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INDIAN EXPERIENCE IN FUEL REPROCESSING

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INTRODUCTION

Reprocessing in India on a plant scale was started with the commissioning of the Trombay Plutonium Plant in 1964. The plant intended for processing spent fuel from the 40 MW thermal research reactor 'CIRUS' and recovering plutonium required for research and development activities of the Indian Atomic Energy Programme, was built and commissioned in a period of about 4 years. This plant has helped a great deal in generating expertise and trained manpower in the design, execution and operation of future reprocessing plants in the country and has served all the requirements for which it was built. Based on this experience, a larger plant to reprocess spent oxide fuels from power reactors has been built at Tarapur which is undergoing precommissioning trial runs. A plant to reprocess fuels from the natural uranium heavy water moderated power reactors and the fast breeder test reactor (FBTR) under construction at Kalpakkam, has been planned, the preliminary design work for which is in progress.

DESIGN PHILOSOPHY

In view of the highly radioactive nature of the material handled in a fuel reprocessing plant, the process equipment and piping necessarily have to be located in heavily shielded process cells. From the radiological health and safety considerations, such plants have to be operated remotely. While there is no choice regarding the necessity for remote operation, maintenance of the plant could either be carried out substantially by using remotely operated gadgets or the plant could be designed for direct maintenance in which case decontamination of relevant portions of the plant will be required to achieve direct access. The remote maintenance concept to be effective calls for sophisticated equipments requiring very high reliability involving high cost of installation in contrast to direct maintenance concept.

Processes available for reprocessing are classified under aqueous and non-aqueous methods. Though non-aqueous methods are known to have certain advantages, they have not found favour so far on large-scale applications in view of technological problems. On the other hand, the aqueous methods by virtue of less complicated process equipment, amenability for continuous operation and capaibility for obtaining high separation factors, have been widely used. However, with high burn-up fuels, problems like solvent degradation, undissolved solids in the feed solution etc. will have to be taken into consideration. In the case of large size plants handling high burn-up fuels, problems involved in dealing with large volumes of high active wastes will be significant in the aqueous methods.

The most widely used contactors for the solvent extraction are pulsed columns and mixer settlers. Centrifugal extractors are gaining importance particularly for reprocessing high burn-up fuels. While pulse columns and mixer settlers have their own relative merits, experience with pulsed columns has been good. The use of mechanical pulsers may lead to maintenance problems which can be overcome by adopting pneumatic pulsing system whose characteristics are comparable to the mechanical pulsing system. The interface control in the column can be achieved by regulating the flow of the aqueous stream using an airlift system. Further, airlift can be used as a metering device for radioactive solutions with adequate accuracy and reliability.

Evaporators are used for concentrating inter-cycle process streams and waste streams. While considerable experience with "pot" type of evaporators is available, in view of certain favourable characteristics like amenability for better control of system parameters and higher heat transfer coefficients with lesser hold-up, "vertical thermosyphon" type of evaporators are finding increasing application.

TROMBAY REPROCESSING PLANT

Direct maintenance concept was adopted for the Trombay plant and this proved highly successful as during the course of the operation of the plant many portionsof the plant could be approached after decontamination as and when required in order to effect modifications to suit operational requirements.

The Trombay plant adopted the purex flow sheet using mechanically pulsed solvent extraction columns with 30% tributyl phosphate as solvent. To achieve the desired quality of the products, two cycles of co-decontamination with final purification cycles for uranium and plutonium were adopted. The fuel being of uranium metal with aluminium cladding, the dejacketing was carried out by chemical means. Plutonium was purified by anion exchange and the uranium was subjected to final purification by solvent extraction. The purified plutonium nitrate solution was further converted to oxide or metal as required.

In view of the difficulties involved in the maintenance due to high radiation fields, use of mechanical pumps for transfer of solutions was kept to a minimum and restricted to only streams where metering was required. In all other cases, transfers were by steam jet syphons. For process instrumentation, pneumatic instruments were used employing air purge for density and level measurements. Column interface control was achieved by regulating the flow of aqueous stream through diaphragm control valve.

EXPERIENCE WITH DECONTAMINATION OF TROMBAY PLANT

In view of the corrosion attack the plant equipment and piping are subjected to, the Trombay plant is being decontaminated and partially decommissioned for detailed inspection and for incorporating additions and alterations to extend its life which will also permit expansion of its capacity.

The decontamination/decommissioning operation has been highly successful as is proved from the general radiation levels achieved in the process cells. The personnel radiation exposures have been kept within permissible limits throughout. Some of the details of this decontamination experience are discussed below.

The decontamination/decommissioning programme was planned on the following lines:

(i) Internal decontamination of all the equipment and piping in the heavily shielded concrete process cells to the extent necessary and possible to facilitate personnel entry into the cells;

(ii) Carry out radiation survey inside cells, ascertain extent of external contamination on the surfaces of cell and equipment and detect possible failures if any causing such contamination;

(iii) Decontamination of external surfaces of cell equipments, piping and cell internal surfaces wherever necessary;

(iv) Dismantle process equipment, piping and structural support stagings to the extent necessary and removal of the same out of the cells for further inspection before deciding on their re-use or disposal;

(v) Decontamination of empty cells to remove residual contamination to limits stipulated by radiological health and safety standards to enable safe and convenient entry into the cells for further installation work;

(vi) Carry out decontamination and decommissioning of affiliated areas in the plant to the extent necessary for effecting modifications.

For the execution of the above, various aspects like man rems involved, training programme for personnel employed, waste management, items of equipment and material supplies required, cost, etc. were considered.

A full-fiedged campaign was then started for internal decontamination of equipments and piping in the cells planned for recovery following multiple decontamination routes. Maximum number of equipments were covered in a single route to minimise quantity of decontaminants used thereby keeping down the volume of radioactive liquid wastes generated and the cost. Equipments decontaminated include pulsed perforated plate columns, evaporators, ion exchange columns, storage vessels and associated piping.

Following the internal decontamination of the equipment, the task of decontamination of cell interior surfaces and equipment external surfaces was undertaken involving elaborate planning of personnel exposure and use of plastic suits and fresh air-line respirators by personnel entering cells. Use of high pressure water jets, steam, chemicals, chipping of surfaces, concreting, etc. was resorted to as appropriate to remove contamination and bring down radiation levels. At convenient stages, the equipments and piping were cut and moved out of the cells. These items were further subjected to detailed inspection, internal and external, to determine their condition after many years of operation. The feed back information thus obtained has been useful for the design of future plants.

TARAPUR FUEL REPROCESSING PLANT

The plant at Tarapur built based on the experience of the Trombay plant and extensive development studies on pilot scale, also adopts purex process with direct maintenance concept. This plant is designed to reprocess zircalloy clad oxide fuels. Chop leach method has been chosen for the head-end treatment in preference to the chemical decladding in view of the excessive corrosion problems expected from the chemicals required to be used and the resulting waste management problems. As against this, the mechanical chopping of the fuel into small pices before dissolution involves a number of mechanical operations which are to be carried out remotely and the reliability of the performance of the equipments has to be ensured. Taking into account the relative merits of the two alternatives, the chopping method has been preferred in this plant.

The fuel handling area has a spent fuel storage pool with provision for horizontal storage of fuel, pool water purification system and the associated mechanical handling equipments like overhead crane, pool bridge with motorised tong assembly unit etc. It is from this area the spent fuel is charged through a transfer port embedded in the head-end cell wall into a fuel magazine with an automatic pusher for feeding the fuel to the chopper. The chopped fuel pieces are then dropped into a dissolver through a distributor. The head-end cell is equipped with, in addition to the above, an in-cell crane, a pair of master-slave manipulators, shielded viewing windows, closed circuit television camera etc. for operation and maintenance requirements. After the dissolution of the fuel, the undissolved hardware like zircalloy, is transferred remotely to a drum mounted on a motorised trolley for retrieval through an underground tunnel extending to the fuel handling area into a shielded cask for disposal as radioactive solid waste suitably.

The solution from the dissolvers is moved out for further processing by solvent extraction. The process equipments and piping are installed in three concrete cells of varying thickness. The first cell houses the conditioners for the feed solutionandtwo cycles of co-decontamination with associated evaporators, scrubbers etc. for separation of bulk of the fission products.Maximum amount of activity is handled in this cell. The equipments for partition cycle and the uranium purification cycle are installed in the second cell. The equipment for the plutonium purification cycle and neptunium recovery are housed in the third cell from where the purified plutonium and neptunium product solutions are taken out into the plutonium reconversion laboratory for further processing. In this laboratory, the plutonium nitrate solution is processed in a series of glove-box trains for conversion to plutonium oxide through the oxalate precipitation step. The depleted uranyl nitrate solution from the second cell is moved out for further purification if necessary with silicagel columns and precipitation to ammonium diuranate and calcination to uranium oxide in a separate building. The highly radioactive and intermediate level liquid waste solutions are concentrated and stored in large waste storage tanks for interim storage before they are taken out for immobilisation in solid matrices. The low level wastes are treated suitably if necessary, monitored and discharged after ensuring that the activity is within permissible limits stipulated in the radiological health and safety regulations.

The plant control room is located in a separate adjoining building with all the instrumentation connections brought out from the process building. This building also houses the plant room consisting of compressed air plant, air-conditioning plant, equipment for supply air ventilation system, electrical switch gear room etc. Personnel entry into the process building is through the change rooms provided in this building. To ensure safety, utmost care is taken in the ventilation aspects to maintain desired pressure gradients and air flow patterns. For this purpose, the whole plant is divided into different zones each identified suitably depending on the radiological status of the areas involved. The air from the active areas is exhausted through absolute filters before discharging through a tall stack.

FUTURE PLANS

With growing experience in the field of fuel reprocessing and with problems anticipated in reprocessing high burn-up fuels, development efforts need to be directed, among others, towards finding solutions in areas like solvent damage, feed clarification to remove effectively insoluble particles either of the fission products or the fuel cladding material, and behaviour of materials of construction under different corrosive conditions in the plant to increase plant operating efficiency and extend life.

Since the efficiency of operation of a fuel reprocessing plant depends to a large extent on the speed with which the chemical analyses of various process streams are made available, development of in-line instrumentation techniques merit consideration. For proper management of various nuclear materials, the analytical techniques need to be constantly assessed to improve the accuracy and reliability.

In view of high potential for health hazards involved in handling radioactive materials, methods to ensure both industrial and radiological health and safety should be continuously reviewed.