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Consolidated Fuel Reprocessing Program

REPROCESSING IN BREEDER FUEL CYCLES*

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END

OUTLINE

- I. INTRODUCTION
- II. EVOLVING PLANS FOR BREEDER REPROCESSING
 - A. Demonstration Reprocessing Plant (DRP) (Slide 1)
 - 1. Design capability for both breeder and LWR fuels.
 - 2. Advanced technology will demonstrate reliability and operability.
 - 3. Flexibility will allow introduction of new technology.
 - B. Reprocessing Head-End Colocated at an Existing Facility
 - 1. Assumes existence of an operating facility.
 - 2. Will allow demonstration of essential technical improvements.
- III. RELATIONSHIP TO LWR REPROCESSING
 - A. Need to Recover Plutonium From LWR Fuels for Early Breeder Industry.
 - B. Much of the New Technology Applicable to LWR Reprocessing in New Plants.
- IV. INTEGRATED EQUIPMENT TEST (IET) FACILITY AND RELATED HARDWARE DEVELOPMENT ACTIVITIES
 - A. Mechanical Considerations in Shearing and Dissolving.
 - 1. Need based on breeder fuel element design and irradiated properties.
 - 2. Remote maintenance systems.
 - B. Remote Operations and Maintenance Demonstration (ROMD) Phase of IET. (Slide 2)
 - 1. Simulated processing cell containing all operations through dissolution.
 - 2. Flexible test bed will demonstrate and evaluate advanced maintenance systems.

C. Integrated Process Demonstration (IPD) Phase of IET.

1. Together with ROMD, IPD will simulate reprocessing at 0.5 t/d through the first cycle of solvent extraction.
2. Experience with nonradioactive integrated operation will minimize uncertainties when DRP is operated.
3. Opportunities for component evaluation within a total plant environment.

D. Separate Component Development Activities.

1. Shear and disassembly machine. (Slides 3, 4)
2. Voloxidizer, rotary kiln.
3. Rotary dissolver. (Slide 5)
4. Solvent extraction contactor. (Slide 6)
5. Servomanipulator systems. (Slide 7, 8)
6. Maintenance vehicle, sampler vehicle. (Slides 9, 10, 11)

V. SUPPORTING PROCESS R&D

1. Voloxidation, tritium recovery.
2. Dissolution, digestion.
3. Feed clarification. Pu polymerization.
4. Solvent extraction flowsheets and contactors.
5. Off-gas processing and its demonstration.
6. Production of improved mixed-oxide fuel materials. (Slide 12)

REPROCESSING IN BREEDER FUEL CYCLES

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INTRODUCTION

Over the past decade, the United States has developed plans and carried out programs directed toward the demonstration of breeder fuel reprocessing in connection with the first breeder demonstration reactor. A renewed commitment to moving forward with the construction of the Clinch River Breeder Reactor (CRBR) has been made, with startup anticipated near the end of this decade. While plans for the CRBR and its associated fuel cycle are still being firmed up, the basic research and development programs required to carry out the demonstrations have continued. This paper will update the status of the reprocessing plans and programs. Policies call for breeder recycle to begin in the early to mid-1990's.

EVOLVING PLANS FOR BREEDER REPROCESSING

Over the past three to four years, the concepts for a major pilot plant demonstration facility for breeder reprocessing, now called the Demonstration Reprocessing Plant (DRP), have evolved. Slide 1. An overall conceptual design was completed in mid-1981. Designed to demonstrate engineering prototype systems and equipment, the DRP has capacity for handling fuel from about six breeder reactors. Although primarily oriented toward reprocessing fuel from early breeder reactors, the DRP was also designed to accommodate light-water reactor (LWR) fuel to provide an adequate fuel load for operability and reliability testing during early years when available breeder fuel is limited. An important objective of the facility is to advance the state of

reprocessing technology applicable to any fuel cycle by developing reliable, cost-effective advanced technology for reprocessing spent breeder fuel to achieve a 99.9% recovery of fissile material by minimizing environmental emissions and doses to plant workers, and for protecting the fissile material with effective, workable safeguards systems. The major innovative improvements include (1) flexibility for the incorporation of new technology through the REMOTEX concept of totally remote maintenance, which allows for replacement of any equipment module without access to the reprocessing cell, (2) the use of a low-flow ventilation system that requires low-leakage cells with in-cell cooling and recycled ventilation and allows the use of reduced-size but more effective off-gas treatment processes, and (3) advanced concepts for process monitoring systems for control and safeguards. These improvements translate into many fundamental design considerations throughout the sequence of reprocessing steps, although the well understood and demonstrated conventional chop-leach Purex process remains as the basis for reprocessing.

Recently, colocation of the head-end operations at the Allied-General Nuclear Services (AGNS) plant was examined to simplify and reduce the costs of a breeder reprocessing demonstration, assuming that this facility is brought on-line for LWR reprocessing sometime this decade. Alternate arrangements and refinements to this option are now being pursued. No specific decisions have been made regarding the strategy that is to be followed.

RELATIONSHIP TO LWR REPROCESSING

Major efforts, which are intended to provide a suitable framework for private business to close the back-end of the LWR fuel cycle, are being pursued under new administration policies. A probable result will be the startup of the AGNS facility near the end of this decade. While institutional arrangements, specific goals, and schedules (with respect to reprocessing LWR fuels) remain to be determined, an important objective will be to recover plutonium for the liquid-metal fast breeder reactor development program.

A second point to be made is that the new and improved reprocessing technology, being developed for the breeder program for demonstration in the DRP or colocated facility, has spin-off applications for improved LWR reprocessing in future new plants.

INTEGRATED EQUIPMENT TEST FACILITY AND RELATED HARDWARE DEVELOPMENT ACTIVITIES

For the past five years, a major focus of the United States breeder reprocessing program has been on developing prototype equipment and facility concepts for the mechanically intensive head-end of a reprocessing plant. The complex hardware of a breeder fuel element, combined with high-heat loads and high-fissile contents, make the problems of shearing and dissolving breeder fuels much more difficult. The special maintenance requirements for this mechanical equipment have provided a focal point for examining overall facility concepts which provide totally remote maintenance. We have upgraded the canyon

concepts of the United States plutonium production plants, which employ remote maintenance systems. Rather than rely solely on cranes and impact wrenches, the facility will also include remotely operated servomanipulators for carrying out maintenance activities more nearly related to what man can do with hands-on operations.

The mechanical head-end equipment and remote maintenance features, which I will describe later, are in various stages of development today. Operations are ready to begin at Oak Ridge in the Remote Operations and Maintenance Demonstration (ROMD) phase of the Integrated Equipment Test (IET) facility. Slide 2. The ROMD facility is a large simulated remote reprocessing cell in which the head-end equipment, through dissolution, will be tested in an integrated mode with capability for complete remote operation and maintenance. Overall, the IET facility will simulate, using nonradioactive materials, reprocessing operations with prototype equipment, scaled at 0.5-t/d capacity from shearing through first-cycle solvent extraction, including solvent cleanup and acid and water recycle.

The major items of process equipment being developed, all of which will be designed, procured, and installed in the IET by 1984, include a modular shear with associated hardware disassembly and feed mechanism, a continuous rotary dissolver, and improved centrifugal solvent extraction contactors. Process testing of the rotary dissolver is nearing completion, and remote maintenance tests will be conducted in the ROMD later this year. A pair of servomanipulators mounted on a rigid boom extending down from a crane bridge and complete with on-board TV cameras will be tested in the ROMD system in the next few months.

A major effort has been organized to develop improved models of the manipulator and examine all facets of viewing, signal communication, power transmissions, and the man-machine interface between the in-cell slave arm and the man-controlled functions from the operating control room. These efforts will continue over the next five to ten years. The DRP maintenance concept uses servomanipulators mounted on a rail-supported floor transporter as well as the overhead bridges.

Additional justifications for this nonradioactive intermediate pilot plant include (1) the IET provides confidence that the improved processes will function properly in the DRP, and (2) the IET provides an opportunity for individual component evaluation within a total plant function.

Development of the mechanically-intensive head-end components has been under way for a number of years. Whole element shear tests which define compacting conditions, blade configurations, and forces required are now complete. Although whole element shearing of breeder fuel subassemblies appears feasible, removal of the sheath and shearing of the entire bundle of tubes (excluding the sheath) is desirable because of the excess metal and potentially irregular shape of the sheath pieces routed through the dissolver. A remote modular shear is now being designed and procured. Slide 3. This shear incorporates three in-cell hydraulic pistons for compacting, gagging, and shearing with through the-wall water hydraulic lines. This design prevents activity from being moved across the primary shield wall and simplifies the seismic design of the shear. All parts are assembled with simple accessible

hold-down bolts that permit replacement and repair of worn or failed parts. Slide 4. A disassembly-feed system is also being procured. The sheath will be removed after longitudinal slitting with a laser. The end piece will be cut off with a laser, and gas plenums will be sheared and removed in the shear.

Voloxidation is a new step that has been developed for the purpose of releasing tritium to the off-gas system and deactivating residual sodium in sheared breeder fuels prior to dissolution. It involves the use of a rotary kiln to subject the sheared fuel to an oxidative heat treatment. The application of this process in a demonstration plant is currently in question and engineering development work has now stopped.

Development work with the continuous rotary dissolver has essentially been completed. Slide 5. By operating on a continuous rather than a batch basis, better control of off-gas evolution can be obtained and complete rinsing of metal fragments is possible following dissolution of the fuel. Heat loads and high plutonium contents of breeder fuels complicate these operations and require special design considerations.

Solvent extraction performance in the initial codecontamination cycle will be improved through the use of a new generation of centrifugal mixer-settler contactors. Slide 6. Because of very short residence times, these contactors will minimize solvent radiation damage and respond quickly to changes in feed rate and concentration. The system will incorporate connected groups of single-stage units where the rotor is suspended from the drive motor in such a way that

the rotating parts can be simply withdrawn and exchanged should failures occur. Tests with single-stage units have been completed, and multistaged systems are now being tested. An important feature of this unit is the capability of handling reasonable quantities of solids without plugging or gross changes in contactor efficiency. Although the units appear to be capable of accepting some solids in the feed, the flowsheet will include good feed clarification preceding solvent extraction.

Facility and equipment concepts are being developed as part of the REMOTEX design philosophy. Individual process components and modules must be remotely repairable or replaceable. This means that remote tooling must be developed to perform these jobs, and in fact tools to repair the tooling. This is the nuclear equivalent of the field of robotics, where the dexterity of man is provided in a radiation resistant form, capable of being directed to a work location, and then performing work.

About two or three years ago, a major decision was made to employ servomanipulators and CCTV viewing as the primary remote handling system. Slide 7. Development work on servomanipulators is under way to improve reliability, provide modular and easily replaceable units for repair of failures on the manipulators, and to uncouple master and slave from hard wiring by using wireless or inductively coupled multiplexed signal transmission. The man-machine interface problem of providing an operator the optimum set of information and capability to carry out the task is being studied. Slide 8.

Application of this concept in a processing cell involves a layout where equipment is mounted on two walls of the canyon in removable modules. Slide 9. A center aisle provides both the space required for removing the equipment modules and a track arrangement for a transporter-repair vehicle equipped with CCTV viewing and servomanipulators. This maintenance vehicle can reach virtually any area of the front and sides of the module to do limited or even extensive repairs to subassemblies of equipment on the module. Slide 10. The intent is to repair most failures by replacing small units rather than the entire module. The concept considerably broadens the kinds of equipment which can now be placed in-cell. Whereas, the placement of certain types of pumps or instruments has been unthinkable in the past, it appears practical with this concept. Obviously, we still believe that all in-cell systems should be extremely reliable, should minimize or eliminate moving parts, and be intended for very infrequent maintenance or no maintenance. The overall concept, however, recognizes the large amount of mechanically intense equipment that must be used in the head-end operations and strives to provide reliable tools to ensure that necessary maintenance can be performed. Once such systems are available for the mechanical head-end, application to the rest of the plant is straightforward.

The concept for an automatic sampler system includes a robot vehicle for traversing the cell to collect solution samples in arrangements which use the conventional glass bottle, two-needle air jet with air-lift assist principles. Slide 11. The robot can be

programmed to obtain samples wherever needed, and then deliver them to the analytical cell. Considerable savings are achieved over the normal hot-cell sample blisters now used. Final design of the robot vehicle is nearly complete, and a model should be ready for testing this year.

The automatic sampler system concept incorporates many of the conventional safeguards principles for physical protection, material accountability and containment, and surveillance. Sensitive areas containing fissile materials free of fission products are zoned for special protection. Sampling operations are conducted entirely within the shielding; thus, no sample lines, which might provide access to material, penetrate the shielding. Concepts for near real-time accountability are being studied, and other computer-monitoring systems are being developed which use continuously available process instrument signals to trigger alarms if sensitive material transfers appear abnormal. Many of these safeguards systems will be further developed as the facility design is undertaken.

SUPPORTING PROCESS R&D

Reprocessing flowsheet research and development activities currently address new and improved process steps that are necessary to satisfy the overall objectives of improved reliability, lowered personnel exposure, and less environmental impact for facilities that may exist in the year 2000 and beyond. These activities include basic laboratory research, as well as bench-scale engineering to provide a basis for prototype hardware development.

The use of a rotary-kiln for voloxidation has been investigated through fundamental heat and mass transport studies, an evaluation of commercial components in an overall system of 0.5-t/d scale to include state-of-the-art unit process control, and development of the off-gas treatment step for recovery and concentration of tritiated water.

Supporting efforts for the rotary dissolver include the development of descriptive mathematical models for reliability and nuclear criticality studies, development of downstream digester systems that ensure complete dissolution of heavy metals and means for transfer of insolubles, and small-scale dissolution tests in hot cells using available irradiated breeder fuels. Three related activities include an evaluation of methods for feed clarification (using irradiated fuel dissolver solids), characterizations of insolubles in the hot cell (using available breeder fuel samples), and studies of processing conditions where plutonium polymers can form. As fuel becomes available from the FFTF reactor, additional dissolution and residue characterization tests will be made. Laboratory work to study plutonium polymer formation mechanisms has recently addressed the kinetics of polymer growth, the effect of uranyl nitrate on polymer formation, and reflux conditions that lead to the production of polymer that has the characteristics of an aged polymer in that it is not easily redissolved.

Major efforts in solvent extraction are directed toward developing improved centrifugal contactors and flowsheets. Improved flowsheets for breeder fuels are tested in alpha-contained and hot-cell facilities

with mixer-settlers and small pulsed columns. Among the major areas of interest are partial partitioning, alternate solvent systems, and improved methods for solvent cleanup.

Hydrazine carbonate, hydrazine oxalate, and a caustic-treated silica gel are all being compared to the standard sodium carbonate wash for removal of TBP degradation products. Diluent degradation has also been studied and methods to reduce its degradation by nitrous acid are being developed. Mathematical modeling of solvent extraction systems continues to improve and provide guidance to experimental efforts and system designers, and is now being advanced to account for axial dispersion in pulsed columns.

The development of off-gas treatment processes is now largely completed. The fluorocarbon absorption process that can effectively trap and concentrate ^{85}Kr and ^{14}C is a key component to the overall treatment scheme. An integrated demonstration of many treatment steps is planned over the next five years, using a hot off-gas stream available at the Savannah River Plant.

Advanced processes for the conversion of heavy metal nitrate solutions to oxide forms suitable for pellet fabrication are being examined. The gel-sphere process, based on internal gelation, provides spherical materials for pellet pressing and an engineering-scale mixed-oxide line is now being tested. Slide 12. Direct thermal denitration in a rotary-kiln has also been demonstrated to produce highly active powders for pellet fabrication. Materials from both processes have been fabricated into good quality pellets. Further work will be done to develop these processes and compare them with the conventional blended powder processes.

An important goal of this work is to obtain mixed-oxide materials that are completely soluble in nitric acid. Laboratory dissolutions of products from these conversion processes are done routinely using a standard procedure.

81-1093

930-030

(1)

HEF PROCESS BUILDING
PLAN AT GRADE LEVEL
(ELEVATION 101')

920-057

(2)

80-10214

310-035

3

FUEL
EJECTOR

OFF
GAS

FEED

DISCHARGE

DISASSEMBLY SYSTEM

0248-78
330-022

5

SHAFT TO MOTORIZED SPINDLE

4327-80R2

330-020

6

AIR INLET TO PNEUMATIC WEIR
FOR INTERFACE CONTROL

1 - ROTOR INLET

2 - ORGANIC WEIR

3 - AQUEOUS UNDERFLOW WEIR

4 - AQUEOUS OVERFLOW WEIRS (2)

AQUEOUS COLLECTOR
RING

AQUEOUS EXIT PORT

ORGANIC COLLECTOR
RING

ORGANIC EXIT PORT

AQUEOUS INLET PORT

ORGANIC INLET PORT

ROTOR

HOUSING

SEPARATING ZONE
VANES (4)

ANNULAR (COUETTE)
MIXING ZONE

ANTI-VORTEX
VANES (4)

SCHEMATIC OF ANL CONTACTOR

INDUSTRY STANDARD
IN-CELL (SLAVE) MANIPULATOR
SYSTEM

SCOPE OF ACTIVITIES — TELEOPERATORS

ORNL-DWG.80-6710R1

875-027

MAN-MACHINE INTERFACE

- DISPLAY — VIDEO
- DISPLAY — GRAPHICS

- MANIPULATOR CONTROLLER
 - FORCE FEED-BACK
 - CONTROLLER COMMAND FEED FORWARD
- SUPERVISORY MONITORING (COMPUTER)

TELEOPERATOR — IN-CELL ADVANCE SERVOMANIPULATOR

80-7181

930-168

(9)

ARMV-1 AT PROCESS MODULE WORK STATION

ILLUSTRATED BY PRC

PROCESS CELL SECTION

ATLS LIQUID SAMPLER

5368-79
400-010
(12)