Demonstration of Reprocessing of High Burn up Carbide Fuels

**EXECUTIVE SUMMARY**

Fast reactor fuel reprocessing is an important component of the three stage Indian nuclear power programme which is aimed to enhance the utilisation of indigenous resources. In the CORAL (COMPact Reprocessing of Advanced fuels in Lead cell) facility for demonstrating the Fast reactor fuel reprocessing, which was commissioned in Dec 2003, reprocessing of FBTR mixed carbide spent fuel pins with various burn ups such as 25, 50 and 100 GWD/t, was successfully carried out. Several equipment and systems which have been designed and developed at the Reprocessing Laboratory, were validated at CORAL. This provides a launching pad for the optimization of design and operation of vital equipment and systems of future plants.

**OUTLINE**

The spent fuel subassembly from Fast Breeder Test Reactor (FBTR) is dismantled at the Post Irradiation Examination Facility and the pins are loaded in magazine. This magazine, kept in special alpha tight container in a shielded cask, is transported to the CORAL facility, where it is charged to the core container box. Several transfers have been carried out without alpha contamination which proved the design features of fuel transfer system. The fuel pins are then chopped in a Single Pin Chopper for dissolution of the fuel in a titanium dissolver by electro oxidative technique. Chopping was carried out in argon atmosphere to avoid flashes as the fuel pins of FBTR are pyrophoric in nature. The examination of the hulls after dissolution of the fuel indicated that the present design of chopper is ideally suited for the slender pins of FBTR. The Inspection of the chopped pin pieces also revealed that there was no significant crimping and hence the fuel loss in the hull is very less.

As the dissolution of the Plutonium-rich mixed carbide fuel of FBTR, is found to be very sluggish, boiling under refluxing conditions with high nitric acid is chosen for dissolution. The fuel solution after dissolution was clarified using an air turbine driven centrifuge for removal of clad fines. During the campaign, the centrifuge bowl was visually inspected which did not show any measurable quantity of undisolved solids. Solvent extraction using Tri-butyl phosphate solvent with an alkane diluent is used to separate Uranium and Plutonium from the fission products. This solvent preferentially extracts Uranium and Plutonium, leaving behind the fission products in the aqueous phase itself. The solvent loaded with Uranium and Plutonium is stripped with nitric acid for further processing of the fissionable material. The solvent is recycled back for reuse. This solvent extraction is carried out in Centrifugal Extractors designed and developed specifically for fast reactor fuel reprocessing to reduce the radiation damage to the solvent. These Centrifugal Extractors performed very satisfactorily and the campaigns provided a lot of information for fine tuning the design, operation and maintenance philosophy. The product containing Uranium and Plutonium are separated by oxalate precipitation and calcined to their respective oxides.

The process performance of these campaigns was very good as the raffinate losses were very low. The purity requirements could be achieved in a single cycle of solvent extraction itself, though three cycles are provided in the facility. The campaigns provided an opportunity to optimize the flow sheet conditions to reduce the waste volumes. For cleaning the solvent before reuse, an ammonium carbonate process was developed and implemented after extensive experiments in the laboratory.

The operational experience proved that it is possible to have control over α-contamination by adopting the policy of remote operation and maintenance. It is supplemented by contact maintenance in glove boxes, wherever required. The experience with CORAL operations indicates that for small scale operations, it is possible to address criticality issues with a combination of ever safe geometry design with administrative controls.

Several campaigns with spent fuel of various burn up such as 25, 50 and 100 GWD/t have been carried out successfully without any radiological event.
**CARBIDE FUEL REPROCESSING**

Plutonium and Uranium Carbide fuel with 70% plutonium is the driver fuel for FBTR. This fuel has good thermal conductivity and neutron characteristics. But reprocessing of this fuel poses unique problems as the fuel is pyrophoric in nature and the dissolution of the fuel yields soluble organics which interfere in solvent extraction. This requires special care in the design and operation. High Plutonium in the fuel adds another dimension to the complexity as criticality accident issues have to be addressed in the plant and process design.

**CORAL**

Coral comprises of lead shielded hot cell with 250 mm or 200 mm thick lead shielding (depending upon the $\beta, \gamma$ radioactivity in different zones). The cell is a compact one and constructed on an area of 11m * 2 m. The overall height is 3 m. A $\alpha$-tight stainless steel containment box of 10 m long, 1.2 m wide and 1.5 m high is housed inside the lead shielding. The cell is provided with six radiation-shielding windows and six pairs of articulated arm type master slave manipulators to facilitate remote operation and maintenance of different equipments and systems. In addition, a $\alpha$-tight blister box provides access for direct maintenance of small gadgets, which can be brought out of the cell. Specially designed tanks (annular or slab type) have been installed to store solutions containing Plutonium to meet the safety requirements of criticality. About two Km of intricate stainless steel piping involving 3000 bends and 2000 X-Radiography joints has been successfully completed within the limited area of the facility. The dense of piping is a challenging task for the manipulation by welders. Around 35 process vessels and 30 equipments are installed in the hot cell. Since large concentrations of plutonium are handled, the hot cell facility is designed $\alpha$-tight in addition to providing criticality control measures and like thermal reactor fuel reprocessing where cells with $\beta, \gamma$, shielding is sufficient.

**ACHIEVEMENT**

Uranium and plutonium from the highly active spent reactor fuel were separated to the required purity and recovery. Several gadgets designed & developed for this activity has performed very satisfactorily and has provided vital inputs for future plants. Reprocessing of this type of fuel has been carried out successfully for the first time in the world.

**PUBLICATIONS ARISING OUT OF THIS STUDY AND RELATED WORK**


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