A. NUCLEAR FUELS

1. FUEL FABRICATION/PRODUCTION

INTRODUCTION

Fuel requirement for regular operation of all our research reactors viz. CIRUS, DHRUVA, KAMINI and FBTR are met by the fuel fabrication / production facilities of BARC. To meet enhanced requirements of fuel in future, the production capacities of these plants are being augmented. Automation and remotisation are also being introduced for reduction in manpower and reduction in operator exposure. Large production plants have been commissioned in BARC facility at Tarapur for MOX fuel fabrication for BWRs and PHWRs with provisions for production of MOX fuel for PFBR and AHWR in future.
1.1 PRODUCTION OF FBTR FUEL PINS

Production of mixed (U,Pu) carbide fuel pins for FBTR are carried out by the process of carbide synthesis from the oxide and graphite starting materials, followed by milling of carbide clinkers, compaction of powder to green pellets and sintering of the carbide pellets. Fuel pins are delivered to IGCAR as per requirement. As the existing facility is more than two decades old, a special campaign of cleaning the facility was recently taken up in order to bring down the background radiation levels in the facility. The accumulated carbide scrap was removed from the glove box train and stabilized as oxide by controlled oxidation under He + O\textsubscript{2}, taking care of criticality and fire-safety hazards. The broken heaters and reflector shields of the high temperature vacuum furnaces, a major source of high radiation levels due to deposition of plutonium containing vapours, were also removed from the glove box train, oxidized safely and stored separately.

In the mean time, considerable progress was made towards setting up of a new FBTR fuel production laboratory under a X-Plan project. Several glove boxes of the new line have been commissioned with cold testing of the equipment. A welding chamber complete with vacuum system was set up to carry out Laser welding trials for end-cap welding of the fuel pins, as part of the development of a Laser welding set-up in the new fabrication line. Procurement of a Laser power source and
completely automated mechanical system for remotely operated end-cap welding by laser beam inside glove box is under progress.

1.2 MOX FUEL FOR BWRS

A number of TAPS MOX bundles were fabricated and irradiated in the two Boiling Water Reactors at Tarapur. The technology for fabricating MOX fuel for BWRs was developed by BARC and experimental irradiation of a number of elements was carried out in PWL of CIRUS reactor. MOX fuel with PuO$_2$ enrichment of 0.9%, 1.55% and 3.25% was used in the bundle.

Fabrication of the fuel has been carried out in a train of glove boxes specially erected for this purpose in the BARC facilities at Tarapur.

MOX fuel pellets were encapsulated in 4 m long Zircaloy - 2 clad tubes, inspected, characterized and assembled.

1.3 MOX FUEL FOR PHWR

As a part of the work on development of high burn-up fuels for PHWRs, MOX fuel bundles have been fabricated in the BARC facilities at Tarapur. This will permit about 40% higher burn-up as compared to the burn-up achievable in conventional natural UO$_2$ fuel bundles resulting in conservation of natural uranium.

The MOX fuel pellets containing 0.4 wt % of PuO$_2$ have been used for this purpose. The PHWR MOX bundles consist of two inner rings of MOX fuel pins and an outer ring of 12 Nat UO$_2$ fuel pins. Technology for TIG welding of end plugs of PHWR MOX fuel pins has also been developed. The end plugs were specially designed to meet the requirement of TIG welding and inspection by X-ray radiography.

1.4 URANIUM METAL FUEL FOR DHRUVA & CIRUS

The fabrication of natural uranium metallic fuel elements for CIRUS/ DHRUVA research reactors involves vacuum induction melting of uranium ingots (received from UED) & casting them into billet, hot rolling and/or hot extrusion to rod shape, heat treatment, rod straightening, machining to obtain finished dimension, eddy current testing, end threading, aluminium tube cladding, aluminium end plug welding, glycol leak testing, radiography etc. Over the years, metallic uranium fuel assemblies and sub-assemblies and other core components were fabricated and supplied to CIRUS & DHRUVA reactors as required. To achieve the demands of increased fuel requirements and reduction in manpower; manipulators, pick and place system, conveyors and other mechanisation systems have been introduced wherever feasible.
Process Improvements

The emphasis has been on reducing radiation exposure, improving safety aspects and better housekeeping along with increased productivity and yield.

Time saving in rolling & heat treatment

The roll grooves were redesigned with uniform area reduction of 10% per pass to achieve final size in 3 sets of rolls for Dhruva and 2 sets of rolls for CIRUS fuel instead of 4 and 3 sets of rolls. This saved 4 shifts of rolling for every batch of rolling. Efforts are being made to roll CIRUS rods in single stage.

Similarly, β quenching process was made faster by modifying the traverse time of the hoist to suit single dip instead of two. Ultrasonic velocity measurement, metallography and thermal cycling tests as well as XRD tests were found satisfactory.

Active effluent discharge system

During the fuel fabrication processes and other jobs connected with uranium, active waste is generated. As the old settling tanks have become obsolete, a new improved discharge disposal system for AFD/UED is being set up. For this, work on effluent discharge facility comprising of a piping system with storage tanks, delay tanks, filters, pumps etc. is nearing completion.

Autoclave

Autoclave facility was installed to assess clad quality and study the reasons for clad failure. Autoclaving of Dhruva fuel pins was carried out at 7 bars for a duration of one week. No change was observed in the fuel pins.

Close circuit TV

CCTV camera has been installed in uranium oxidation room to monitor the safety aspects of the operation.

Mechanisation / Automation

Extrusion Billet Handling System

Pneumatically-operated PLC-based pick & place type hot billet handling system was installed and commissioned for 500 Ton extrusion press. This system picks hot billet from the outlet of continuous furnace and loads it on to billet holder of extrusion press. This has eliminated manual handling of hot billets ensuring better safety.

Roller conveyor system for handling of ingots

For movement of uranium ingots from uranium storage room to band saw machine and back to uranium storage room, a roller conveyor system was procured and commissioned. An ingot-tilting unit provided in the system allows the operator to handle ingots weighing up to 250 kg independently and single handedly.

Mechanisation of Various Machines

Materials handling equipment such as manipulators and pick & place systems were procured & installed for handling uranium rods on rod straightening machine and centreless bar turning.
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Machine. The systems work on pneumatic power and PLC control. Rod handling system has also been provided on capstan lathe for end threading of uranium rods. All these systems have reduced manpower requirement for the said operations and have reduced operator fatigue. Retrofitting of capstan lathe is also being planned to carry out the threading operation. This will eliminate requirement of skilled turner for the job.

**Mechanised roll change trolley**

The existing roll set changing trolley was modified to have the roll table movement by motor with safety features such as limit switches, overload trip, shear pins on coupling etc. A new mechanised roll change trolley has also been procured. Conveyor rolls of the rolling table are also being made power-driven. It will reduce the manual efforts and increase productivity.

**Bar cum tube straightening machine**

A bar-cum-tube straightening machine for straightening aluminium tubes and rods was procured and successfully commissioned.

- **Qualification of β heat treatment of uranium rods**

Ultrasonic testing technique based on velocity, attenuation and back scatter measurement was developed to qualify the β heat treatment non-destructively. The study carried out on samples corresponding to different conditions indicated that the ultrasonic velocity in axial and radial direction for properly heat-treated rod was almost identical, while significant difference was observed in velocity in these two directions if the heat treatment was not satisfactory. This technique has been employed to qualify the heat treatment of few batches of uranium rods as well as to qualify the modified heat treatment process.