Abstract

Pool side inspection programme for LWRs started in India with the inspection of BWR fuel assemblies at Tarapur and this involved sipping, visual inspection, UT and Eddy current testing. In view of the possibility of having VVER type of reactors in our country, a R&D program has been initiated for study of behavior of these type of fuel. The program would involve irradiation, pool side inspection and hot cell examination of specially designed fuel assemblies. Well characterized fuel assemblies irradiated in research reactor are transferred to the fuel pool with the help of fuel transfer system. The fuel assemblies are taken out of the transfer system, sipping test performed and de channeled using under water handling and cutting tools. The fuel pins are then taken out of assembly and loaded on to the stand for underwater UT and Eddy current testing. The details of the handling and inspection facilities provided in pool for inspection of the hexagonal fuel assemblies has been discussed in the text. Dismantling and inspection procedure used for control assembly pins have also been discussed.

1. INTRODUCTION

The pool side inspection program would involve irradiation, pool side inspection and hot cell examination of specially designed fuel assemblies. The fuel assemblies irradiated in research reactors are transferred to the fuel storage pool using a flask. The flask is dismantled using under water handling tools. Using a fuel grappler the fuel bundles are handled remotely and taken for inspection. A schematic is shown in Fig 1.

The pool side inspection program for PWR fuel in India will have the following facilities.

1. Sipping facility to detect failed fuel assemblies.
2. Visual/dimensional inspection test rig.
3. Fuel assembly de channeling/cutting facility.
4. Eddy current testing facility.
5. Ultrasonic testing facility.

Each of these facilities is explained in the following paragraphs.

2. SIPPING FACILITY

Gross fuel failures can be detected by wet sipping and the water samples are analyzed for Iodine and Caesium levels using a Gamma ray scanning chamber. The fuel assembly is separated from bulk of the pool water by transferring it in to a canister using the fuel grappler.

The canister (Fig. 2) is a 400 mm dia double walled SS vessel about 3.75 Mts. long mounted vertically on a stand. The top and bottom portions of the vessel are connected by a pipe line, pneumatic valves and a hermetically sealed motor pump set for mixing the water inside the canister. It has also got a heating coil at the bottom for heating the water in it.

After required parameters are reached (for ex. temp of water inside the canister, flow rate etc.) water samples are cooled and passed through a Gamma ray scanning chamber. The gamma ray scanning chamber consists of a lead shielding for water samples, a detector unit, a counting device and a channel analyser. The gamma activity of the sample is measured using high performance Germanium detector. The results are compared with the back ground levels. Depending up on the Energy peaks obtained on the CRT monitor the isotopes are identified.
FIG. 1. Fuel transfer flask inside the pool
FIG. 2. Under water sipping facility
3. VISUAL/DIMENSIONAL INSPECTION TEST RIG

In this facility overall condition of the fuel assembly like shape, length, surface condition of the fuel assembly/pins can be inspected. The fuel assembly is inspected before and after dechannelling using this facility. This facility consists of a specially designed fixture on which fuel assembly can be guided and rested on a rotary supporting platform. Visual inspection of the fuel assembly is carried out using a flexible video image scope arrangement as shown in the Fig[3].

The video image scope consists of a light guide’s fiber bundle for illumination, an objective lens and a CCD (Charge Coupled device) at the distal end. The image of the object is converted into electronic signals by the CCD based on the intensity of reflected light from the object. This signal is fed to a Camera Control Unit that processes and outputs them as video signal and displayed on a TV monitor. The depth of field and angle of vision can be changed using proper optical adopters at the inspection end of the scope. Additional illumination can be obtained by under water lights inside the pool if required. The images can be stored permanently for future references if required.

The length of the fuel assembly can be measured by rotating a screwed shaft that moves the pointer on a calibrated scale between the reference points on the fuel assembly. The pointer moves up and down on accurately machined guides by the screw shaft whose rotational motion is calibrated using an electronic encoder. The pointer can be moved across the length of fuel assembly by a separate motor. The pointer motion is controlled from the control panel thus giving the measurement accurately. The video image scope viewing head is used to move the pointer to the required position.

4. FUEL ASSEMBLY DE CHANNELING/CUTTING FACILITY

The fuel assembly is dechannelled (removal of outer hexagonal channel) for surface examination of fuel pins. The control rods along with its spider are dismantled by removing the lock nut and the total control cluster is kept on a storage rack, before proceeding to the cutting of outer hexagonal channel. In some of the variations of fuel assembly it is possible to de channel the assembly without cutting operation. In this case the channel locking fasteners are spark eroded and the channel is lifted up using a channel handling tool. But in the present design, the fuel assembly is de channelled by cutting the hexagonal shroud by slitting saw. Water hydraulic actuating systems are used as all the operations are to be carried out under water.

The outer hexagonal channel of the fuel assembly is removed by slitting the channel at predetermined locations (based on fuel assembly design). This facility consists of fuel assembly gripping table, hydraulically operated slitting saw enclosed in a chamber. The cutting operation can be seen from the top of the chamber. Water is circulated through the chamber to collect cutting chips and debris present if any using a filter that can be replaced after decontamination.

The fuel assembly is held horizontally by hydraulic gripping heads of the gripping table. An air motor drives the slitting saw and can be moved on guide ways along the length of the fuel assembly. Each face of the hexagonal channel is cut by successive indexing of gripping heads. Top and bottom portions are removed from the chamber for reuse after decontamination and visual inspection.

The active fuel portion of the fuel assembly is separated from the hexagonal channel and taken for visual and dimensional inspection using under water handling tools. After visual inspection the active fuel portion is transferred to reconstitution facility for removing individual fuel pins to carry out pin level examination. A schematic diagram is shown in Fig[4].
FIG. 3. Visual and dimensional test rig
FIG. 4. Fuel assembly dechanneling/cutting facility
5. EDDY CURRENT TESTING FACILITY

In this facility fuel pins and control rods are tested for discontinuities like cracks, wear of clad tube, hydride formation, hardness of clad tube etc.

This facility consists of a stand to support fuel pin/control rod handling tools in vertical condition, cylindrical measuring coils, reference coils, an AC oscillator unit, Eddy Current channel analyser, a personal computer connected with a plotter. After visual examination individual fuel pins are transferred to this facility using fuel pin grappler. The fuel pin is inserted concentrically in to the measuring coils held by the testing fixture. Two nos. of encircling type measuring coils are used, one is used while lowering fuel pin and other while rising it. Separate measuring and reference coils are used for control rod testing. The fuel pin is moved up and down concentric to the coils and the outputs from the measuring coil and a reference coil is compared by EC channel analyser and the cross sectional variations can be plotted along the length of the fuel pin. In a similar manner the control rods of the fuel assemblies can also be tested to know the control rod wear characteristics. The arrangement is shown in Fig [5].

6. ULTRASONIC INSPECTION FACILITY

Ultrasonic inspection is done to characterize the discontinuities precisely those grossly indicated by the eddy current testing. In ultrasonic inspection the fuel pins are inserted in to the test stand and gripped in position by the spring loaded grippers. The measuring head is moved up and down along the length of the fuel pin. The measuring head consists of two ultrasonic transducers placed diametrically opposite and can be moved back and forth with reference to the fuel pin center line. The probes are also rotated inside the measuring head around the fuel pin. A wedge of ultrasonic energy is given by line focusing probe at approximately 26° angle to the surface to be tested which gets converted into a 45° shear wave after refraction that passes all around the circumference of the tube. Another probe is a spot focusing probe which is used for determining the cross sectional variations of the clad. Separate UT channels are used for each of the probes. The results are stored and plots can be taken for records.

Using this facility it is possible to detect the fuel clad failure by sensing the presence of entrapped coolant between clad and the fuel and also the cross sectional variations of the fuel/control rod clad can be measured accurately to know the wear characteristics of the clad. The details are shown in Fig [6].

7. CONTROL ROD INSPECTION

The control cluster along with its spider is dismantled by removing the lock nut and kept on a storage rack. Visual inspection will be carried out on each of the rodolets for fretting corrosion, cracks and clad wear. The individual control rods can be disassembled and can be taken for Eddy Current, Ultrasonic testing. The facility design is such that the cluster also can be inspected without disassembly.

In Eddy current testing, the control cluster with spider is rested on a movable table. The table is moved up and down in such a way that each control rod moves concentric to the measuring coils. The control rod inspection will be completed with one up and down motion of the table. Individual Eddy current signals are compared with a single reference coil signal. By selecting the appropriate channel on EC channel analyser the results can be recorded.

In ultrasonic testing, a control cluster with spider is made to rest on the top guide table of the testing fixture. Individual control rod is passed through the measuring head and
FIG. 5. Eddy current testing facility

LEGEND:--

1. FUEL PIN
2. GUIDING JAWS
3. MEASURING COILS
4. CONTROL ROD TEST SET-UP
5. PIN HOLDING COLLET
6. MOVING TABLE
7. REF. COILS
FIG. 6. Ultrasonic testing facility
inspection is carried out. In a similar manner, other rodolets are brought to the centre line of the measuring head by lifting and rotating the cluster before resting on the table.

Normally three types of rod failures are expected during the operation.

i) Fretting corrosion between rod and the outer guide tube.

ii) Wear of the rodlet bottom tip due to non parallel motion between spider shaft and the rodlet.

iii) Cracking of the rod clad tube due to radiation swelling.

8. CONCLUSIONS

1. Pool side inspection facility being established is intended to be used basically for identification of failed assembly and supplement to the inspection in hot cells.

2. The facility when commissioned will be used for all the LWR type irradiated fuel assemblies.

3. The facility design can be modified to suit variations in the fuel designs.

4. Reconstitution facility can also be added to the pool side inspection program for new fuel assembly designs.

REFERENCES
