CONF-820943--2

Consolidated Fuel Reprocessing Program

CONF-820943--2

DE82 022269

WATER STORAGE OF LIQUID-METAL FAST-BREEDER-REACTOR FUEL

MASTER

S. A. Meacham
Fuel Recycle Division
Oak Ridge National Laboratory*
Oak Ridge, Tennessee 37830

Presented at the International Topical Meeting
"Spent Fuel Storage Options"
American Nuclear Society
September 26-28, 1982
Savannah, Georgia

*Operated by Union Carbide Corporation for the U.S. Department of Energy.

Consolidated Fuel Reprocessing Program

WATER STORAGE OF LIQUID METAL FAST BREEDER REACTOR FUEL*

S. A. Meacham
Fuel Recycle Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

The purpose of this paper is to present a general overview of a concept proposed for receiving and storing liquid metal fast breeder reactor (LMFBR) spent fuel.

This work was done as part of the Consolidated Fuel Reprocessing Program (CFRP) at the Oak Ridge National Laboratory (ORNL). The CFRP has as its major objective the development of technology for reprocessing advanced nuclear reactor fuels. The program plans that research and development will be carried through to a sufficient scale, using irradiated spent fuel under plant operating conditions, to establish a basis for confident projection of reprocessing capability to support a breeder industry. The program plays an integral part in the long-range U.S. nuclear options which of necessity result in some form of fuel recycle for breeder reactors.

To achieve the research and development objectives, flexibility in handling a variety of spent fuel configurations was a major requirement; included were both sodium-cooled breeders, as well as the light-water reactors (i.e., LWR-boiling water and pressurized water).

---

*Research sponsored by the Office of Spent Fuel Management and Reprocessing Systems, U.S. Department of Energy, under Contract No. W-7405-eng-26 with Union Carbide Corporation.

This storage concept was developed as part of the conceptual design for a hot experimental facility (HEF), used primarily as a basis for identifying research and development needs in breeder reprocessing. The HEF concept was developed to accommodate any fuel envisioned to be shipped in currently licensed casks and with the capability of receiving fuel in sodium-filled containers with a maximum of 15-kW decay heat per assembly.

One of the major concerns in closing the breeder fuel cycle is the shipment of LMFBR fuel. To date, this area has not been resolved relative to providing a licensable cask for handling the high decay heat associated with short-term cooled fuel. In order to anticipate the potential transportation solutions, capability to handle a variety of cask/coolant configurations was considered.

The capability of receiving LMFBR fuel includes provisions to handle and process clean fuel assemblies shipped in a helium-pressurized cask, assemblies sealed in sodium-filled canisters contained within a helium-pressurized cask, assemblies shipped in a sodium-filled cask, and LWR fuels shipped in water-filled casks. Capability is also provided to remotely identify assemblies for verification and inventory control, to remove sodium from the surfaces of LMFBR fuels, and to assay assemblies for fissile material content.

A water-filled pool was provided to store enough fuel for 100 d of operation. The storage facility has provisions for detecting, handling, and canning, if necessary, suspect or known failed-fuel assemblies. A general schematic of the fuel receiving process is shown in Fig. 1.

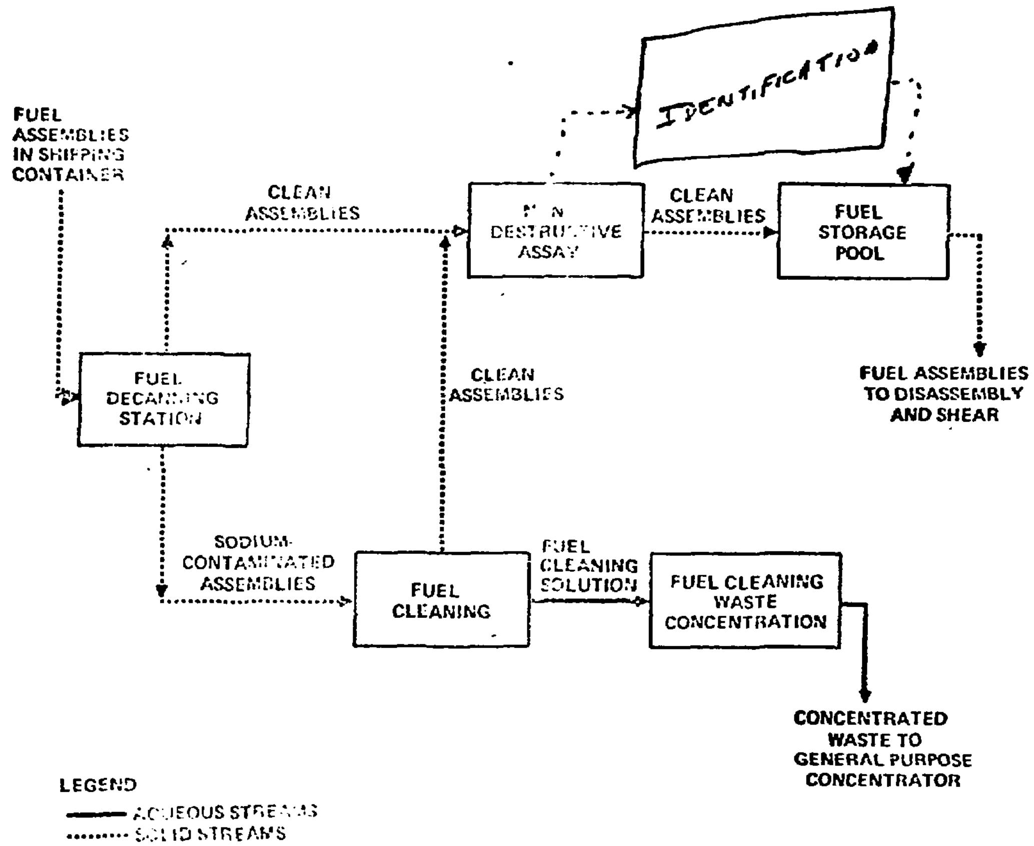
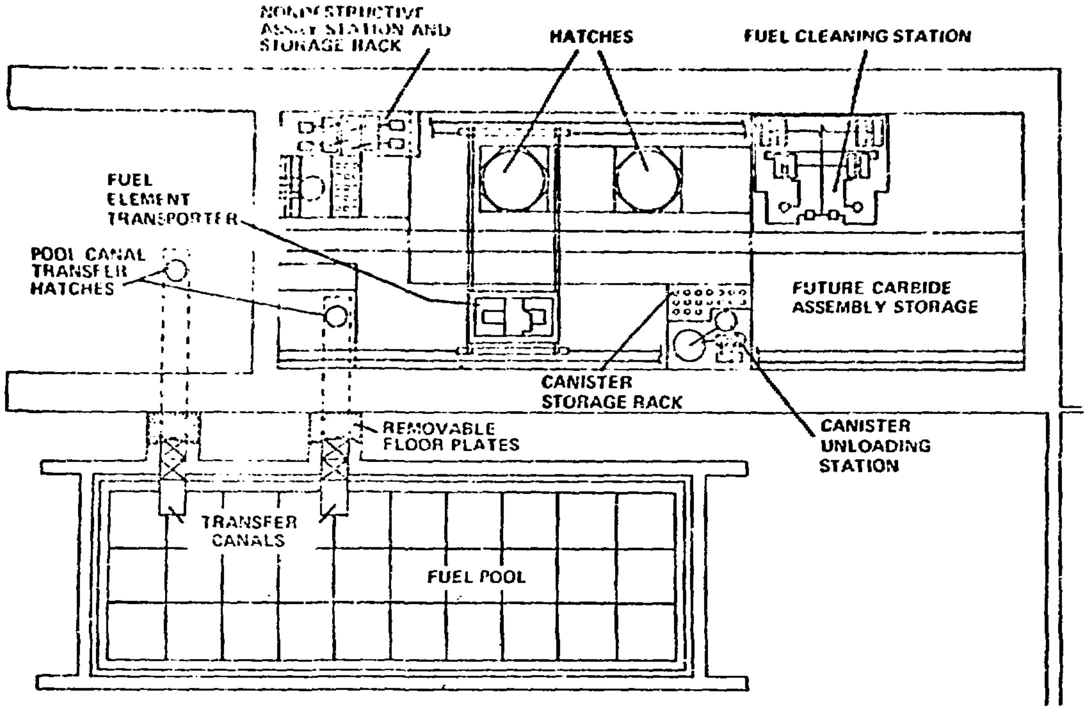


Fig. 1. Schematic of fuel receiving process.

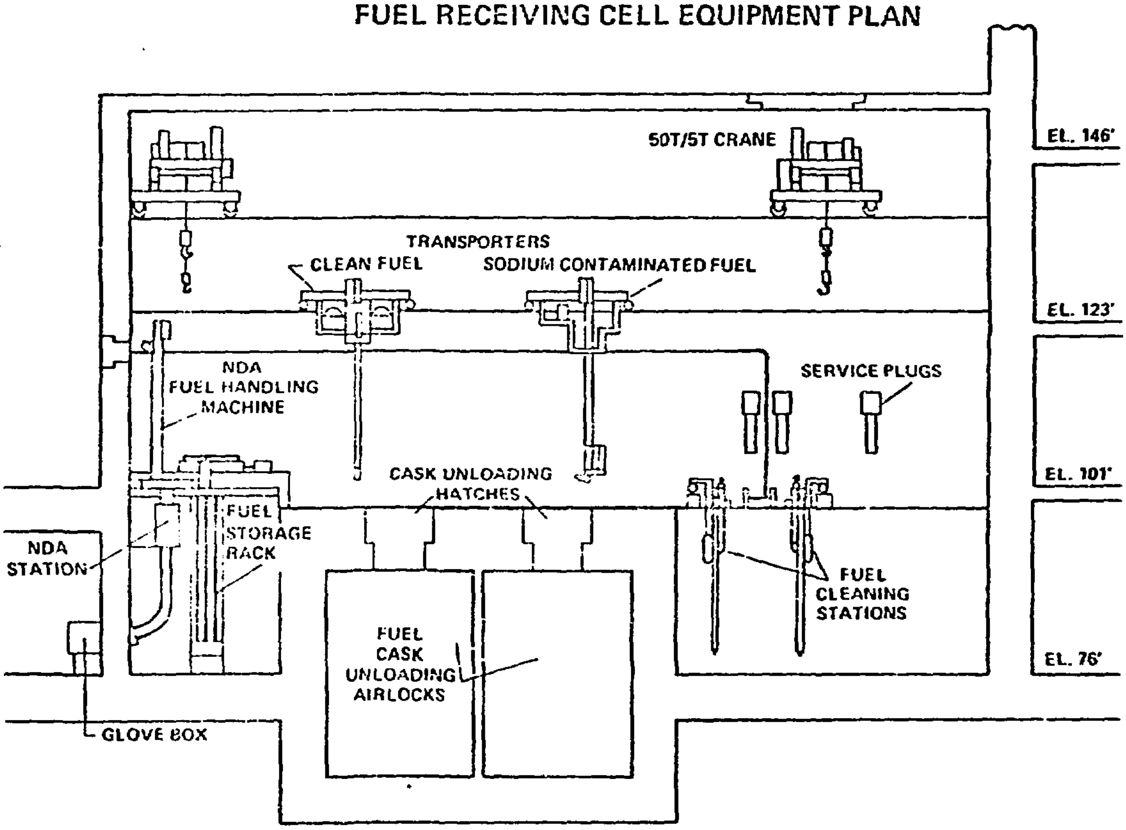
In addition to equipment usually associated with handling LWR fuels, additional equipment is required to handle and process sodium-cooled fuel. This equipment consists of (1) a transfer device to totally contain the sodium-wetted fuel during transport through the fuel receiving cell, (2) a remotely operated identification system, (3) a sodium removal system, and (4) a nondestructive assay system. The schematic shown in Fig. 2 represents the general arrangement of this additional equipment which are contained in a remotely operated/remotely maintained cell.

The fuel storage pool provides for storage of the assemblies within mobile canisters located in racks. The equipment in this area is remotely operated but contact-maintained. A major innovation regarding the operation of the storage pool system is that transfer and storage of the assemblies are carried out by total remote control. Mobile canisters are used as storage containers to facilitate handling a variety of fuel configurations. Only the canisters are handled by the pool conveyors and handling machine which are shown in Fig. 3. The handling machine is computer-controlled and movement of the storage canisters is automatic to and from the storage racks and conveyors. The canister handling machine can retrieve a specific assembly upon command and place it on the transfer conveyor. The system automatically maintains the location and inventory of each fuel assembly.

Three types of canisters have been conceived to accommodate LWR, Clinch River Breeder Reactor and Fast Flux Test Facility, and Large Develoment Plant-type fuels. The handling machine can interface with



FUEL RECEIVING CELL EQUIPMENT PLAN



FUEL RECEIVING CELL ELEVATION

Fig. 2. General arrangement of fuel-handling equipment

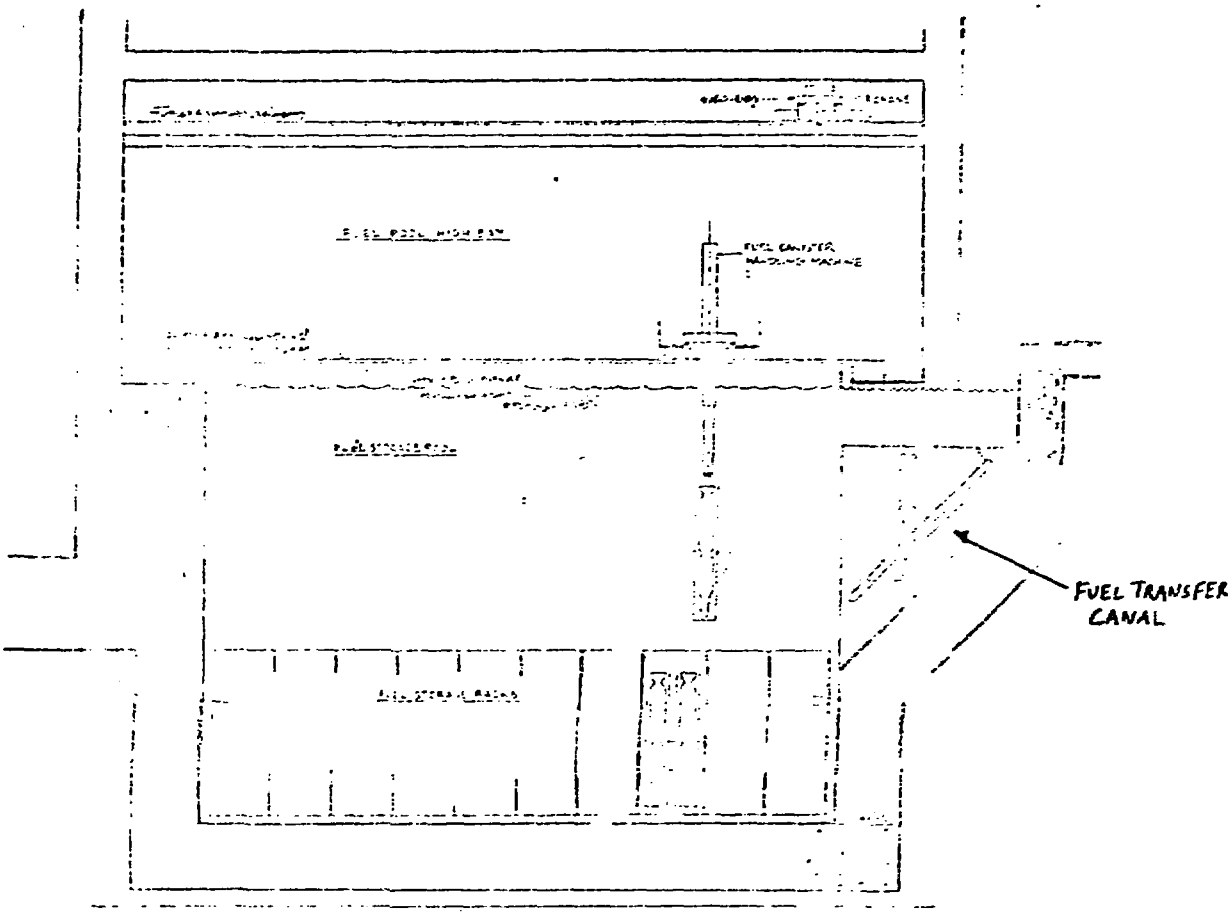


Fig. 3. General arrangement of storage pool equipment.

each type of canister since the lifting lugs are the same. The open-topped canisters are designed to retain released particulates. The water within the canister can be retained, if required, to aid in heat transfer during transport in the process cell.

The three types of canister storage racks have capacities of 25 to 36 canisters depending on the fuel type and appropriate spacing is used for geometric criticality control. The three types of racks are interchangeable (the same overall dimensions) thereby permitting storage capability of the pool to be easily changed as the storage requirements vary with fuel type inventory.

As stated earlier, the receipt and storage of LMFBR spent fuel requires additional process steps prior to the actual reprocessing operation. It has been assumed that water storage of LMFBR fuel could be safely done provided that sodium removal was accomplished without severe degradation of the fuel cladding. The sodium removal process however must have a high process throughput to meet the throughput requirements of the plant. The advantages associated with water storage of spent nuclear fuel (shielding, cooling, containment of soluble radioactivity and cleanup) have long been recognized and adequately demonstrated in the LWR industry. In addition, the cost of storing spent LMFBR fuel prior to reprocessing can be greatly reduced if water can be used as the storage medium rather than sodium.

To determine the feasibility of long-term water storage of LMFBR spent fuel, two research programs were initiated by the CFRP. One involves the development of a rapid sodium removal process, and the other concerns the effects of long-term water storage on prototype fuel cladding after sodium removal.

A rapid, water-based, sodium removal process was successfully developed for the CFRP by the Westinghouse Advanced Reactors Division (WARD) under subcontract. The results of the development activity demonstrated that the process can be conducted in less than one hour per assembly. Also, no physical or corrosion damage resulted from the process even after six months of storage in typical storage pool water. These conclusions were based on processing a sodium-wetted 37-pin CRBR-scale model fuel assembly with pressurized sodium-corroded nonirradiated pins to simulate spent fuel cladding conditions. Fuel pin integrity was verified by post sodium removal examinations and by metallographic examinations conducted following the six-month water storage test. Using appropriate heat and mass transfer similitudes, the process parameters of the model can be extrapolated to an equivalent water vapor (steam)-nitrogen-water rinse process for a full-scale fuel assembly.

A parallel research program investigated the corrosion behavior of nonirradiated and irradiated sodium-exposed LMFBR fuel cladding in simulated water pool storage conditions. This activity was also conducted under subcontract with WARD. The conclusions reached as a result of this investigation can be summarized as follows. After long-term water exposure (up to two years) pitting and rusting were observed only on those cladding surfaces where sodium corrosion had attacked the alloying elements and produced a susceptible ferritic layer. Significant ferrite formations occurred on the 20% cold-worked 316 stainless steel when the cladding was exposed to sodium with temperatures in excess of 600°C for periods up to 12 000 h. These temperatures represent the upper fuel region and top plenum region of a fuel assembly. Comparative metallographic analyses of nonirradiated and irradiated cladding indicate that irradiation does not significantly affect the corrosion behavior of the cladding.

Water chemistry was a factor in the cladding corrosion during the two-year storage period. Pitting and rusting were most prevalent in the high chloride (2 ppm Cl^-) and neutral (pH 6 ± 1) solutions. Significantly less pitting and rusting occurred in the low chloride (0.2 ppm Cl^-) and neutral solutions. However, only minor pitting was observed in solutions having a pH of 11. In all cases examined, pitting and rusting affected only the superficial ferritic layer, leaving the austentic base cladding material undamaged.

Based on the results from these two basic development activities, it can be concluded that long-term water storage of LMFBR spent fuel is indeed feasible, and has been adequately substantiated by the experimental programs. Evolution of specific equipment designs required to prepare LMFBR spent fuel for water storage can now be accomplished with minimal technological risk.