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THE MARCOULE PILOT PLANT.

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1 INTRODUCTION - HISTORICAL BACKGROUND

The Marcoule spent fuel reprocessing pilot facility was built in 1960-1961 for extended testing of the PUREX process with various types of fuel under conditions similar to those encountered in a production plant, and for experimental development of remote handling methods to reduce shutdown time and to improve job safety.

The initial natural uranium metallic fuel processing line was modified several times, notably to allow reprocessing of MTR (U Al, Pu Al) fuel and Np recovery, before it was upgraded in 1973 for compatibility with oxide fuels in general, and in particular from fast breeder reactors.

After a number of reprocessing campaigns from 1974 to 1976 with oxide fuel from the RAPSODIE and KNK reactors, systematic reprocessing of the PHENIX reactor core charge was undertaken from 1977 to 1983, for a total of 2.6 metric tons of 26% ^{235}U and 6.6 metric tons of 25% Pu.

Extensive modification work was undertaken on the facility in 1983 in the scope of the TOR project, designed with the following objectives:

- increase the throughput capacity to at least 5 metric tons of PHENIX equivalent fuel per year,
- extend equipment and process R & D capability,
- improve job safety by maximum use of remote handling facilities,
- maximize waste conditioning treatments to produce waste forms suitable for direct storage,
- provide a true industrial process demonstration in continuous operation under centralized control using computerized procedures.

The redesigned plant is scheduled to begin operation during the second half of 1986. The proximity of the Industrial Prototypes Service and the ATALANTE radiochemical research laboratory scheduled to begin operation in 1990, will provide a synergistic environment in which R & D programs may be carried out under exceptional conditions.

2 PAST EXPERIENCE

Over 1300 kg of plutonium were extracted and purified from 1977 to 1983. One of the subassemblies reprocessed was irradiated to over 100 000 MWd/t and two others contained plutonium that had already been recycled through two irradiation-reprocessing cycles. The cooling time always exceeded one year with a single exception (8 months).

The facility implements the PUREX process in which the pin end pieces are first cut off and the pin is then cut up into sections for batch dissolution in a perforated basket placed in a thermosiphon device. After clarification to 15 µm, 3 consecutive solvent extraction cycles are performed with U/Pu partitioning during the second cycle. All of the extraction devices are pulsed columns except for the partition (electrolytic reduction) and solvent scrubbing in mixer-settlers. The final Pu solution is concentrated by evaporation in zirconium equipment.

The process results have generally been satisfactory:

- The U and Pu recovery yield is better than 99.98% on average, and 99.99% in continuous operation.

- The residual $\beta\gamma$ activity of the uranyl nitrate after the second cycle (<10 $pCi \cdot l^{-1}$) is within tolerances. The residual plutonium $\beta\gamma$ activity after partitioning (0.01-0.2 $mCi \cdot l^{-1}$), followed by oxalic precipitation, results in plutonium containing less than 1 $\mu Ci \cdot g^{-1}$ of γ-emitters.

- The U-in-Pu and Pu-in-U purification factors meet existing specification requirements after partitioning (10 000 ppm and 300 ppm, respectively). The neptunium is suitably eliminated during the second extraction cycle before partitioning.

However, a number of problems have occurred in operation, including:

- remote handling equipment contamination during hull manipulation by a thin brittle layer of metallic ruthenium deposited during the dissolution step. Because of the chemical inertia of metallic ruthenium, the equipment is difficult to decontaminate and maintenance is hindered.

- variations in the operating conditions of the continuous aqueous phase extraction columns due to progressive fouling of the perforated plates, requiring periodic flushing.

- obstruction of process plumbing due to accumulation of solid dissolution residue in the settling zones of the first extraction cycle (waste settler and air lift bottom sections), and also to the accumulation of plutonium dibutyl phosphate due to circulation of concentrated Pu solutions (3rd purification cycle, evapo-concentration).

- buildup of solid wastes with contamination levels too high to allow them to be placed in interim storage for lack of suitable containers.

These conditions inevitably result in shutdowns, "exceptional" working conditions and liquid waste production.

3 NEW FACILITIES

In addition to renovating the existing pilot facilities, two new units were designed and built: TOR 1 and TOR 3.

3.1 Design Principles

TOR 1 is an entirely new facility located to the north of the previous unit. TOR 1 comprises all of the head-end operations: fuel acceptance, storage, cutup, dissolution, clarification, solution adjustment, solid process and technological waste and offgas treatment. The following principles have been observed in this design:

- Maximum use has been made of remote manipulators for dismantling and process operations to avoid "exceptional" process control, intervention and dismantling conditions. A fixed passage master-slave system is used together with heavy handling equipment (travelling crane, wall crane, slide and bracket) actuated by trolleys and a Halberthal carrier current control device, supporting a plug-in unit with remotely interchangeable electronic, electromechanical and actuating components, including lifting devices (2000 daN) and heavy remote manipulators (25-100 daN depending on the modular arm configuration) together with a 1000 daN block and tackle.

- The system architecture is based on remote control of the flow of solid process, maintenance and dismantling wastes and removal after conditioning. Process operations are conducted on three levels in the building; from the top down these are: pin cutup operations, chemical processing (dissolving and clarification), and waste processing (decontamination, melting, etc.). Each level includes a leaktight central zone with radiation shielding, together with integrated intervention areas which are interconnected vertically so that all of the process wastes may be separated from the remainder of the facility and and transferred to waste treatment cells.

- Centralized automatic control and monitoring provisions have been implemented whenever possible in the TOR 1 unit and the older facilities, but with maximum flexibility. Local control is maintained for utilities and for mechanical operations, with local process alarm functions repeated in the central control room. The remainder of the system is entirely centralized. The new R & D units will initially include provisions for local control.

The control and monitoring system is based on a Contrôle Bailey "Micro Z" computer with instrumentation racks (analog and logic signal acquisition and processing equipment including programmable controllers), with decoupling and backup racks for remote transmission and emergency functions. The central control terminals include screens for displaying all or part of the process scheme, image callup and control keyboards, and printers to provide hard copy records of all process advisory and warning messages.

- Provisions have been made where possible for equipment replacement, extension and redundancy in cells designed to allow complete remote dismantling (e.g. mechanical treatment and clarification) and in independent cells (dissolution and waste processing) with connections already provided. In the latter cells, provision is made for remote equipment dismantling.

- Safety provisions have been emphasized throughout the unit: γ shielding, leaktightness, criticality (favorable geometry) and earthquake resistance (force 8).

TOR 3 corresponds to the first cycle of the solvent extraction process, and is capable of U/Pu partition and fission product solution concentration operations. TOR 3 was built in a cell of the existing facility. Since the process equipment had to be entirely rebuilt, the existing facilities were completely dismantled and decontaminated inside the cell, which was isolated from the remainder of the installation by creating a restricted zone with rooftop access for entering new components.

The cell was raised to meet process requirements. The process equipment was prefabricated in thirteen modules designed to be interconnected using the crane after entry into the cell. This concept made it possible to do most of the welding in the construction shop rather than in a restricted access zone.

The equipment cannot be dismantled with remote manipulators. The design includes a sufficient number of components and connections to allow multiple process schemes to be implemented using airlift transfers.

3.2 Process Research and Development Considerations

The project includes the following facilities:

- A conventional reprocessing line for continuous operation, including the following stations in the TOR 1 building: entry station, storage, fuel pin cutup, batch dissolution, centrifugal clarification and adjustment of the acid solution. The remainder of the line is located in the old building: first extraction cycle (pulsed columns and mixer-settlers) with fission product solution concentration (TOR 3), a second and third Pu purification cycle with Pu solution concentration, and a second uranium purification cycle.

- A number of operations are now being implemented either in parallel with existing conventional line operations for comparison between different techniques, or in series at the tail-end of the line for further product and waste conditioning. These "unconventional" facilities include: a pulsed filter for clarification of acid solutions in parallel with the centrifugal process in the same cell; provisions for implementing different first-cycle process layouts by modifying the connections in the TOR 3 cell and with the other cycles (U and Pu coextraction and stripping, different simultaneous scrubbing operations, U/Pu partition during the first or second cycle, extraction using two parallel columns with different packing materials, solvent treatment in mixer-settlers of pulsed columns, backwashing capability in the second purification cycle, etc.).

- At least two years after commissioning of the first process facilities, separate cells will become operational with additional process equipment: a continuous helical-conveyor shaker dissolver in parallel with the batch dissolution line, a zeolite type iodine trap for the dissolver offgases, a hull compaction unit designed to melt cladding scraps after dissolution in order to ensure absorption of the α-emitters in a flux suitable for vitrification, and finally a spacer wire removal unit in the pin cutup cell.

- It will also be possible to couple the line with waste conditioning units, in particular with PIVER II (scheduled to begin operation in 1990 with a high temperature vitrification process using direct induction in the glass with a high unit capacity), with the IRIS incinerator for organic wastes followed by vitrification of the ash, and with a melting furnace for the "technological wastes" produced by dismantling or by periodic equipment replacement.

4 OBJECTIVES

Beginning in the second half of 1986, the "conventional" reprocessing line in the Marcoule pilot plant will begin continuous operation over periods ranging from a few months to one year, initially with a throughput of at least 5 metric tons of PHENIX reactor fuel per year and, starting in 1988, with a fraction of the fuel removed from SUPER PHENIX 1. This facility will thus constitute an industrial-scale demonstration of reprocessing in the fast breeder reactor fuel cycle, and will provide a solid foundation for the design and construction of the MAR 600 plant.

Around 1988, a number of other new units will come on stream, including a continuous dissolver, an iodine trap, a spacer wire removal station and a hull melting furnace, all of which will provide further data for MAR 600.

During the initial radioactive operating tests, the engineered provisions for experimenting with various process layouts and hull conditioning methods will be of considerable interest for the UP3 and UP2-800 plants.

Finally, the program now under development in the Radioactive Engineering Department (DGR) will include future changes in the pilot plants:

- Improved plant operation, use of a nondegradable solvent, development of on-line analyzers, etc.

- Upgrading the plants for use with new fuel compositions and with more universal methods (e.g. clad-powder separation prior to dissolution).

- Process simplification: utilization of high-performance solvents, U/Pu coprecipitation, modified upstream and downstream interfacing, etc.

- Further development of remote-controlled operations and robotization to ensure satisfactory working conditions.