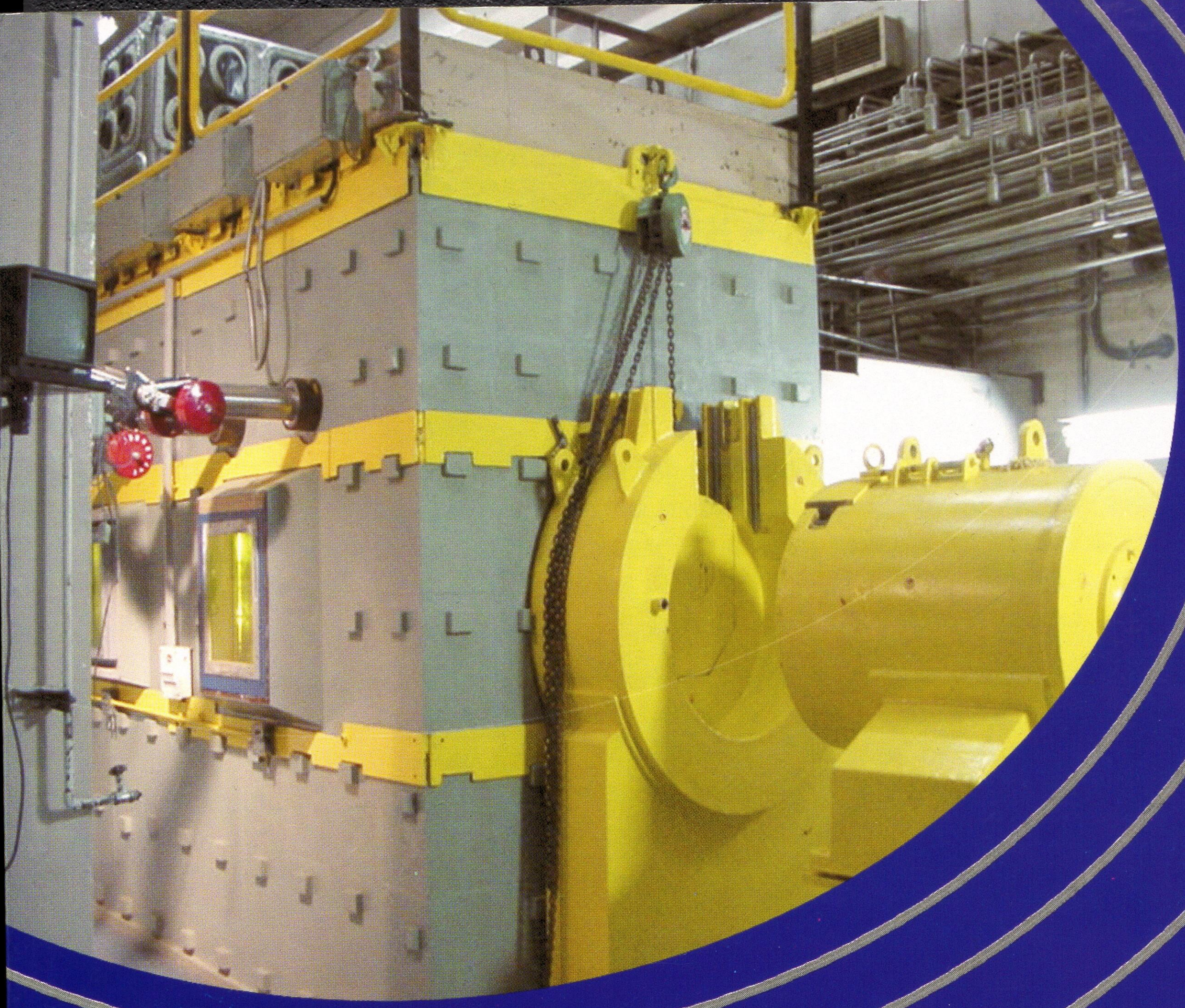

Reprocessing of
FAST REACTOR FUELS
at Indira Gandhi Centre for Atomic Research, Kalpakkam

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परमाणु ऊर्जा विभाग - स्वर्ण जयंती वर्ष
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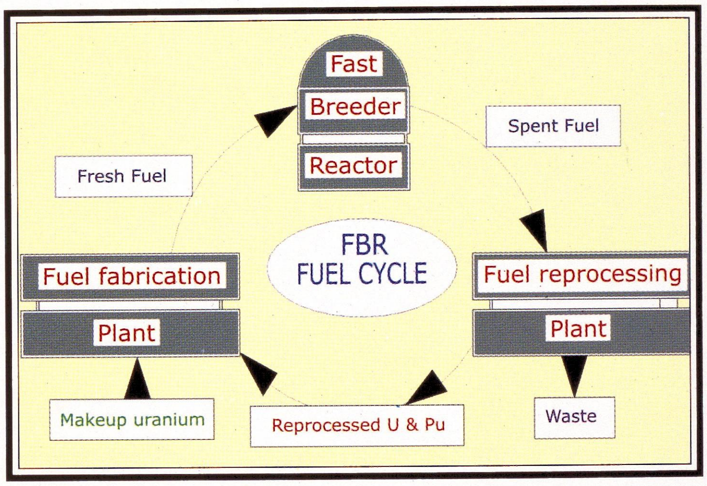
Fast Breeder Reactors (FBR) create a large energy resource by converting the U^{238} present in natural Uranium to Plutonium. The Indian nuclear power programme can expand from 10 GWe to 350 GWe capacity using the modest indigenous uranium resources with breeder technology. This technology requires closing of the nuclear fuel cycle. The Plutonium produced in FBRs is recycled by reprocessing the irradiated fuel discharged from the reactors. Thus, the requirement of fresh uranium for FBR is substantially reduced. FBRs with closed fuel cycle are required to be introduced in India expeditiously, to enable providing a major share, in fulfilling the growing electricity needs of the country.

A test reactor, FBTR (Fast Breeder Test Reactor) of 40MWt/13MWe capacity has been built at IGCAR and operated successfully to develop FBR and associated fuel cycle technologies. India has launched the second stage of nuclear power programme by taking a decision to build the Prototype Fast Breeder Reactor (PFBR) (1250MWt/500 MWe). While FBTR uses Mixed (Pu-U) carbide fuel, PFBR uses mixed (Pu-U) oxide (MOX) fuel.

Reprocessing of FBR fuels, a vital step in closing the fuel cycle, is complex compared to that of thermal reactor fuels, because of high Pu and fission product content. The spent fuel discharged from FBTR has 70% Pu as compared to 0.3% in Pressurised Heavv Water Reactors (PHWR). The fission product is also ten times more. Since these reactors have to be inducted in large numbers in shortest possible time, the spent fuel is reprocessed as quickly as possible after discharge from the reactor. Hence the radiation field in which the separation is carried out is also very high.

FBR FUEL CYCLE



In Fast Breeder Reactor reactors, there is an increase in plutonium content while uranium is consumed. The irradiated fuel is reprocessed for recovering Uranium and Plutonium for reuse in the reactor. In the fuel reprocessing plant, the fuel pins are dismantled from the subassembly. These pins are then chopped and dissolved in nitric acid. Solvent extraction process with tributyl phosphate as solvent is used to separate Uranium, and Plutonium and fission products. A very large fraction of the radioactive fission products and long-lived radioactive elements are fixed in suitable solid matrices such as glass and disposed and monitored in deep geological repositories. A tiny fraction gets released along with the gaseous and liquid effluents from the reprocessing plants, which is controlled and maintained as per the stringent regulatory requirements.

The Plutonium and the Uranium recovered from the reprocessing plant along with fresh uranium are fabricated as fuel elements in fabrication plant. The refabricated fuel is used in the reactor. The fuel cycle is thus closed.

FOUR STAGES PROGRAMME OF FBR FUEL REPROCESSING

Stage I	:	Development of complex technologies for process, equipments, remote handling systems, waste management methods and instrumentation control
Stage II	:	Reprocessing of FBTR fuels in the pilot plant, lead mini cells (LMC)
Stage III	:	Reprocessing of FBTR fuel & demonstration of PFBR fuel reprocessing in DFRP
Stage IV	:	Reprocessing of fuel and blanket subassemblies of PFBR fuel in PFRP

PROCESS DEVELOPMENT

- Reduction in extraction cycles and direct denitration to mixed oxide to reduce the process steps
- Solvent extraction codes & distribution models for improving the process performance
- Solvent wash methods with salt free reagents and purification and recovery of solvent and diluents to reduce the waste volume
- Insitu partitioning to reduce process steps
- Electrochemical methods for acid killing, destruction of organic wastes, lab waste, resins and solvents to reduce the waste volume
- Development of flow sheets with alternate solvents to reduce the waste volume

PROCESS EQUIPMENT DEVELOPMENT

- Laser based dismantling systems
- Development of chopper, rotary continuous dissolver and advanced clarification systems
- Development of centrifugal extractors and high efficiency ejector mixer settlers
- Insitu electrolytic partitioning mixer settler
- Constant volume feeders for accurate metering of active liquids
- Fluidic pumps for active liquid transfer

INSTRUMENTATION AND CONTROL

- Development of drives and speed sensing systems in radioactive areas
- Assay of leached hulls for accurate Pu accounting
- On-line assaying of Pu in high active streams

R & D IN FBR FUEL REPROCESSING ENCOMPSSES DEVELOPMENT AND INTERFACING OF SEVERAL COMPLEX TECHNOLOGIES

WASTE MANAGEMENT

- Removal of radioactive Iodine, krypton, xenon and tritium from the gaseous effluents
- Technologies for near zero activity discharges of low and intermediate wevel wastes
- Actinide separation for encapsulation in ceramic waste forms
- Separation of fission products such as Cs and Sr for encapsulation in ceramic waste forms

REMOTE HANDLING SYSTEMS

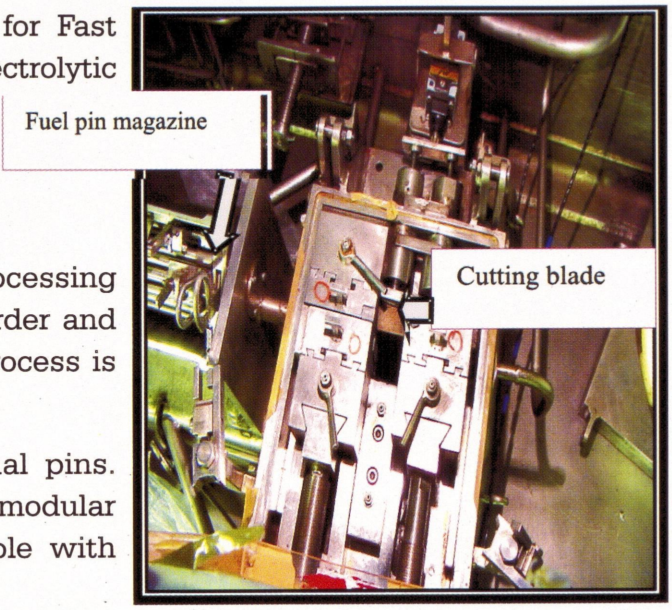
- Development of remote sampling and analytical systems
- Development of remote visual systems for highly radioactive areas
- Development of remote inspections and repair techniques

MATERIALS

- Development of advanced materials alloy for dissolver and raffinate evaporators
- Dissimilar metal joints
- Development of electrode coatings

FBR fuel reprocessing technology involves development in many specialised fields. The vital R&D on process & equipment development work is carried out in the Reprocessing Development Laboratory (RDL) at IGCAR. The equipments are tested in the engineering laboratory before deploying them in radioactive environment. Some of these equipments have been used for reprocessing of irradiated thorium fuel for U^{233} recovery. With this U^{233}, PFBR MOX fuel for irradiation experiments in FBTR has been fabricated. Part of this fuel is also used for KAMINI reactor (30 KWt), the only reactor operating with U^{233} as the driver fuel in the world.

A few examples of equipment developed at RDL for Fast Reactor Fuel Reprocessing are, Single pin chopper, Electrolytic dissolver, Centrifuge clarifier and Centrifugal extractors.



Single Pin Chopper

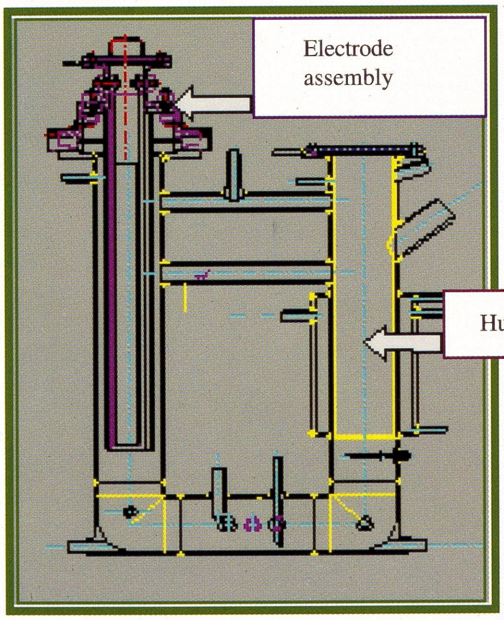
SINGLE PIN CHOPPER

Bundle chopping is used in thermal reactor reprocessing plant. Since, the cladding of fast reactor fuels is harder and pins are smaller in diameter, single pin chopping process is used.

The fuel subassembly is dismantled into individual pins. These pins are chopped in single pin chopper. It is modular in construction. All parts are remotely maintainable with master slave manipulators.

The prototype is installed in the hot cell facility and is undergoing performance trials for reprocessing in FBTR fuel pins.

ELECTROLYTIC DISSOLVER



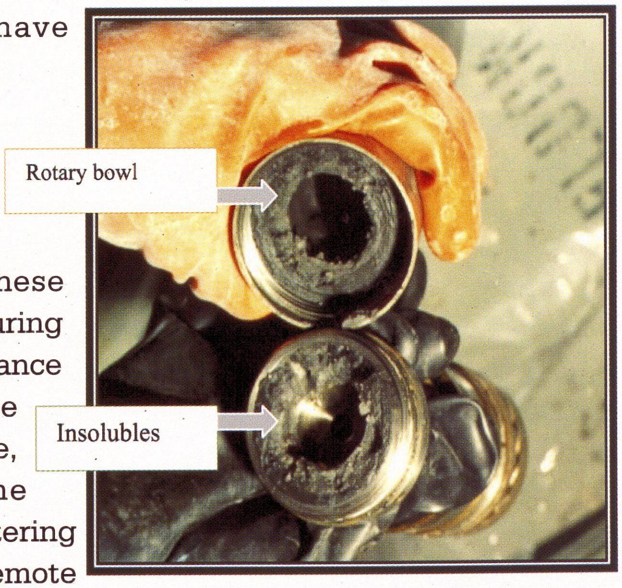
Titanium electrolytic dissolver for mixed carbide fuel

Dissolution of Pu rich fuels is difficult. Mixed carbide fuels used in FBTR, pose additional problem because of the formation of complex organic compounds, during the dissolution. These compounds interfere in solvent extraction process. Advanced dissolution processes, such as silver catalysed electrolysis and ozone based processes have been developed.

Hulls after dissolution of mixed carbide fuel

CENTRIFUGE FOR FEED CLARIFICATION

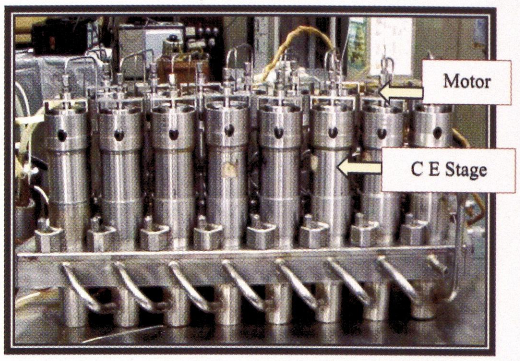
The dissolver solution will have very fine particles of cladding and undissolved fission product alloys. These particles accumulate in the organic-aqueous interface during solvent extraction and degrade the solvent. The performance of the extraction process is reduced by these fine particles. A high speed air turbine operated centrifuge, operating at 15000 rpm providing 125 times the acceleration due to gravity, has been developed for filtering dissolver solution. This equipment is designed for remote operation and maintenance in hot cells.



Insoluble collected in the centrifuge During the Uranium-233 campaign

CENTRIFUGAL EXTRACTORS FOR LOW SOLVENT DAMAGE

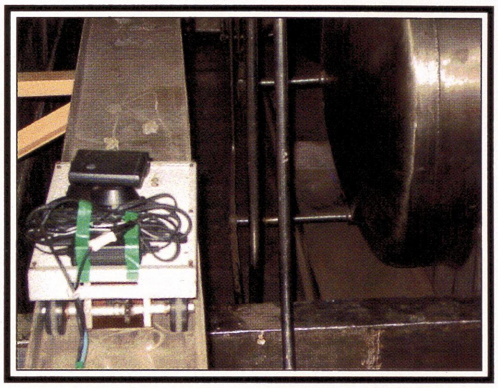
The success of the Indian fast reactor programme lies in reprocessing the fuel from the reactor within a short time of discharge. This calls for processing feed solutions, which are highly radioactive. Since the solvent undergoes radiolytic degradation, short residence time contactors namely, centrifugal extractors (CE) are developed at RDL. In CE, the residence times are of the order of seconds compared to minutes in pulse columns (used in thermal reactor fuel reprocessing). This improves the solvent extraction performance for FBR fuel reprocessing.



16 Stage Centrifuge Extractor

HOT CELL EQUIPMENT AND SYSTEMS

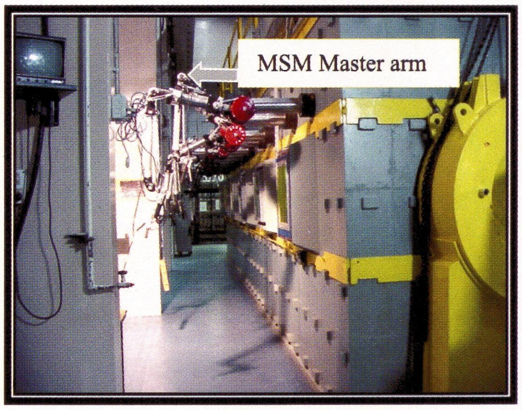
Remote gadgets are required for inspection and maintenance in radioactive areas. One such device for visual inspection is developed for inspecting the high active liquid waste storage tanks installed in underground. Whenever inspection is required, this robot will be introduced and will be remotely operated. A camera mounted on the robot will aid in close visual examination of the integrity of the tanks.


Robot for Inspection of Waste Storage tanks

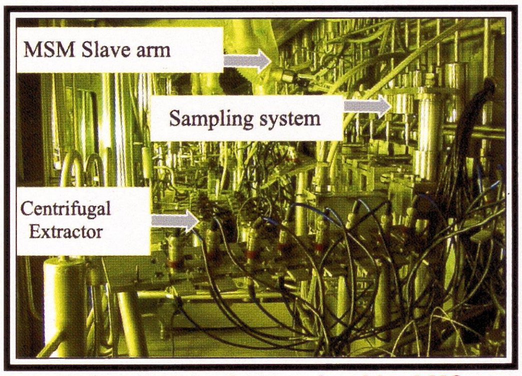
LEAD MINI CELL: A PILOT PLANT FOR FBR IRRADIATED FUEL REPROCESSING

The Lead Mini Cell facility provides a testing bed for the prototype equipment for FBR fuel reprocessing in realistic environment. This facility is a pilot plant for reprocessing the FBTR fuel. The process flowsheet and the equipment designs are fine tuned for deployment in DFRP, demonstration fuel reprocessing plant being built for reprocessing the FBTR fuel.

LMC comprises of a leak-proof stainless steel containment box with adequate lead shielding. The cell is based on a compact layout, constructed on an area of 11 m * 2 m. All equipment such as singe pin chopper, dissolver, centrifuge, centrifugal extractors and sampling systems are housed in a containment box. All the equipment and systems are designed on the basis of no-direct maintenance concept. The cell is provided with radiation-shielding windows, in-cell crane and articulated arm type master slave manipulators to facilitate remote operation and maintenance of equipments and systems in the containment box. Specially designed tanks (annular and slab type) have been installed to store solutions containing plutonium to avoid criticality. The facility has about 2 km of intricate stainless steel piping with approximately 3000 bends and 2000 radiography qualified joints.



Operating area of LMC



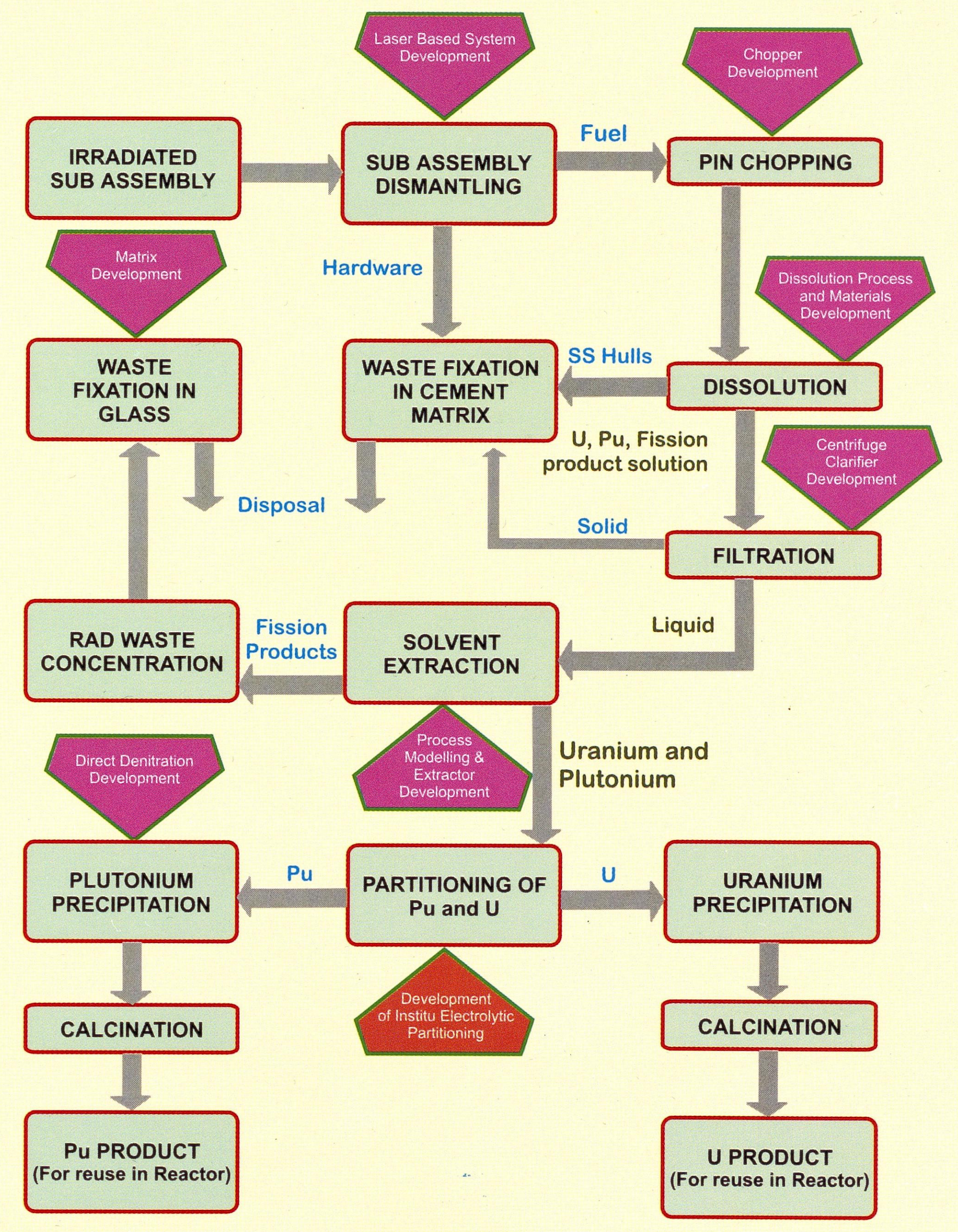
A view of equipment in side, LMC

DEMONSTRATION FBR FUEL REPROCESSING PLANT (DFRP)

DFRP Front View

The design of DFRP, under construction, is based on the process flowsheet evolved in the pilot plant, Lead Mini Cell. This plant will reprocess the FBTR mixed carbide fuel and also will demonstrate the reprocessing of PFBR mixed oxide fuel.

Welding intricate joints in cell



DEVELOPMENT ACTIVITIES IN VARIOUS STEPS OF FBR FUEL PROCESSING

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