QUALITY SURVEILLANCE EXPERIENCE OF PHWR FUEL

P.G. KULKARNI, A.K. BANDYOPADHYAY & B.K. SHAH

Atomic Fuels Division
Bhabha Atomic Research Centre
MUMBAI 4OO O85, INDIA

ABSTRACT

Quality Surveillance activities are being carried out for PHWR fuel for over 25 years in India. A large number of fuel bundles of 19 element design have been produced and successfully irradiated. The quality surveillance practices follow the guidelines given in various Quality Assurance Codes and Guides. An independent third party surveillance is provided to cover major manufacturing and quality control operations. A system of design basis review periodic quality audit and regulatory safety review is in place. Over the years there have been modifications in the quality assurance procedures to comply with changing requirements. Also many innovative improvements have been introduced in the manufacturing procedures. Similarly quality control activities are also modified.

Developments in fuel has remained a continuous activity. The paper summarizes the experience gathered over many years in this exciting process of innovation and improvement.

1.O INTRODUCTION

Third party Quality Surveillance (QS) of PHWR fuel is an important activity in the overall quality assurance programme of manufacture of nuclear fuel in India. This QS activity is carried out by the Atomic Fuels Division (AFD) of Bhabha Atomic Research Centre (BARC) for over 25 years. Thus there is now considerable accumulated experience of QS during manufacturing process of fuel. Over the years, QS procedure is evolved which is modified to meet the variations in requirements. The initial half charge for the first PHWR was manufactured in AFD. Subsequently, the Nuclear Fuel Complex (NFC) was established in Hyderabad where integrated fuel manufacturing facilities were set up. The NFC has two streams of manufacturing lines. One is to produce zircaloy components for PHWR fuel starting from indigenous zircon sand.
The other stream produces uranium dioxide fuel pellets starting from magnesium diuranate (MDU) supplied by Uranium Corporation of India Ltd (UCIL). UCIL produces MDU from indigenous ore. The QS covers processes for final products for both the zircaloy components and fuel pellets and their final assembly into finished fuel bundles.

2.O ORGANIZATION

In India, the PHWRs are constructed and operated by Nuclear Power Corporation of India Ltd (NPCIL). NPCIL are buyers of nuclear fuel and NFC is the supplier. Atomic Fuels Division of BARC carry out third party QS of nuclear fuel manufactured by NFC on behalf of NPCIL. Thus the QS activity of AFD is a constituent part of the overall QA programme of NPCIL. The overall QA programme of NPCIL follows the guidelines of IAEA Safety Code on QA. It also meets the requirements of the QA Code of Atomic Energy Regulatory Board of India (AERB). The QS activity is in line with the QA guide on manufacture of fuel published by IAEA under NUSS Programme.

AERB, through its various committees at different tiers, exercises control by monitoring fuel performance so as to keep any release of radioactivity in PHT system within acceptable limits.

3.O OTHER INTERFACES OF QS ACTIVITY

The NPCIL has fuel development committees. The fuel development committee has representatives from fuel design groups, fuel management and fuel handling groups from various NPPs, fuel manufacturers, fuel development group, materials group, PIE group etc. The QS group participates in this committee and assists their deliberations by providing information on trends in manufacturing processes. The QS group interacts with fuel development and materials groups whenever improvements are incorporated in manufacturing processes.

The QS group interacts with fuel design group whenever revisions are incorporated in fuel specifications. Fuel specifications are revised based on fuel performance experience and development activity results of various R&D groups.

4.O QS PROCEDURE

Quality surveillance of the nuclear fuel and its components is executed on the basis of three primary documents.

i) The fuel specifications including relevant material specifications and drawings are issued by NPCIL. NPCIL also issue test procedures for various tests such as mechanical tests, corrosion tests, NDT etc. The acceptance standards are also covered by the NPCIL procedures.

ii) Based on these documents, the NFC formulates Manufacturing Engineering Instructions (MEIs) and Quality Control Instructions (QCIs).

(iii) The specifications, procedures, materials standards, MEIs, and QCIs constitute the basic documents on which QS procedures are established.

(iv) Further, NFC have a QA Manual detailing the QA policy, organisation, personnel requirements, control regime, records etc. QS group ensures that the QA requirements are adhered to in practice. Periodically there is external QA audit by NPC and AERB.

5.O QS PRACTICE

During a QS visit at the fuel manufacturer's plant following activities are carried out by QS engineer.

5.1 Scrutiny of Material Certificates :

Material evaluation reports on uranium oxide pellets, zircaloy fuel tubes, end plug material and sheet materials with regard to their chemical composition, physical properties, mechanical properties, corrosion properties, micro-structure.

5.2 Scrutiny of NDT Certificates

The certificates and recorder charts are scrutinised to assess integrity of the product.

5.3 Calibration System for Quality Control Equipment :

Checks are made to ensure that the inspection, and test equipment used are functioning properly in the required range and give adequate accuracy. If deviations beyond prescribed limits are observed, an evaluation is made of the validity of previous measurements and tests.Acceptance of such items is re-assessed. Records are checked to assure proper handling, storing and use of calibrated equipment. Calibration check is being witnessed and certified at regular intervals.

5.4 Basic Quality Control Tests/inspections :

To verify compliance with the documented procedures, specifications and drawings, the following tests and inspections are carried out.

A. Tests

i) Visual examination of UO_2 pellets during loading to assess handling/storage damages on pellets.

ii) Density measurement of uranium oxide pellets.

iii) Weld qualification

- between sheath and end plug : weld metallography on set up and process control weld samples

- between spacers and sheath : weld shear strength test on set up and process control weld samples.

- between end cap and end plate : weld torque strength test on set up and process control weld samples.

iv) Helium leak testing of fuel element and fuel assembly. This is done within prescribed time limit after welding.

v) Gross leak testing : On certain batches nitrogen-acetone bubble test is carried out. Sometimes assemblies are backfilled with He and He leak testing is done.

vi) Tensile properties of zircaloy fuel tubes, bar stock and plate materials.

vii) Ultrasonic examination of end cap to sheath weld as screening test for defect prone lots.

viii) Autoclaving is sometimes done as a QA measure and it is subsequently followed by He leak testing.

B. Inspections

Checks on random fuel assemblies for dimensions and visual quality :
- Envelope dimensions
- Correct positioning of fuel elements
- Inter-element spacing and proper orientation of end plate.
- End plate squareness.
- Absence of inter-locking

5.5 Design document control :

The manufacturer has a system for control of documents essential to the performance and verification of work. Random checks are done to ensure that the system is effective for following

i) Complete and current lists of design documents, which are applicable for the manufactured items is maintained.

ii) Quality plans, procedures and work instructions are reviewed and approved before issue and latest revisions are in use.

iii) Changes in any document are subjected to the same procedures as for original documents.

iv) Information concerning the changes is transmitted to all concerned persons and organisations.

5.6 Process Document Control :

QS check at regular interval ensures that QC/QA records on following test/inspection are maintained properly.

i) Sinterability test
ii) Densification test
iii) Pellet batch inspection records
iv) Fuel element manufacturing history
v) Fuel assembly inspection reports.

All the above records are basic manufacturing documents in accordance with specifications/drawings/ QCI and duly signed by responsible officers.

6.O IDENTIFICATION

Identification of items is maintained throughout the fabrication by batch or lot number, serial number etc. These identifications and control measures are designed to prevent the use of incorrect or defective items. Any concessional items if present in the process, are clearly identified and recorded in the final document.

7.O SHIPPING, HANDLING AND STORAGE

All the fuel assemblies subjected to and satisfactorily passing all inspection and tests are certified for shipment by QS engineer. Fuel assemblies are sealed in polythene bags firmly held in suitable thermocole containers and encased in metal containers to avoid deleterious effects of humidity, shocks and vibrations during transit. Checks are made for any physical damage, distortion, interlocking identification etc., at site for any transit or storage damage.

8.O NON-CONFORMANCE CONTROL

Components not meeting the product specification are not allowed to continue through the manufacturing process until a Design Concession Request (DCR) is raised. DCR has description of deviation by manufacturer, comments from QS engineer and disposition by the designer. Any recommended preventive action is also sometimes indicated in DCR.

9.O REPORTING

After every visit a comprehensive QS report is prepared covering all the aspects of the QS plan and submitted to the designers, manufacturers, operators and other concerned agencies.

1O.O EXPERIENCE IN THE QUALITY FUNCTION

In the last twenty five years, over 1,3O,OOO nos. of natural uranium fuel assemblies for PHWRs, have been fabricated and subjected to QC and QS. Assemblies conforming to the stringent quality requirements have been supplied to different power stations.

1O.1 UO_2 Pellets

Uranium oxide powder is compacted into pellets which are sintered and ground and checked at different stages to meet the final specified requirements like density, chemical composition, metallographic structure, grain size and dimensions. Some pellets with variations in grain size, chemical composition and dish depth have been used in documented fuel bundles and irradiated in reactors. Presently, pellets with a grain size on higher side are made. This is achieved by time/temperature control in hydrogen sintering furnace. Density measuring near upper limit is achieved by processing powder with specific surface are and particle size and control of green density by optimizing compacting pressure.

1O.2 Cladding Tubes

Zircaloy 2 is used as cladding material. Tubes with some deviations in chemical impurities like Al, N, O have been irradiated. Graphite coating of tubes has been used for a long time now. To avoid any weld contamination, the end preparation on tubes is visually checked. Graphite coating has contributed significantly to improved performance of fuel. The mechanical properties of tube are controlled in a narrow band.

1O.3 Fuel Element

Two very sensitive fabrication steps are fuel pellet drying and end cap welding. QS engineer ensures that enough care is taken to avoid any possible humidity pick up by the fuel at any manufacturing steps Drying of the pellets is done immediately before loading into dry cladding tubes. Ultrasonic testing procedure is being established for end plug welding. Pickling and autoclaving procedures are eliminated from the process route. They are occasionally used as QA measure.

In spite of rigid non-conformance control procedures, occasionally it is observed that defective end plugs or fuel sheaths are used in fuel manufacturing processes. Such lots are quarantined till causes of such occurrence are established and it is ensured that corrective action is recorded and implemented.

11.O CONCLUSIONS

The fabrication processes for PHWR fuel are now well established and the strict QC/QS/QA procedures have contributed significantly to the high reliability and satisfactory performance of present fuel. Further the deliberations in the fuel development committee, which works in task force mode have generated continuous interaction of various groups. This has contributed significantly to very low failure rate of fuel.

12.O ACKNOWLEDGEMENT

The authors are grateful to Mr. D.S.C. Purushotham, Associate Director, Nuclear Fuels Group, B.A.R.C for his encouragement and permission to present this paper.