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Consolidated Fuel Reprocessing Program

THE BREEDER REPROCESSING ENGINEERING TEST

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ABSTRACT

The Breeder Reprocessing Engineering Test (BRET) is a developmental activity of the U.S. Department of Energy to demonstrate breeder fuel reprocessing technology while closing the fuel cycle for the Fast Flux Test Facility (FFTF). It will be installed in the existing Fuels and Materials Examination Facility (FMEF) at the Hanford Site near Richland, Washington. The major objectives of BRET are: 1) close the U.S. breeder fuel cycle; 2) develop and demonstrate reprocessing technology and systems for breeder fuel; 3) provide an integrated test of breeder reactor fuel cycle technology--reprocessing, safeguards, and waste management. BRET is a joint effort between the Westinghouse Hanford Company and Oak Ridge National Laboratory.

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INTRODUCTION

The U. S. Department of Energy (DOE) has begun a new initiative to build the Breeder Reprocessing Engineering Test (BRET) near Richland, WA. The new initiative involves a joint effort between the Westinghouse Hanford Co. and Oak Ridge National Laboratory in which a breeder fuel reprocessing capability will be installed in an existing facility at Hanford with operations planned for the early 1990's. As future prospects for the breeder program indicated further stretch-out of schedules for large demonstration reactors, the necessity to close the fuel cycle for FFTF while achieving certain demonstration goals became evident and DOE revised their plans. Where previous concepts for closing the breeder fuel cycle focused on a somewhat larger-scale reprocessing capacity, BRET was conceived to be more limited-scale and limited-demonstration concept that could be accomplished in the near-term and still meet the major needs of the breeder reprocessing community. Potential existing facilities which could be modified for this purpose were examined and the Fuels and Materials Examination Facility (FMEF) was selected for BRET.

BRET OBJECTIVES

The major objectives of BRET are: 1) close the U.S. breeder fuel cycle, 2) develop and demonstrate reprocessing systems for breeder fuel, and 3) provide an integrated test of breeder fuel cycle technology--reprocessing, safeguards, and waste management--interfaced with the existing liquid-metal fast breeder reactor (LMFBR) fuel supply program. As such, BRET will provide a near-term focus for fuel cycle development activities and eventually will provide an independent supply of plutonium for breeder development. In addition, BRET will provide a basis for effective international cooperation and the exchange of information. BRET will be designed so that at a later date it can be upgraded to provide capability to reprocess fuel from a demonstration sized reactor.

FACILITY DESCRIPTION

BRET will be located in the recently completed FMEF. The FMEF is located near the Fast Flux Test Facility (FFTF) in the 400 Area of Hanford as shown in Figure 1. The FMEF will also include fabrication of breeder fuel in the Secure Automated Fabrication (SAF) line as well as fabrication of breeder fuel assemblies. Construction of BRET in the FMEF will enable closure of the breeder fuel cycle for FFTF in a single centralized location.

A schematic of the FMEF is shown in Figure 2. The building has approximately 15,800 m^2 (170,000 sq. ft) of floor space on six different levels. SAF activities will be located on the top level of the building while fuel assembly operations will be located in one portion of the support building. BRET will utilize many of the other areas of the building with the primary fuel reprocessing operations located in a large shielded cell, the Main Process Cell (MP Cell), in the center of the building. A cutaway of the FMEF showing the primary location of BRET operations is shown in Figure 3.

The MP Cell is approximately 12m (40 ft) wide, 30m (100 ft) long, and 16m (56 ft) high with cell walls varing from 1.2m (4 ft) to 1.5m (5 ft) in thickness. Spent fuel is introduced to the cell through the Entry Tunnel which communicates by transporter with the Shipping and Receiving Area.

Adjacent to the MP Cell is the Decontamination Cell (Decon Cell) which will be used by BRET for decontamination and for waste handling. Access to the Decon Cell is through the Entry Tunnel or directly from the MP Cell through a Transfer Tunnel. The Decon Cell also communicates with the Hot and Suspect Repair Areas located on the bottom floor of the FMEF.

The Upper Process Cell (UPC) is located directly above the MP Cell. This cell is also available for use by BRET, but will not be utilized at startup. The UPC is 12m (40 ft) wide, 18m (60 ft) long, and 7m (23 ft) high. The walls are 1m (40 in) thick reinforced normal concrete.

BRET will utilize a series of process support hot cells located on the bottom level of the FMEF for sample preparation and analytical chemistry. The cells are arranged in two parallel rows separated by a horizontal transfer corridor. Sample transfers to the cells will be accomplished by means of a pneumatic transfer system connected to the other processing cells.

PROCESS DESCRIPTION

BRET will be a completely integrated and versatile facility for reprocessing highly irradiated breeder reactor fuels. As such, it will provide all of the following functions: receipt of irradiated FFTF fuel (and any follow on breeder fuel); sodium removal from fuel assemblies; storage and disassembly of spent fuel; shearing and dissolution of spent fuel; feed clarification; recovery and purification of plutonium; conversion of plutonium nitrate solution to fabricable PuO_2; preparation of uranium for disposition; vitrification of high-level liquid wastes; offgas cleanup and treatment of other process wastes for disposal; and performance of all other necessary support functions (e.g., analytical chemistry, material control and accounting, physical security, process control and data management, etc.).

BRET is designed to process two FFTF assemblies per day (~60 kgHM/d) and will have an annual throughput rate of up to 6 MTHM/yr. The fuel will normally be processed after one year of cooling, although the capability to demonstrate at a later date all process steps for small lots of fuel cooled 180 days will not be precluded. Most fuel reprocessing operations will be performed in the MP Cell which will be an inert gas cell (i.e., less than 4% oxygen). A conceptual layout of the MP Cell is shown in Figure 4. The processing steps involved are discussed in the following sections.

Fuel Receiving

Fuel Assemblies from FFTF will be received in shielded casks the FMEF Shipping and Receiving Area, unloaded, and transferred into the Entry Tunnel where they will be transported to the MP Cell. The shipping cask will be mated to the MP Cell transfer hatch and the spent fuel assembly transferred into the MP Cell.

Sodium Removal, Storage, and Disassembly

Within the MP Cell, the spent fuel assembly will be placed in storage or moved to a sodium removal chamber where it will be cleaned of sodium using a moist nitrogen atmosphere, rinsed, and then stored in a critically-safe array. From storage, the assembly will be moved to the disassembly area where the inlet nozzles and the shroud will be removed. This is accomplished using either the Special Container and Assembly Dismantling (SCAD) machine, shown in Figure 5, which uses a milling machine to make the cuts, or a laser disassembly machine being developed as part of the Consolidated Fuel Reprocessing Program (CFRP) at ORNL.[1] The fuel sections will be placed in fuel pin handling containers and then stored or sent to the shear.

Shearing and Dissolution

The fuel sections will be sheared into short sections (~2-5 cm long). The shear is being designed with an enclosure to contain any released contamination and the offgas from shearing will be processed by the dissolver offgas (DOG) system. The sheared fuel sections and wire wrapping will be discharged from the shear into a gaslock between the shear and dissolver. The gaslock will prevent acidic vapors from flowing back from the dissolver into the shear enclosure.

It is currently anticipated that at startup, BRET will utilize two batch dissolvers in a semicontinuous operation (i.e., one dissolver will be loading while the other is in a dissolution cycle). Later addition of a continuous dissolver, such as the rotary dissolver being developed at ORNL, is not precluded. Fuel from the shear will be contained in a stainless steel basket and the fuel leached from the cladding using hot nitric acid without fluoride. Following leaching, the basket will be removed and the cladding hulls will be rinsed with dilute nitric acid, dried, and assayed using nondestructive assay (NDA) techniques prior to disposal as a solid waste.

Feed Clarification and Accountability

The dissolver solution will be transferred to a feed clarification system to separate any undissolved fines and any fuel cladding material. Suspended solids will be removed utilizing the solid-bowl centrifuge shown in Figure 6. The centrifuge was designed and manufactured in the United Kingdom and has been successfully used at Dounreay for clarifying dissolver solution from processing their fast reactor fuel. A similar centrifuge was received from the U.K. as part of the UK/US exchange program on fuel reprocessing and is being evaluated at ORNL for application in BRET. After clarification, the solution will be transferred to a feed adjustment and accountability tank for adjustment of acid and heavy metal concentrations and to be sampled for accountability purposes prior to introducing it to the solvent extraction system. The centrifuge bowls containing the solids will be packaged and normally sent to retrievable storage. If assay of the bowls showed high plutonium content, the bowls could be set aside for recovery and recycle of the plutonium.

Solvent Extraction

The solvent extraction process in BRET will utilize a series of centrifugal contactors similar to the one shown in Figure 7. The contactor is currently undergoing testing at ORNL and is similar in design to those tested at Argonne National Laboratory (ANL)[2] and in use at the Savannah River Plant (SRP)[3]. A mixture of 30% tri-n-butylphosphate (TBP) in 70% dodecane diluent will be used as the extractant. The solvent extraction process will consist of five cycles: a high activity (co-decontamination) cycle; a partitioning-uranium purification cycle; a uranium purification cycle; and two plutonium purification cycles. The solvent extraction system will also include plutonium concentration and recycle of the various aqueous and organic wastes for plutonium recovery. Plutonium nitrate product will be concentrated to about 450 g/l and stored for subsequent conversion to PuO_2.

Liquid Waste Treatment

Handling of liquid waste streams will be fully integrated with the reprocessing operations in BRET. The high-level aqueous waste stream from the first cycle of solvent extraction will be concentrated, stored, then vitrified. Two and one half canisters of vitrified HLLW, using a 30 cm (12 in) diameter cylinder with a 2.4m (8 ft) fill height and a waste loading of 8.1 wt %, will be generated per MTHM processed.

Low-level aqueous wastes will be decontaminated by multiple evaporation and transferred to waste handling systems at Hanford.

Offgas Treatment

Offgases in BRET will be treated in either the dissolver offgas (DOG) or the vessel offgas (VOG) systems to remove ruthenium, iodine, NOx, and particulates prior to discharge. Ruthenium will be removed using silica gel traps while iodine will be removed using silver zeolite. During initial BRET operations, krypton-85 and carbon-14 will not be recovered, although such retention capability could be added later. All gas streams will be treated to meet acceptable DOE and Hanford Site release requirements prior to discharge.

Solid Waste Treatment

Solid wastes from BRET will be packaged in approved radioactive waste shipppping containers, assayed for fissile material content, and then sent to the Hanford 200 Area in a shielded waste cask for retrievable storage (for transuranic contaminated waste, i.e., >100 nCi of transuranic per gram of material) or disposal.

Uranium and Plutonium Conversion

The uranium purification cycle will decontaminate the uranium of residual fission products and plutonium in a single solvent extraction cycle. Currently, it is not planned to recycle the recovered uranium.

Purified plutonium nitrate solution will be stored in concentrated form in critically safe slab tanks within the MP Cell. The planned storage capacity is such that the plutonium can be cross blended for uniform isotopic mixing and the purification operation is decoupled from the conversion operation. Plutonium nitrate will be converted to ceramic, fuel grade PuO_2 powder in a glovebox operation using oxalate precipitation, filtration of the precipitate, and calcination to PuO_2. Aqueous wastes from plutonium conversion operations will be sent to a backcycle system for further plutonium recovery. The PuO_2 product will be stored for subsequent fuel fabrication.

TECHNOLOGY ADVANCEMENTS

A major purpose of BRET is to serve as a test bed for hot demonstration of breeder reprocessing technology currently under development as part of the CFRP at ORNL and other U.S. DOE programs. Major systems to be initially tested in BRET include:

- Remote Maintenance with Servomanipulators - Provides greater remote maintenance capability.
- Modularization of Equipment - Facilitates replacement of equipment.
- Centrifugal Contactor - Reduces the residence time in solvent extraction thereby minimizing solvent damage.
- Automated Sampler - Eliminates separate sample gallery.
- Safeguards System - Provides a demonstration of safeguards techniques to verify that the desired goals can be achieved.
- Waste Solidification - Fulfills a needed demonstration in the U.S.

The BRET operating and maintenance philosophy for the MP Cell is one of center-aisle maintenance using cranes and an advanced servomanipulator (ASM) system mounted on overhead bridges. The ASM, shown in Figure 8, utilizes a force-reflecting manipulative device with a 23 kg (50 lb) handling capacity. Two ASMs are attached to two separate transporter systems capable of covering the entire volume of the MP Cell such that full coverage of in-cell process equipment is provided. The ASM is remotely maintainable with modular design features that allow replacement of failed slave arm segments to minimize system downtime. The system is operated from an out-of-cell control station.

The process equipment is placed on precisely engineered modules mounted along the walls of the MP Cell, accessible to the ASM and other maintenance equipment as shown in Figure 9. The process systems will normally be maintained by replacing a failed module or component with a spare and repairing or discarding the part as appropriate. However, the modular arrangement facilitates complete replacement of equipment and/or substitution of processing systems. Thus, BRET can serve as a test bed for hot demonstration of future technology.

Centrifugal contactors were selected for use in the BRET solvent extraction system because their low residence time reduces the process inventory, reduces organic solvent degradation, and enhances the system process control and response. The system has a short equilibrium time, so can be operated for short cycles and then shut down. The contactor design, known as the annular centrifugal contactor, will be an adaptation of contactors currently in use in the Savannah River Plant. The design being used facilitates simple unit replacement by remote maintenance techniques in the event of a failure.

An automated sampler, shown in Figure 10, will also be utilized in the MP Cell to remotely retrieve bottled process samples from sample stations mounted on the process modules. The track-guided, self-propelled sample vehicle remotely removes and replaces sample bottles at a sample station and delivers the samples to an unloading station where they are transferred from the MP Cell for laboratory analysis. Use of a remote sampling system eliminates the requirement for a sample gallery next to the MP Cell, reduces potential radiation exposure of operating personnel, and improves safeguarding of special nuclear materials.

The BRET safeguards will be an integral part of the existing FMEF Safeguards Systems. Since the FMEF will contain all operations associated with a complete fuel cycle (from incoming fuel assemblies to outgoing fabricated fuel), it will provide an excellent demonstration of integrated safeguards. A central computer system will collect, monitor, and analyze data associated with Special Nuclear Materials (SNM). Various near-real-time accountability monitoring techniques and penetration monitoring techniques will be employed in the safeguards systems. BRET safeguards will be consistent with the latest DOE requirements and when defined, will also implement IAEA requirements.

As mentioned previously, high-level liquid wastes (HLLW) generated in BRET will be vitrified using either a liquid fed ceramic melter or a liquid fed in-can melter. BRET will provide an opportunity for demonstrating vitrification technology on high-level liquid waste unique to breeder fuel (i.e., higher heat load, etc.).

SUPPORT ENGINEERING AND TESTING

The major equipment items specified for BRET are based either on established technology or technology currently under development at either ORNL under the CFRP, at Pacific Northwest Laboratory (PNL), or at Westinghouse Hanford Co. Much of this equipment will undergo extensive critical feature testing in either the Integrated Equipment Test (IET) facility at ORNL or in the Hot Cell Verification Facility (HCVF) at Hanford Engineering Development Facility (HEDL).

The IET facility will serve as a test bed for bridging the gap between individual component or system development activities and the detailed design of BRET. The IET provides a test bed for confirming the design bases for BRET through the testing of design features and remote maintenance principles of prototype equipment in a nonradioactive environment. Two major areas comprising the IET program are the Remote Operation and Maintenance Demonstration (ROMD), where remote aspects of the mechanical head-end equipment will be tested, and the Integrated Process Demonstration (IPD), where chemical process systems will be remotely operated to demonstrate controlled continuous operations.

The ROMD Facility, shown in Figure 11, is designed to address the remote handling, maintenance, and operating problems anticipated during operation of BRET. Simulated shielding and viewing windows in modular configurations are used to provide a flexible arrangement. The facility is fully equipped with hoists, manipulators, and material transfer equipment. Critical remote maintenance techniques and procedures for use in BRET will be demonstrated and verified in ROMD.

The HCVF at HEDL will also be used to verify and test equipment concepts planned for BRET. A major portion of the HCVF, shown in Figure 12, is an approximate reproduction of the MP Cell in the FMEF. The simulated cell includes windows in the same location, an overhead crane of the same capacity, an electromechanical manipulator, and through-the-wall manipulators. HCVF will be used to qualify and test equipment prior to installation in BRET; to perform feature tests on selected BRET components and systems including verification of mechanical, electrical, and optical equipment; to develop maintenance and operational procedures; and for operator and personnel training. In addition, system integration testing and development will be used to verify the compatibility between process and handling equipment, their controllers, and data acquisition hardware.

Other activities in HCVF will include dimensional and operational envelope checks to assure proper mechanical clearances and compatibility with adjacent equipment, and final equipment and process module qualification checks prior to installation of modules in the MP Cell. Once BRET is operational, HCVF will continue to serve as an operator training facility and will be used to mock up any replacement equipment for BRET operations in the MP Cell.

ACKNOWLEDGMENTS

This work was performed under the auspices of the U.S. Department of Energy. Input provided by members of the BRET Project groups at both HEDL and ORNL is greatfully acknowledged.

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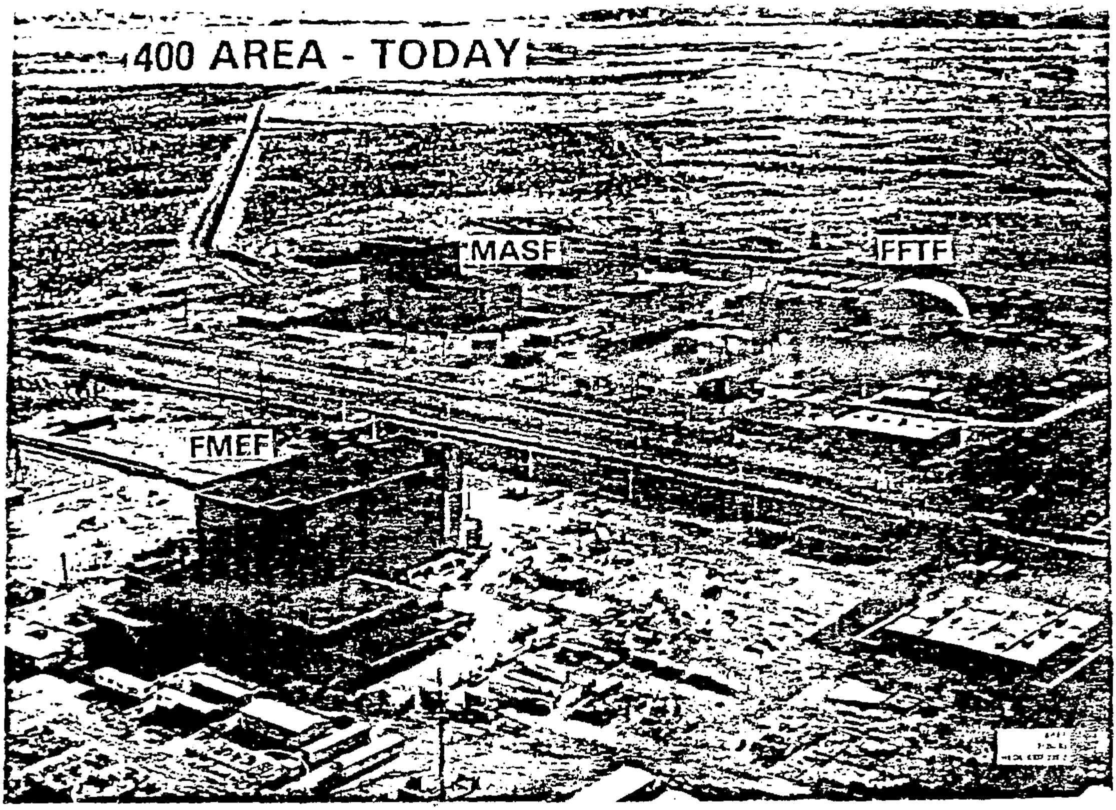

Fig. 1. The Fuels and Materials Examination Facility (FMEF), Fast Flux Test Facility (FFTF) and Materials and Storage Facility (MASF) in the 400 Area at Hanford

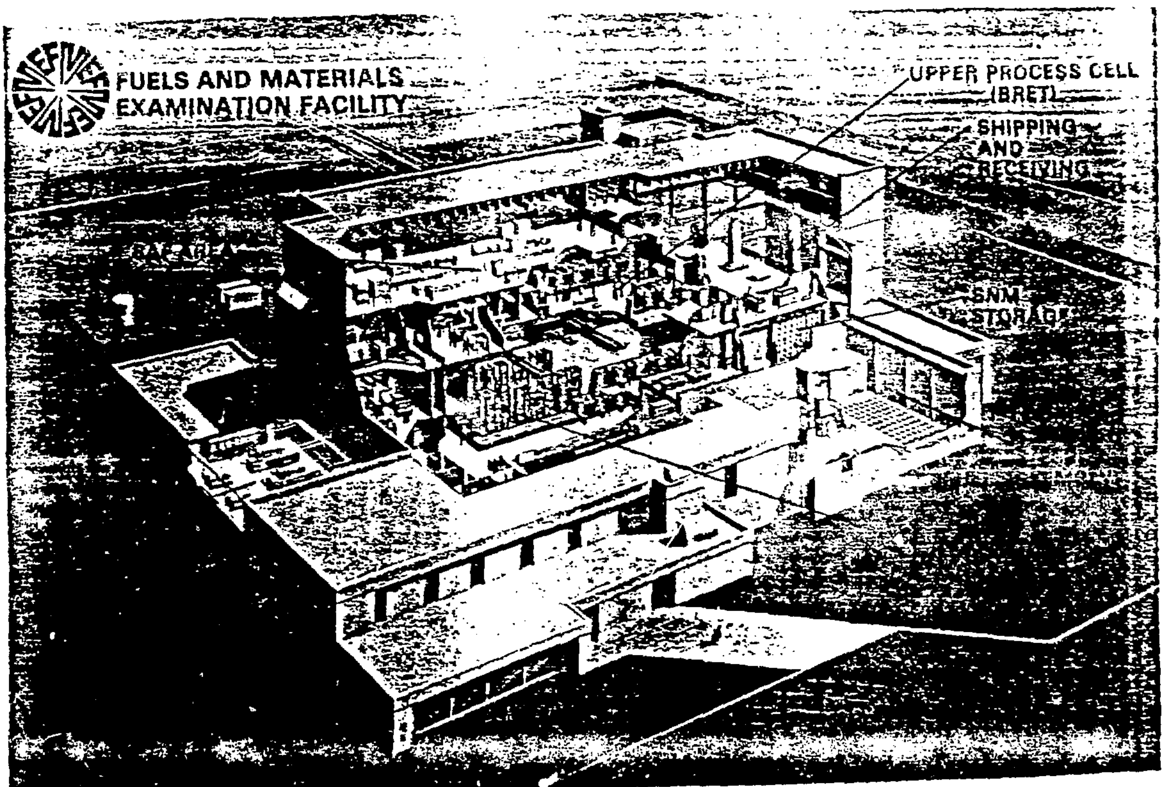

Fig. 2. Schematic of the Fuels and Materials Examination Facility (FMEF) at Hanford

BRET ACTIVITIES IN FMEF

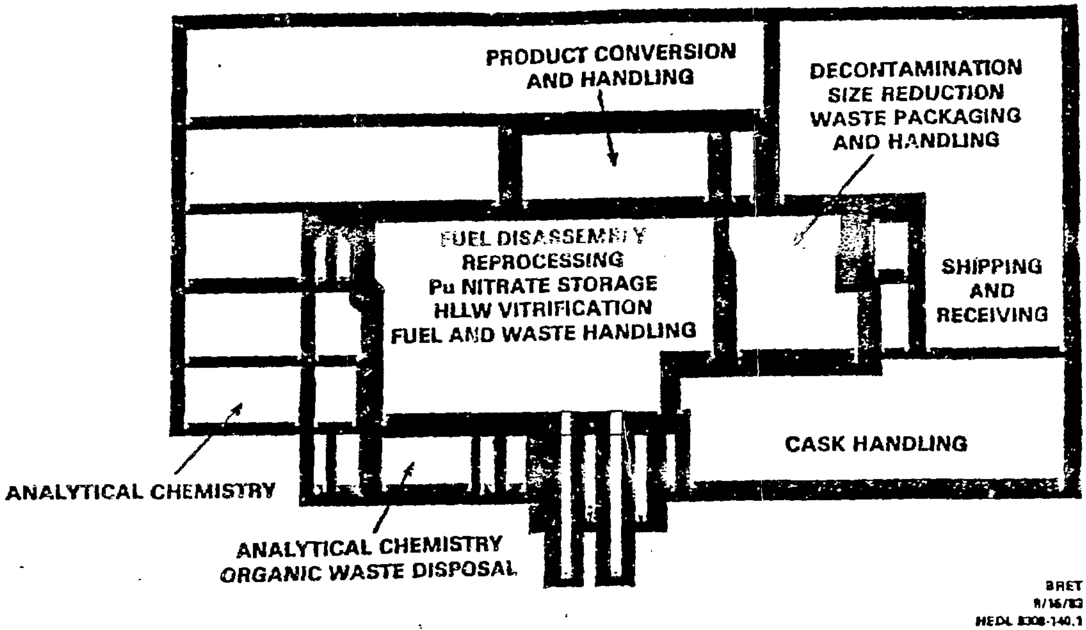

Fig. 3. Breeder Reprocessing Engineering Test (BRET) Activities in the FMEF

BRET BREEDER REPROCESSING ENGINEERING TEST

MAIN PROCESS CELL FLOOR PLAN

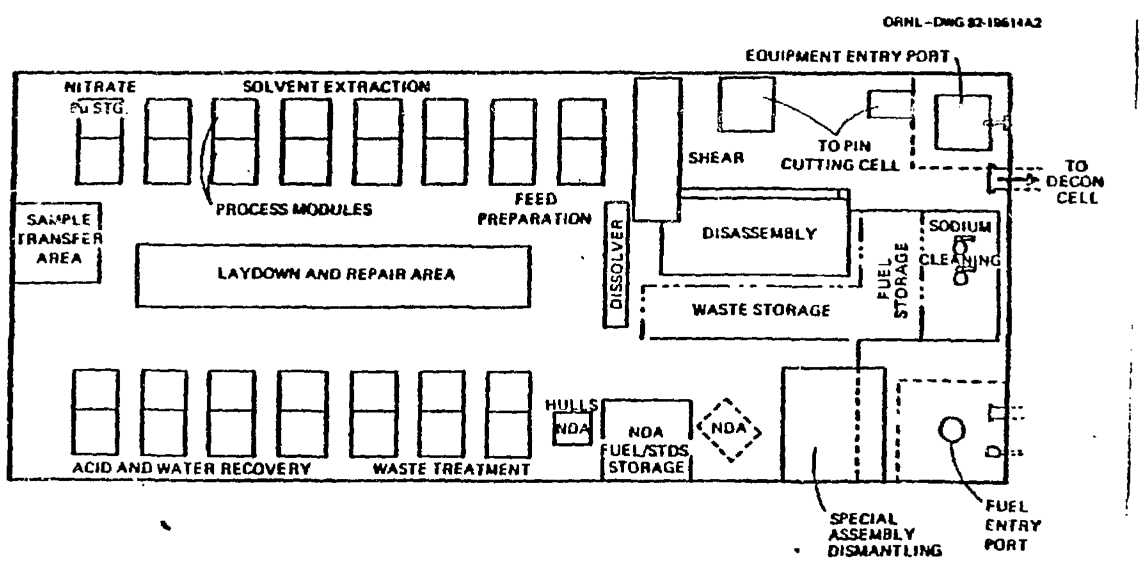

Fig. 4. Layout of Main Process Cell in BRET

BRET
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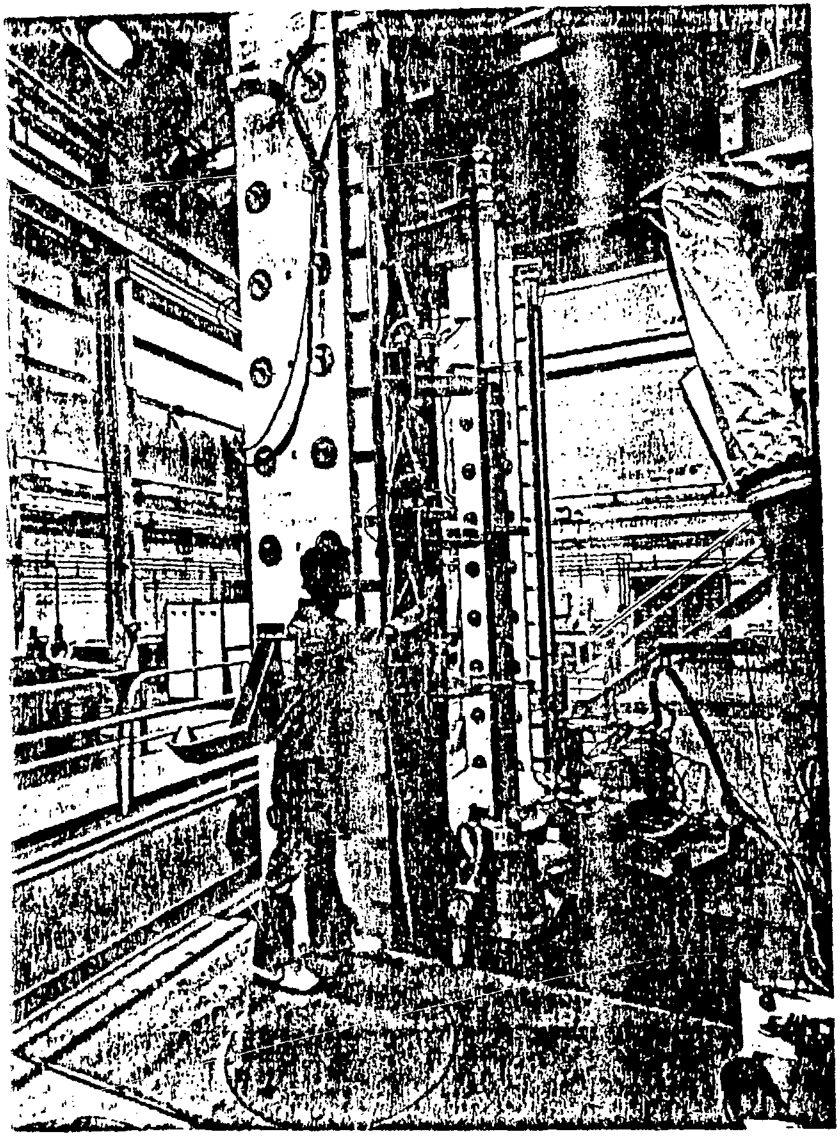

ig. 5. Special Container and Assembly Dismantling (SCAD) Machine at the Hanford Engineering Development Laboratory (HEDL)

picture to be supplied by ORNL

Fig. 6. United Kingdom Solid Bowl Centrifuge for Use in BRET Feed Clarification

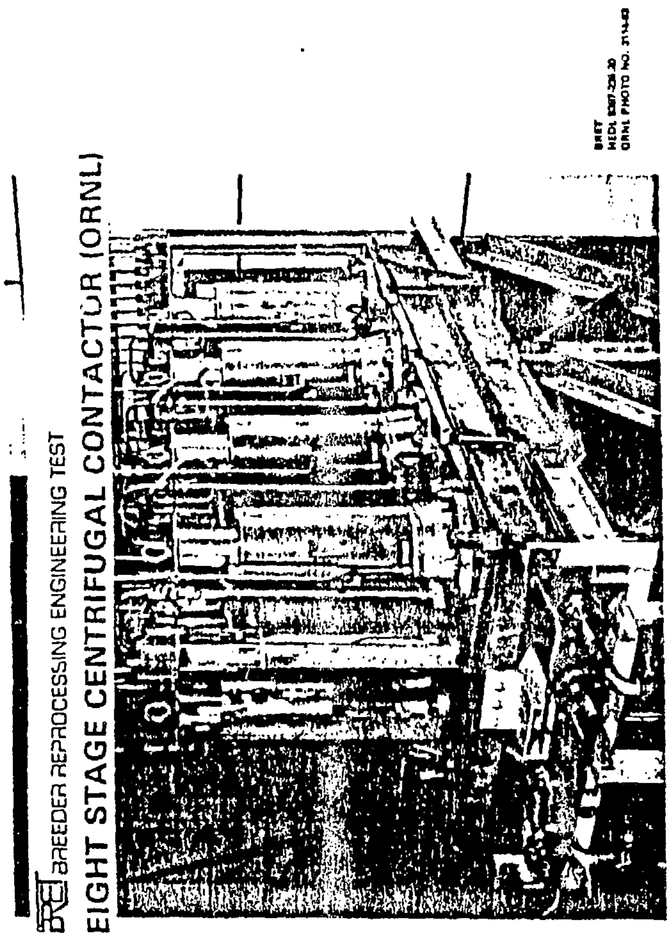

Fig. 7. Centrifugal Contactors for BRET

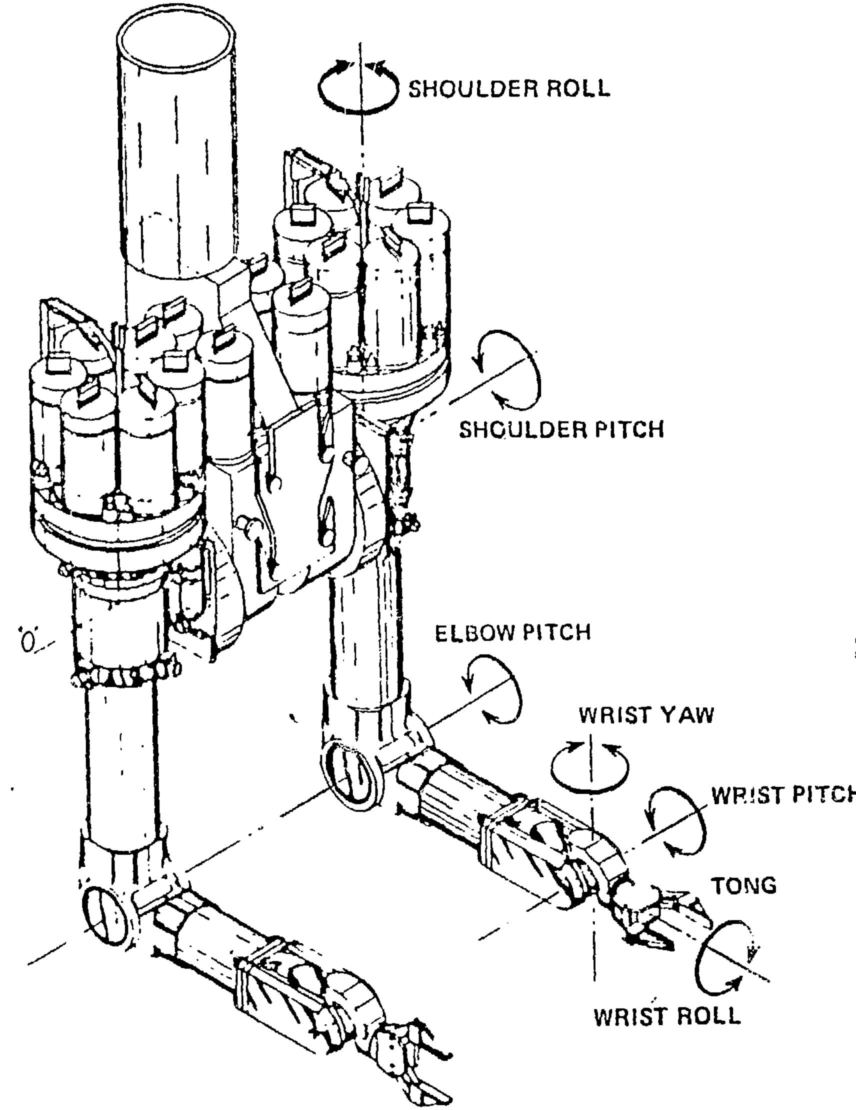

Fig. 8. Advanced Servomanipulator (ASM) Design Proposed for Use in BRET