EXPERIENCE WITH UNDERWATER STORAGE OF SPENT FUEL IN CIRUS AND DHRUVA

S.K. SHARMA
Bhabha Atomic Research Center,
Trombay, Bombay,
India

Abstract

CIRUS, a 40 MWt Research Reactor and DHRUVA, a 100 MWt Research Reactor have been in operation since 1960 and 1985 respectively at the Bhabha Atomic Research Centre, Trombay, Bombay. Over three decades of experience in handling and storage of irradiated fuel in Cirus has been extensively utilized for making several design improvements in Dhruva. Details of some of the important experiences in Cirus and the design improvements made in Dhruva are presented in this paper.

1. INTRODUCTION

CIRUS, a 40 MWt research reactor located at the Bhabha Atomic Research Centre (BARC), Bombay, is in operation since 1960. The reactor uses natural uranium as fuel, heavy water as moderator and light water as coolant. DHRUVA is a 100 MWt research reactor located at BARC and is in operation since 1985. Dhruva uses natural uranium as fuel and heavy water as coolant, moderator and reflector.

The fuel elements in Cirus are in the form of a single solid metallic uranium rod with aluminium cladding and are about 3 M in length and 3.5 cms in diameter. The fuel elements are placed in aluminium flow-tubes and top and bottom extensions are attached to provide cooling water inlet and outlet passages and shielding in the vertical direction. The total length of a fuel assembly is about 10 M and the fuel assemblies are loaded vertically in the reactor. The fuel elements used in Dhruva are in the form of 7-pin clusters with one central pin and six pins placed around the central pin. Each fuel pin is about 3 M long and 1.25 cms in diameter and is encased in an aluminium cladding. The cluster is placed inside an aluminium flow-tube with a top section attached to provide cooling water outlet passage and shielding in the vertical direction.

2. POST-IRRADIATION FUEL HANDLING SCHEME

2.1. In Cirus the fuel assemblies are removed from the reactor with the help of a vertical fuelling machine and are either stored in a water filled storage pool located inside the reactor building or transferred to the Spent Fuel Storage Building (SFSB) through a water filled canal using an underwater buggy. After receiving the fuel assembly in the vertical position, the buggy travels initially to change its position from vertical to horizontal and then emerges into the SFSB. The fuel assembly is transferred from the buggy to a cutting station where it is trisected using underwater cutting equipment. The central section containing fuel is stored underwater and the top and bottom sections are removed for reuse after decontamination.

2.2. Irradiated fuel handling scheme in Dhruva is essentially similar to that in Cirus except that the fuelling machine caters to the requirements of removing irradiated fuel from a heavy water cooled channel in the reactor and is therefore provided with a heavy water coolant circuit of its own. Irradiated fuel from the machine is either discharged into a water filled storage pool inside the reactor building or into a buggy for transfer to the SFSB. Before the fuel is lowered from the machine into the light water filled storage pool or SFSB, the heavy water coolant around the fuel in the machine is drained off and the fuel remains dry for a short time. It is ensured that the dry time of the fuel assembly is kept within prescribed limits. Provisions also exist for dousing the fuel with light water in case the dry time approaches the limit due to delay caused by unforeseen reasons. In Dhruva, the fuel assembly is handled vertically in the SFSB. After transportation to SFSB, the assembly is bisected to disconnect the top section from the fuel portion.

3. EXPERIENCE IN CIRUS

3.1. In Cirus, the irradiated fuel elements were being stored vertically in underwater storage racks where the elements were resting at the bottom. It was observed that during long-term storage, the fuel elements used to bow due to self weight which sometimes resulted in their breakage. Based on this experience, the storage methodology was changed and the fuel removed from the reactor is now stored in fully assembled condition in the storage pool inside the reactor building. In this arrangement the fuel elements remains suspended from the top shielding section and thus there is no problem of bowing due to self-weight. The assemblies are transferred to SFSB only when required for further processing thus avoiding the need for long term storage in SFSB.

3.2. The fuel elements which suffer clad failure during service are canned inside aluminium cans and the cans are then plugged. The cans were observed to suffer failures due to internal pressure build-up on account of uranium water reaction during long storage periods. This problem was overcome by providing a small vent hole in the plugs.

3.3. During long term underwater storage, breakage of fuel elements results in release of uranium powder to the bay floor. Removal of the uranium powder from the bay floor has been found to be an extremely difficult task even though a cleaning system based on cyclone separators has been developed for the purpose.

3.4. For maintaining the required water clarity and optimum chemistry and for keeping the bay water radioactivity level to a minimum, the bay water is purified by recirculation through filters and ion-exchange resins. Earlier the ion-exchange resins were being regenerated periodically on exhaustion. This was found to result in significant radiation exposure to operating personnel and was also giving rise to active liquid waste. Cartridge type ion-exchange units, with the cartridges located inside the bays, are now used for bay water purification. On exhaustion, the cartridges are disposed off as a unit in the form of solid waste. This methodology is feasible on account of low ionic impurity load in the bay water and has been adopted for regular use. This obviates the need for regeneration of resins, disposal of liquid waste and maintenance of associated equipments with significant benefit in terms of reduced personnel exposures and maintenance efforts.

3.5. Maintenance of underwater equipments is another area which calls for large efforts. This is so, especially in view of the long years of service seen by these equipments in Cirus giving rise to ageing related degradations. Recently there was an incident where the wire ropes constituting the drive mechanism for the fuel transfer buggy got disconnected from the buggy due to failure of a socket joint on account of corrosion. The resulting slackness of the rope led to its displacement from the underwater guide pulleys. For repairs, the section of the bay housing these pulleys had to be dewatered after isolation from other bay sections using gates with inflatable seals. This required a large effort towards preparatory work as also for the actual repairs due to difficult site conditions.

4. DESIGN IMPROVEMENTS IN DHRUVA

Based on the experience in Cirus, several design improvements have been made in Dhruva and some of these are described below:

4.1. Adequate storage capacity for irradiated fuel has been provided towards avoiding the need for costly Away-From-Reactor storage facilities in future.

4.2. The spent fuel storage bays in Dhruva have been located above the ground level. This obviates the problem of ground water table exerting pressure on the stainless steel liner with the consequent possibility of its buckling when the bay is dewatered for repairs etc. Stress corrosion cracking of the S.S. liner due to chlorides in the sub-soil water is also avoided.

This arrangement also facilitates the layout of bay water purification and ventilation equipments without congestion.

4.3. The design of the fuel transfer buggy and its drive mechanism has also been significantly modified in Dhruva such that the drive wire ropes and guide pulleys are laid close to the water surface in the bay. For repairs to these components, the bay water level has to be lowered only by about 1 meter without the need for complete dewatering.

4.4. Improvements have also been made in the design of underwater cutting equipment by use of submersible electrical motors for driving the cutting equipment. With this arrangement there is no need for long shafts to connect the underwater cutting saws with the motors located above the bay. Consequently, failures due to vibrations have been minimized.

4.5. Removable trays have been provided below the underwater fuel storage racks for collecting any debris/uranium powder. With this the bay floors remain clean and the trays can be removed for cleaning when required.

4.6. A gantry crane has been provided over the bays which travels over the entire length of the bays. This has facilitated underwater fuel handling to a large extent.

4.7. A pool site inspection facility is being provided to carry out post-irradiation examinations of routine nature at the reactor site itself avoiding the need for frequent transportation of irradiated fuel to hot-cells.

4.8. For canning of fuel elements with clad failure, the flow-tube itself is used as a can. For achieving this, significant developmental work had to be done towards working out the design of plugs and the plugging tools.

5. CONCLUSION

Over 3 decades of experience in the field of underwater storage of irradiated fuel from Research Reactors exists in BARC. Based on the experience several improvements have been made in the design of spent fuel storage bays and associated equipment and in the underwater storage and handling methodology of irradiated fuel.

Vertical storage of spent fuel with the fuel elements suspended from the top has been found to be better than storage with fuel resting at its bottom towards avoiding the problem of bowing and breakage of elements. Provision of collection trays below the storage racks has been found to be helpful for improving bay floor cleanliness. For canning of fuel with clad-failure, the flow-tubes themselves are used as cans with provisions to prevent internal pressure build-up inside the cans.

Use of non-regenerable cartridge type ion-exchanger units for bay water purification is found to be beneficial in terms of reduction in radiation exposures of operating personnel and maintenance efforts.

Location of spent fuel handling bays above the ground level has been considered superior from the view point of the pool liner integrity.

Provision of adequate underwater storage capacity, improved design for ease of maintenance of underwater fuel transfer and handling equipment and availability of pool site inspection facilities are some of the other improvements made to facilitate management and storage of irradiated fuel from Research Reactors in BARC.

ACKNOWLEDGEMENT

Assistance provided by Mr. S. Duraisamy, Reactor Operations Division, BARC by way of useful discussions and suggestions in preparation of this paper is gratefully acknowledged.