as well as supporting any specific initiatives such as introducing new fuel assembly designs or clad types, increasing maximum fuel burnups, or deploying other operational changes such as increases to maximum allowable rod internal pressures. The areas of particular interest to British Energy are those in common with many worldwide utilities such as clad oxidation, PCI resistance, fission gas release, and high burnup fuel structures. In addition a watching brief is maintained on other potential future applications such as MOX fuel development and long term spent fuel management.

AGR PIE Requirements

Overview of AGR Technology

The AGR is a 2nd generation reactor design unique to the UK was first commissioned in the 1970s. The reactor consists of graphite moderated, pressurised carbon dioxide cooled primary circuit. Each reactor contains approximately 300 fuel channels, each containing a stringer of seven or eight fuel elements joined together vertically by a steel tiebar. A fuel element consists of a cylindrical graphite sleeve containing 36 stainless steel clad fuel pins, each around a metre long, arranged in three rings, and held in place by a stainless steel support grid and two braces. Each fuel pin contains approximately 64 fuel pellets which possess a central hollow bore.

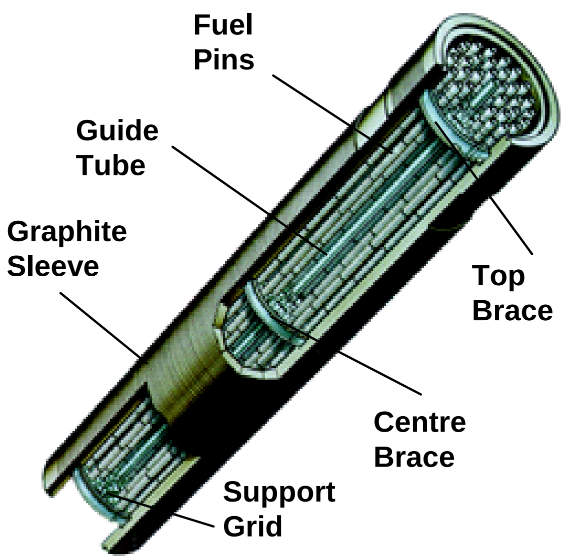

Fig 1. AGR Fuel Element

The initial fuel enrichment can be up to ~4% Uranium-235, pin ratings are ~20kW/m and maximum pin burnup is now above 40GWd/tU. A typical fuel stringer dwell is up to 7 years, and some fuel may be shuffled to a new core location once during this period. Clad operating temperatures in normal operation are up to 800°C, and fuel centre temperatures can reach 1200°C.

AGR Fuel PIE Challenges

The unique technology of the AGR design presents specific challenges where PIE has been, and will continue to be, a vital part of the programme to underwrite the safe operation of the reactors. Many of these technical challenges are analogous to similar issues that occur in PWR reactors. In addition, there are several topics such as code validation, fission gas release (FGR) and high burnup UO_2 fuel performance, where the issues overlap considerably.

In the absence of any worldwide AGR operating experience a large AGR fuel PIE hotlab condition monitoring programme has been developed. The key objective of this has been to provide AGR specific fuel operating experience, confirm satisfactory fuel performance, validate codes within AGR operating regime conditions, and to develop a database of irradiated fuel and materials behaviour from which to baseline any future changes. The comprehensive condition monitoring PIE programme has monitored issues such as graphite sleeve irradiation shrinkage and internal stress, fuel pin thermo-mechanical performance, irradiated clad mechanical performance and included other component examinations. The content of the programme is constantly reviewed and refined based on the stability or otherwise of the observations.

The PIE programme has also investigated a number of emergent issues. In particular there have been a number of different clad damaging mechanisms observed which, in the worst cases, have led to isolated AGR fuel pin failures. Although the safety case allows the AGRs to safely operate with a limited amount of failed fuel, this is not considered to be good practice, and all practical steps are taken to remove the failures from the core, and to avoid further failures. Specific challenges to AGR fuel integrity have recently included: pellet clad interaction (PCI), fission gas release, pin brace interaction (PBI – analogous to PWR grid-rod fretting), and carbon deposition (analogous to PWR crud). PIE of fuel has been essential in determining the failure mechanisms, investigating any secondary effects or fuel degradation, and establishing the global effects of the mechanism and thus justifying the continued safe and reliable operation of the AGR fleet.

In-pond visual inspections (by overhead TV camera and endoscope insertion) have also been heavily utilised for the AGRs. They have been used specifically to assess issues such as fuel pin carbon deposition, element graphite sleeve damage, PBI, and pin rotation. Some of the pond inspection techniques rely on an ongoing mechanism of validation through selected hot-cell PIE.

The PIE programme has supported the deployment of new fuel designs, changes to manufacturing routes and changes to operating regimes such as the introduction of on-load refuelling and fuel shuffling. Such changes have been made either to maintain the competitive nature of the generating units or to mitigate risks to continued operation. Many of these developments have relied upon PIE to underwrite satisfactory performance and to confirm the continued applicability of safety case models and methodologies. These initiatives have often included the use and subsequent inspection of lead or pilot loaded stringers, extended dwell stringers, or early discharge fuel to gain an early in-sight to the behaviour of the components.

In the past British Energy has also conducted specific AGR in-pile test reactor experiments involving on line measurement of key parameters. These concentrated on ramp tests and power-cycling experiments simulating AGR normal operation and fault conditions. This included several pins pre-irradiated in commercial AGR reactors and involved pre and post-characterisation PIE. These experiments have provided further support for code validation under AGR normal operation and fault conditions particularly for FGR and PCI, and have allowed development of fuel performance safety cases for on-load refuelling of the AGRs.

In addition several instrumented stringers (thermocouples were attached at various points) were loaded into the AGRs and PIE conducted after their dwell was complete. There are no current plans for any further AGR specific in-pile tests.

Tiebars

In addition to the fuel itself a range of other AGR components have been examined historically in the shielded hot cells. Of particular interest is the tiebar; this is a speciality steel bar which supports the full weight of the fuel stringer during refuelling operations which may occur on-load. It is a non-redundant component which can not be inspected whilst in core; as such a very high reliability is required.

PIE has been vital in validating the tiebar reliability codes and supporting safety assessments. With increasing demands being placed on the tiebar due to higher burnups and more demanding refuelling strategies, as well as developing new manufacturing routes, continuing testing of irradiated tiebars is essential to support ongoing operations.

Graphite Core

The graphite core itself also requires ongoing monitoring. During statutory outages the core is remotely inspected and in addition small samples are trepanned for hot-cell investigations of density and mechanical properties. The measurements are compared against predictions in order to validate the understanding of the ageing behaviour of the graphite core

The graphite core is also one of the limiting issues which will determine reactor lifetimes. Given the commercial opportunities in extending the AGR operating lives test reactor programmes are planned to provide irradiation experience ahead of the core irradiation.

General Requirements

Although British Energy has a unique set of technical requirements for PIE services, many of the general requirements will be common for most Nuclear Power utilities. A programme of pond inspections, specific Hotlab PIE investigations, and membership of international programmes must complement each other and, together with any worldwide operating experience or fuel vendor information, provide the information needed to support safe and reliable operation of the current fleet into the future.

Hotlab PIE represents an essential component of this strategy for British Energy whether from a direct supplier of PIE services, or as a part of an international programme. It is essential that a reliable and flexible service is available to meet the constantly changing demands of the customer. It is essential that the selected supplier works in partnership with the customer and maintains a PIE service to address emerging issues and mitigate future risks. The ability to produce high quality results, to programme, and in a cost effective manner is paramount. It is also expected that service providers will be proactive in maintaining standards, a skilled staff capability and in developing new and improved techniques. It is increasingly becoming the case that it will be advantageous to develop partnership arrangements with complementary programmes across a range of different facilities in order to fully meet future requirements and to provide cost effective total solutions.

Conclusions

An outline has been presented of current and future need of shielded PIE in supporting the safe and reliable operation of British Energy's fleet of Nuclear Power Stations.

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