SPENT FUEL STORAGE AND ISOLATION

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INTRODUCTION

Current national policy states that the decision to reprocess spent fuel from commercial light water reactors to recover fissile materials is being deferred. The spent fuel that has been discharged thus far from reactors in the United States is practically all stored in water pools at the various reactor sites. Since the capacity of existing pools will soon reach its limit, investigations of environmentally safe methods for longer-term storage and ultimate disposal of radioactive wastes have intensified in the past few years.

Rockwell Hanford Operations has conducted studies of passive, near-surface, interim storage concepts (1,2) and has recently shifted emphasis to investigations of waste forms and packages for retrievable storage or permanent disposal in geologic repositories. Highlights of the analytical and design activities in the Spent Unreprocessed Fuel (SURF) Program were reported previously (3); during this past year, major activities within the program (reconstructed, expanded and presently designated Commercial Waste and Spent Fuel Packaging (CWSFP) Program) have included several experimental investigations involving simulated and actual spent fuel, as well as completion of the conceptual design of a Spent Fuel Receiving and Packaging Facility (SFRPF) (4). This paper presents a review of program achievements during this past year.

The fundamental objective of radioactive waste storage/disposal is that public health shall not be endangered by the presence of the stored material. Stated in such general terms, this objective is of limited value in defining the characteristics of an acceptable storage/disposal technique; the objective must first be translated into specific criteria before it can provide useful guidance to package and repository designers. These criteria are presently being developed.

Unmodified spent fuel assemblies, packaged in relatively simple steel containers along with inert gas or some solid medium for improved thermal and/or mechanical properties, have indicated potential as an acceptable waste form if stored in a suitable repository. The simplicity of processing this type of package configuration is clearly advantageous from the standpoints of cost and safety. As a result (and in the absence of a clear definition of an "advanced" package), the primary thrust of analytical and experimental spent fuel activities in the CWSFP Program thus far has been based upon "simple" packages comprised of steel cylinders containing one or more fuel assemblies and back-filled with helium prior to final closure.

This program is being conducted under sponsorship of the United States Department of Energy through the Office of Nuclear Waste Isolation in Columbus, Ohio. Technical direction is provided by Rockwell Hanford Operations. The principal technical participants, whose contributions to this paper are gratefully acknowledged, are Rockwell Hanford Operations, Westinghouse-Hanford Engineering Development Laboratory, Westinghouse-Advanced Energy Systems Division, Battelle-Pacific Northwest Laboratories, and Kaiser Engineers.

DISCUSSION

The principal spent fuel activities conducted within the CWSFP Program since the previous status report (3) are:

1. Simulated near-surface (drywell) storage demonstrations at Hanford and the Nevada Test Site (NTS).
2. Surface (sealed storage cask (SSC)) and drywell storage demonstrations at the NTS.
3. Spent fuel receiving and packaging facility conceptual design.

These investigations are described in the following sections.

Simulated Drywell Demonstration

A simulated drywell experiment is currently in progress in the 200 West Area at Hanford. The test setup, illustrated in Fig. 1, has been operating since February 1978 and is intended 1) to provide data describing the thermal properties of soil in the vicinity of a potential drywell storage facility, 2) to define the temperature transients for a representative drywell, and 3) to verify and improve heat transfer models of drywell installations.

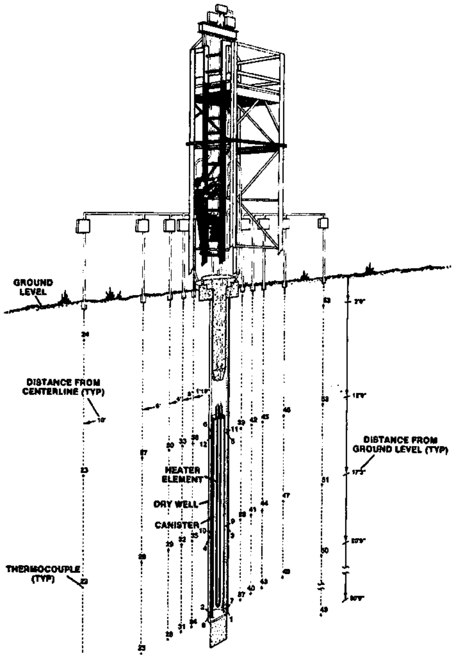


Fig. 1. Simulated Drywell Demonstration

The package used for this experiment consists of a carbon steel canister, approximately 16 inches in diameter and 15 feet long, containing an electric heater operating at one kilowatt. This heating rate is representative of either a single Pressurized Water Reactor (PWR) fuel assembly with 33,000 MWD/MTU in-reactor burn-up and 5 years storage or 3 Boiling Water Reactor

(BWR) fuel assemblies with 27,000 MWD/MTU in-reactor burn-up and 5 years storage. The package and surrounding area are instrumented to record temperatures at various distances and soil depths.

The data obtained thus far indicate that thermal equilibrium in the vicinity of the fuel package is achieved in approximately 9 months, a result that agrees reasonably well with analytical predictions. Representative analytical and experimental data are shown in Fig. 2.

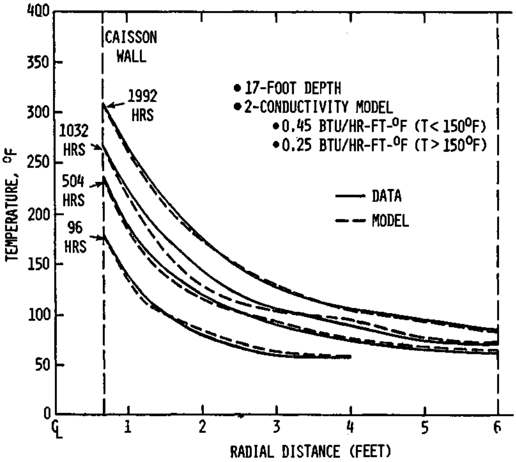


Fig. 2. Radial Temperature Profile

At 7000 hours, recorded and predicted canister temperatures differed by 5°F. It is interesting to note that the best correlation of analytical and experimental data was achieved by assigning different soil conductivity values to cool (moist) and warm (dry) regions; the values were 0.45 and 0.25 BTU/hr.-ft.-°F, respectively.

The test has progressed smoothly with the exception of an early problem resulting from rain water entry into the canister (through the electrical conduit) during system installation. The evaporation/condensation cycle induced within the system prevented the expected monotonic temperature increases in the area surrounding the canister. The canister was blown dry, and no further surprises were experienced. Although none of the heat transfer analyses conducted during this program has indicated that the fuel, canister or surrounding medium will suffer any deleterious effects from the imposed thermal environment, the observed behavior suggests that charging a small quantity of liquid into a spent fuel package is a possible method of restraining temperature increases, if such restraint appears warranted. Further study would be required (e.g., liquid selection, chemical and structural effects) if an incentive for temperature reduction were identified.

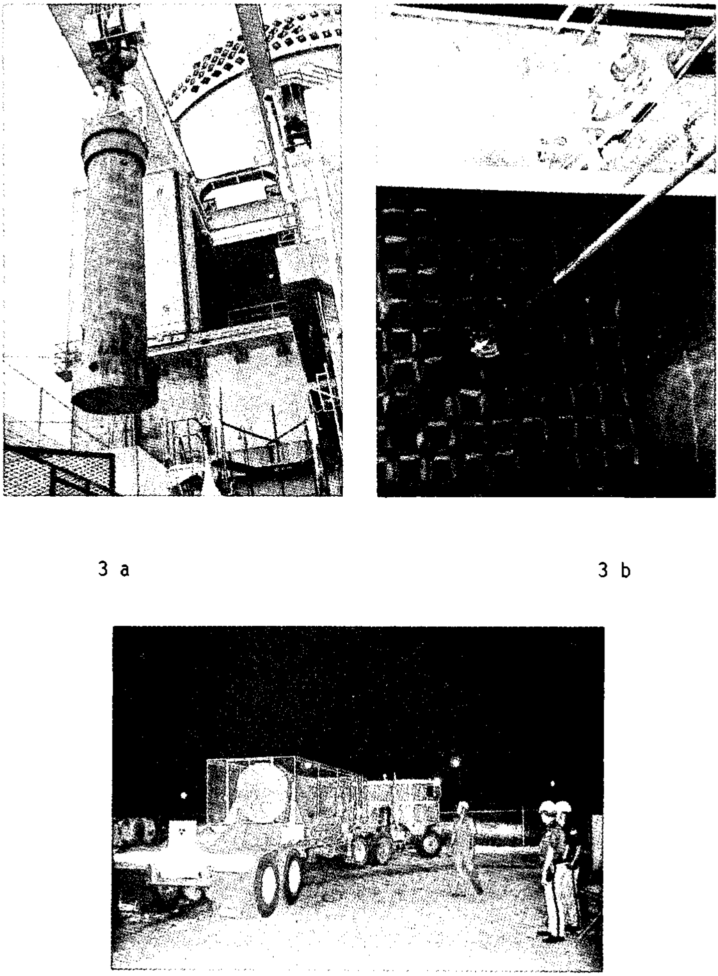
A similar installation was tested at NTS. Data obtained thus far indicate soil conductivities essentially equal to those observed at Hanford. Slight variation with depth was noted, but the average conductivity for ambient soil was approximately 0.48 BTU/hr.-ft.-°F and for warm, dry soil, 0.27 BTU/hr.-ft.-°F.

Nevada Test Site Demonstrations

The most important spent fuel task in the CWSFP Program during this past year has been the preparation for, and the initiation of, SSC and drywell demonstrations at the Engine Maintenance, Assembly and Disassembly (EMAD) area of the Nevada Test Site (NTS). Pre-test examination of the fuel assemblies has been completed, and prototypes of each storage concept are presently in place; EMAD is now preparing to implement fuel characterization and packaging plans for several geologic repository demonstration programs.

Thus far, only PWR fuel from Turkey Point Unit #3 (Florida Power and Light) has been utilized in the program. The four assemblies used in the SSC and drywell test phase were symmetrically located in the reactor core, were discharged on October 25, 1975 after burn-up of 25,665 MWD/MTU and will be emitting heat at a rate of 1.0 kw in March 1979.

The fuel assemblies were shipped by truck from Turkey Point to the West Jefferson Facility of Battelle Columbus Laboratories (BCL) during April and May of 1978. The major loading operations, shown in Fig. 3 are: 1) lift the NAC cask from the truck and lower it to the bottom of the fuel storage pool (Fig. 3a), 2) lift the selected fuel assembly from the storage rack and set it into the shipping cask (Fig. 3b), and 3) replace the cask lid and put the cask back on the truck (Fig. 3c). The total loading operation required approximately 8 hours.



3 a

3 b

3 c

Fig. 3. Spent Fuel Pickup at Turkey Point Reactor

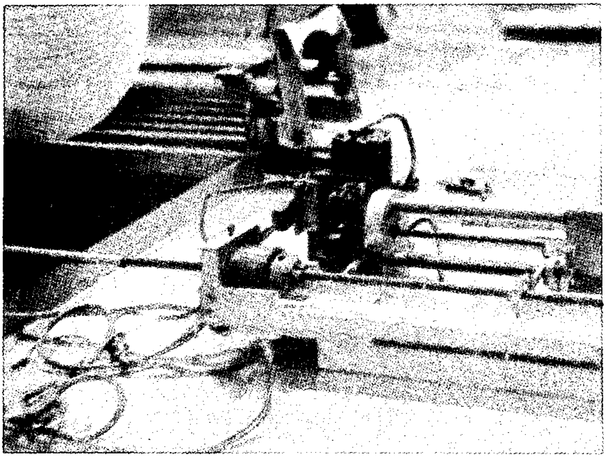
BCL was the site of the non-destructive pre-storage characterization of the four EMAD test assemblies, in addition to destructive examination of a fifth Turkey Point assembly. Characterization studies constitute an essential element in any program to demonstrate the safety of a spent fuel storage concept. Maintenance of fuel integrity is important primarily during any specified period during which the fuel might be retrieved. The objective of the characterization studies is to develop the methodology and analytical capabilities required to predict the physical condition of spent fuel upon receipt at the storage facility, and the integrity of spent fuel during its storage lifetime. Primary emphasis is placed on (1) degradation mechanisms for fuel assemblies in storage, (2) mechanical properties of irradiated fuel assembly materials, (3) structural analysis for transportation and handling operations, (4) nondestructive and destructive examinations of fuel assemblies and cladding, and (5) equipment design and procurement for fuel assembly/pin characterization.

The non-destructive examinations at BCL include geometric and radiologic measurements on assemblies and individual fuel pins. A 3-inch hole was cut in the forward nozzle, providing access to approximately 30 pins. Typically, five or six pins in each assembly were withdrawn (Fig. 4a); a pin undergoing eddy-current testing is shown in Fig. 4b. Extensive data were obtained; these are currently being reviewed and interpreted and will be compared later to post-storage measurements of the same characteristics.

Results of the destructive examination of one assembly will provide a reference base for assessment of in-storage changes in the other assemblies. Since the assemblies experienced nearly identical in-reactor service histories, it is hoped that subtle changes, such as nuclide migrations within pins, can be identified by comparing the results of chemical and metallographic examinations currently being performed on the reference assembly with the post-storage results obtained from the stored assemblies.

A particularly important addition to the fuel examination capabilities currently being developed is the design and fabrication of a calorimeter to measure the decay heat of PWR or BWR assemblies. Detail design of the unit shown schematically in Fig. 5 is near completion, and the first prototype will be tested at EMAD in late 1979. The device is predicated on recondensing and measuring water boiloff caused by the decay heat.

4 a. Pin Removal



4 b. Eddy Current Scan

Fig. 4. Characterization at Battelle Columbus Laboratory

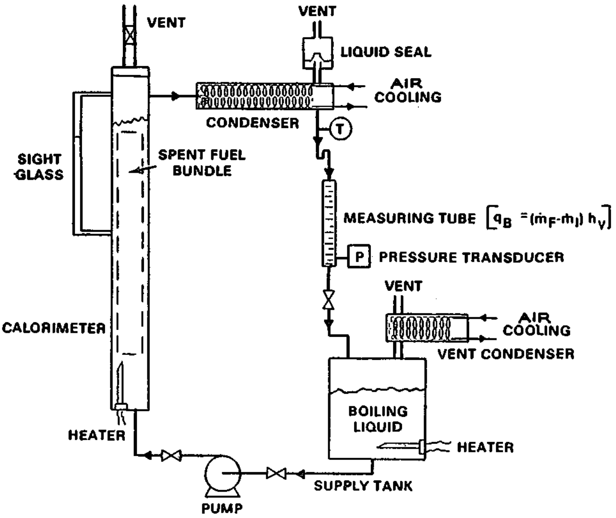


Fig. 5. Calorimeter Schematic

Calorimetry is likely to offer benefits beyond its contribution to the scientific and engineering information presently being generated in the CWSFP Program. First, measurement of fuel assembly decay heat appears to be a simple and reliable means of verifying the burnup and storage period for units delivered to a packaging facility; it can, at least, detect substantial anomalies. A second, related attribute of calorimetry is that it can prevent inadvertent acceptance of "green" or low-burnup fuel if such an assembly was somehow not detected during receiving inspection. Since this is a key link in the chain of unlikely events that could trigger an occurrence of criticality (5)(a), verification that a particular assembly is in fact "used" should assure certainty of near zero probability for criticality.

The SSC and drywell storage concepts, shown in Fig. 6 and 7, were selected for experimental verification on the basis of studies conducted previously (1,2). The canisters designed and fabricated for the EMAD demonstrations are not prototypical.

(a) also required: fuel disintegration; water intrusion; suitable geometry

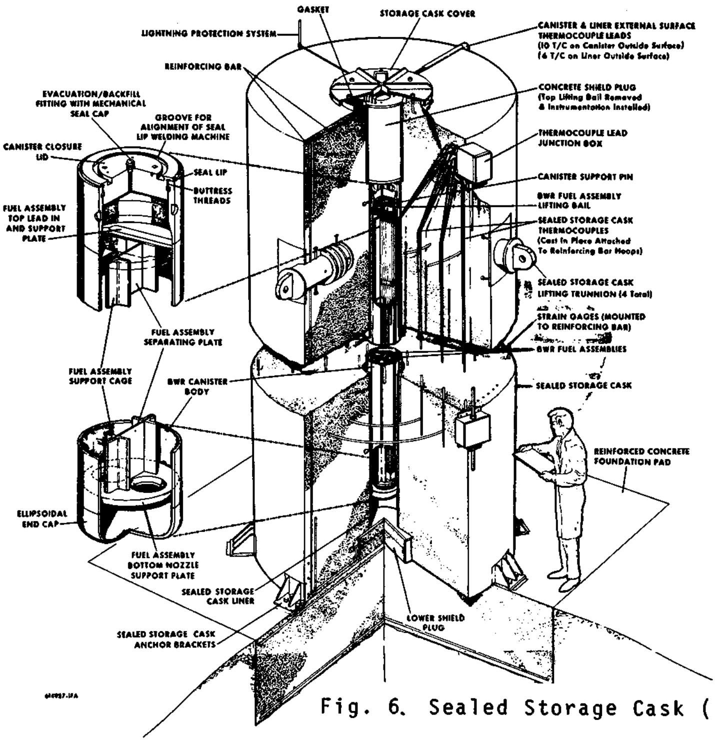


Fig. 6. Sealed Storage Cask (SSC)

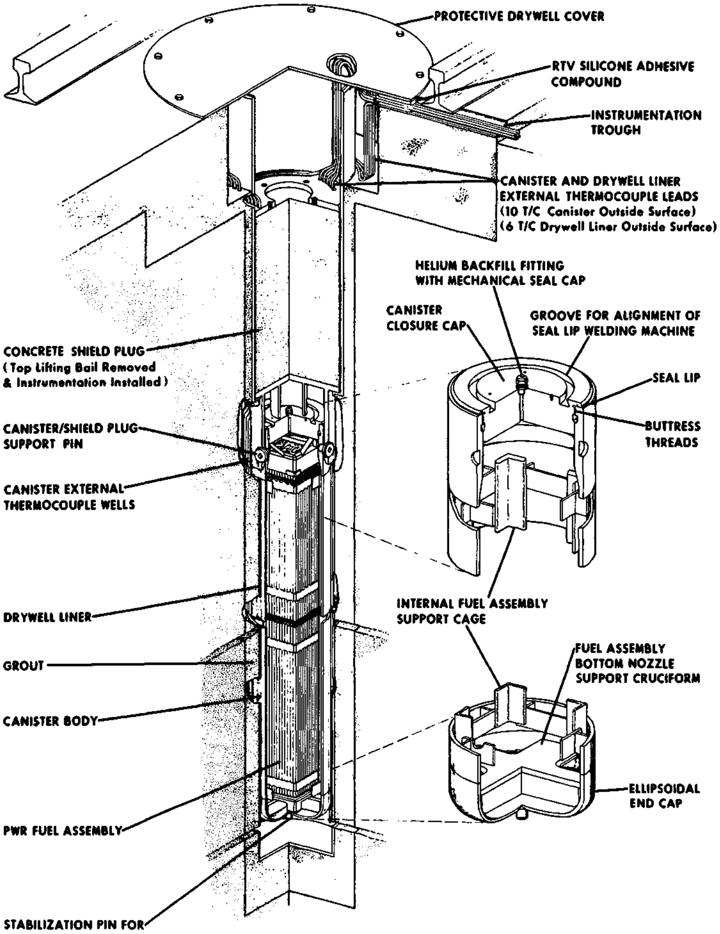


Fig. 7. Drywell Installation

Packaging and emplacement of 3 PWR fuel assemblies, one into an SSC and two into drywells, was successfully completed during January 1979 (Fig. 8 and 9).

The fourth unit at EMAD will be tested in a hot cell to evaluate effects of external temperature on fuel pin temperatures. Electric heaters will surround the assembly to provide control of the boundary temperature and permit measurement of interior pin temperatures as a function of the surrounding thermal environment. The data obtained in this effort will support analyses of close spacing in a repository or burial in a particularly insulative medium.

Plans for retrieval and post-storage fuel examination for these assemblies have not been established at this time, though it is anticipated that the units will remain in storage no less than one year nor more than five years. Examination and packaging schedules for geologic repository demonstration programs will determine when the next phase of this activity will occur.

Receiving and Packaging Facility Conceptual Design

Conceptual design of a Receiving and Packaging Facility (RPF) for BWR and PWR spent fuel assemblies was completed during this year (4). The reference RPF was assumed to be located adjacent to the Hanford 200 West Area and was sized to encapsulate, during a 15 year operating period, all of the fuel projected to be discharged by commercial reactors through 1990.

The RPF is illustrated in Fig. 10. The dominant structure is the Receiving and Packaging Building; the overall facility also includes all of the required support services for RPF operation. Some of the satellite structures (warehouse, administration building, maintenance building, etc.) are shown, while others (electric substation, fuel and water storage tanks, security building, etc.) are not apparent in this artist rendering.

The sequence of operations for fuel packaging is shown in Fig. 11. The RPF is equipped to receive fuel either by truck or rail. Unloading fuel from the shipping cask and lag storage prior to packaging are both done underwater. An interesting aspect of the operating sequence is that, since the package is highly radioactive, X-ray inspection of the canister closure weld is not feasible. Ultrasonic inspection is a logical, reliable alternative, but in the context of current regulations governing containers for radioactive materials, a code variance will be obtained, as in similar applications. The helium pressurization station provides the inert environment for the package interior and provides helium as an additional canister leak check.

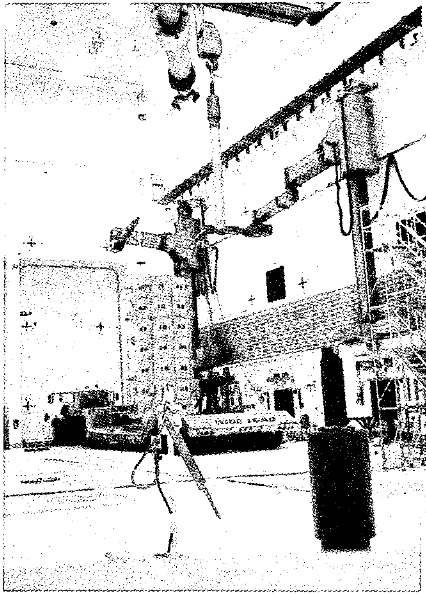


Fig. 8. Fuel Canister Loading in SSC Test Unit at EMAD

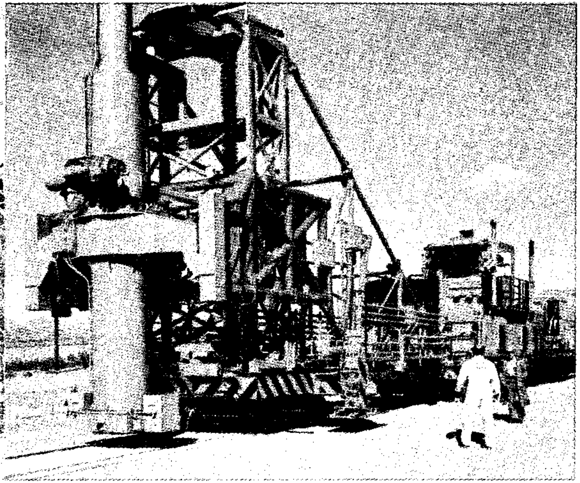


Fig. 9. Fuel Emplacement in Drywell Unit at EMAD

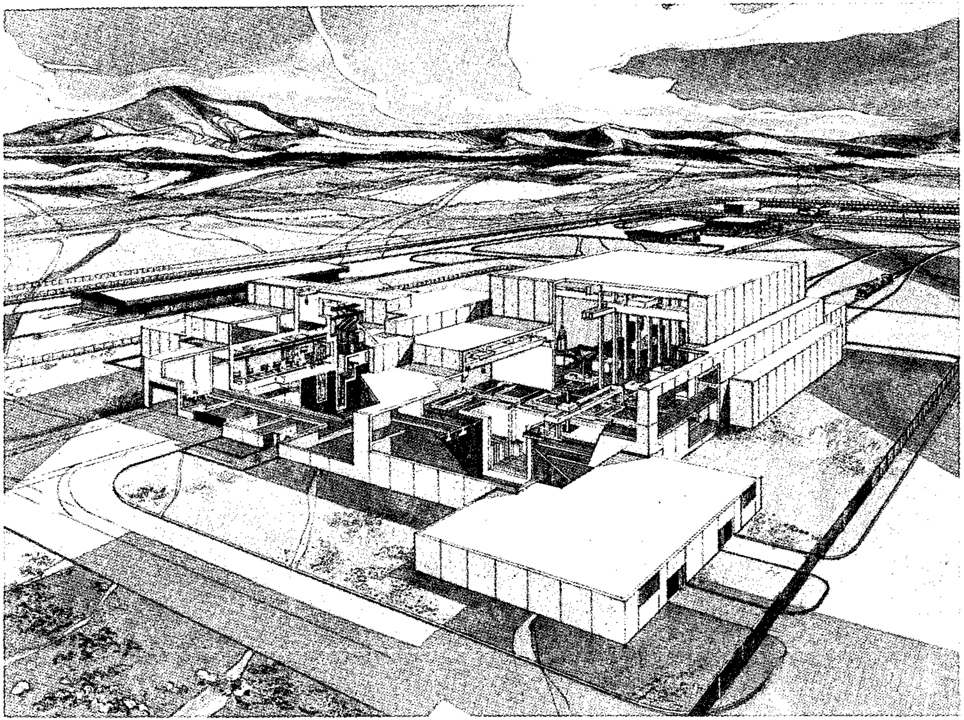


Fig. 10. Spent Fuel Receiving and Packaging Facility

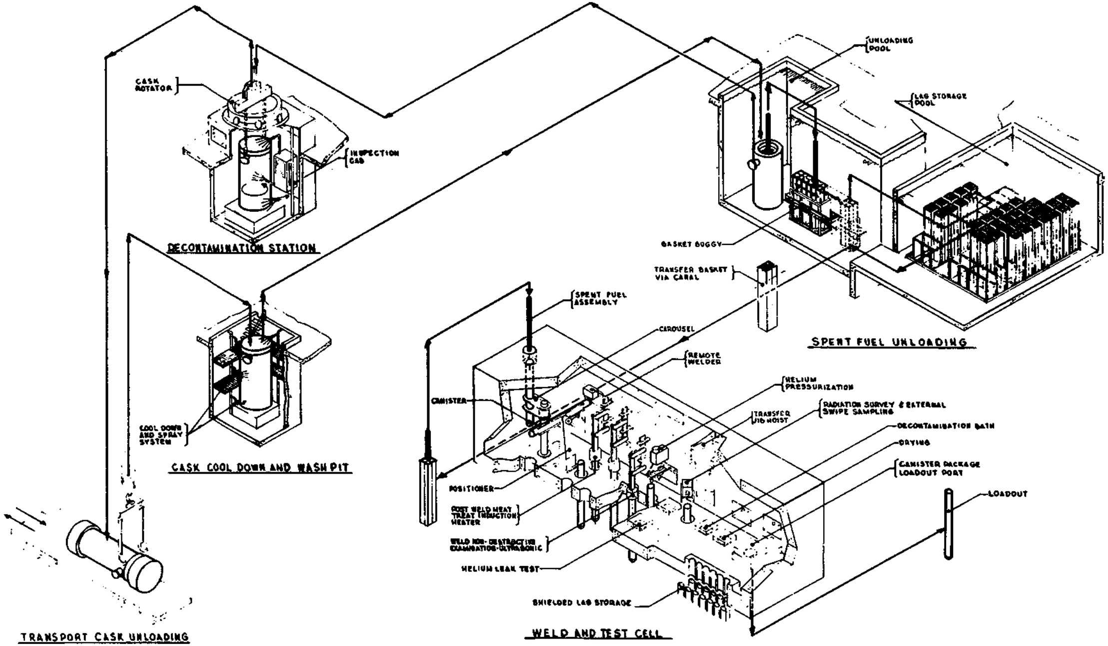


Fig. 11. Spent Fuel Packaging Sequence

The Weld and Test Cells will be kept "clean" to the greatest extent possible. Toward this end, a Special Function Cell will be utilized for packaging leaking fuel assemblies and for unpackaging and repackaging those units which exhibit defective canister welds. This approach should ensure isolation of spilled contaminated material.

The RPF, on a typical day in its 250 day per year packaging activity, encapsulates 18 PWR fuel assemblies, one per canister, and 27 BWR assemblies, three per canister. The package configurations used in this study are shown in Figs. 12 and 13. As noted earlier, package criteria are still under development; features such as the simple bail are quite unlikely to be included in the next design iteration.

An important issue relative to definition of the loadout area in the RPF is the identity of the next step in the storage/disposal cycle. The basic alternatives stem from whether or not the RPF is colocated with a repository; transfer onto a transporter (i.e., in an integrated packaging/disposal complex) is quite different from preparation and loading for shipment in the public domain.

Conceptual design of a Drywell Facility as an adjunct to the RPF was recently completed (Fig. 14). Although emphasis has shifted away from this mode of storage as a main-line element in the storage/disposal cycle, drywell storage may play a significant backup role. Analysis of possible scenarios for repository development indicates that in the event a selected repository proves unacceptable, drywells may be an economical method of passive, easily retrievable storage for at least 50 years.

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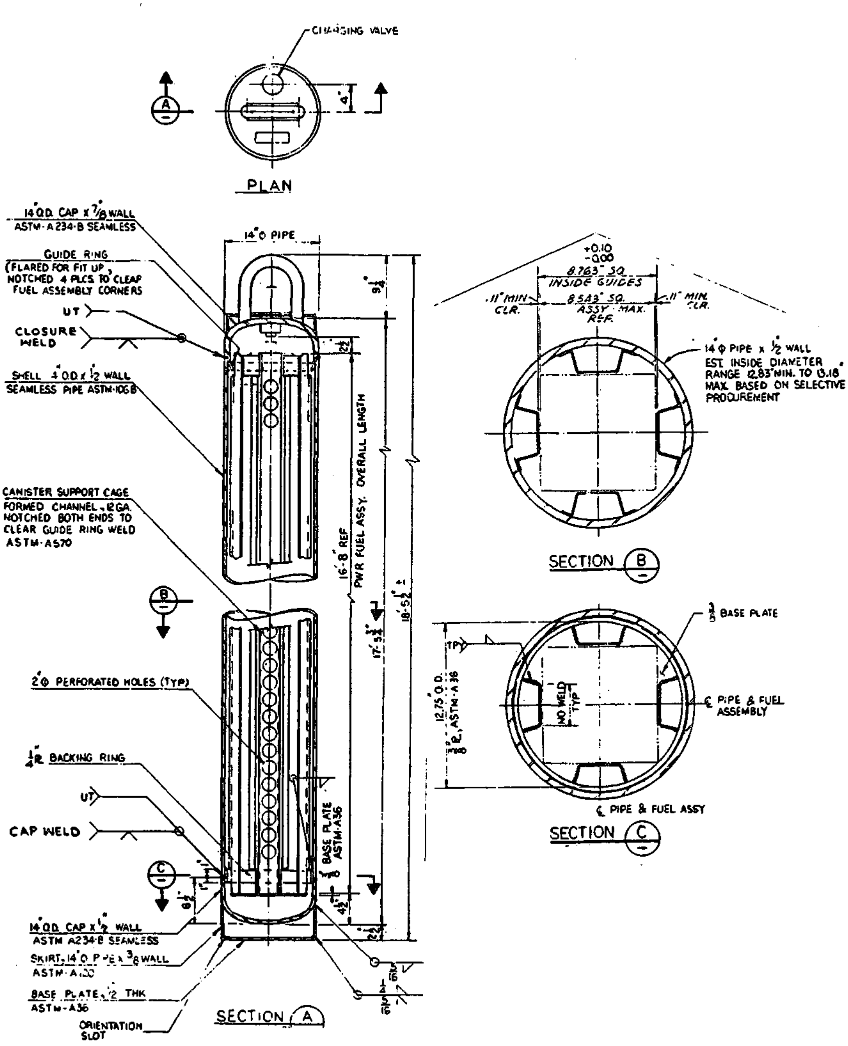

Fig. 12. PWR Fuel Package

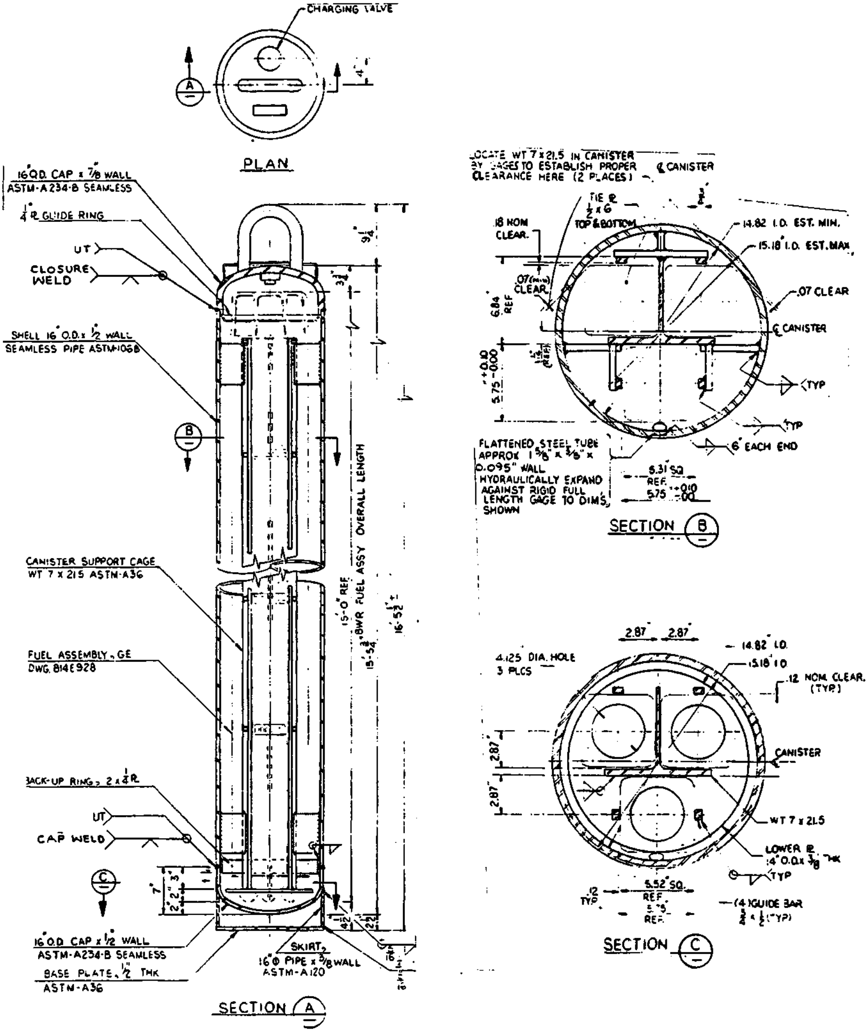

Fig. 13. BWR Fuel Package

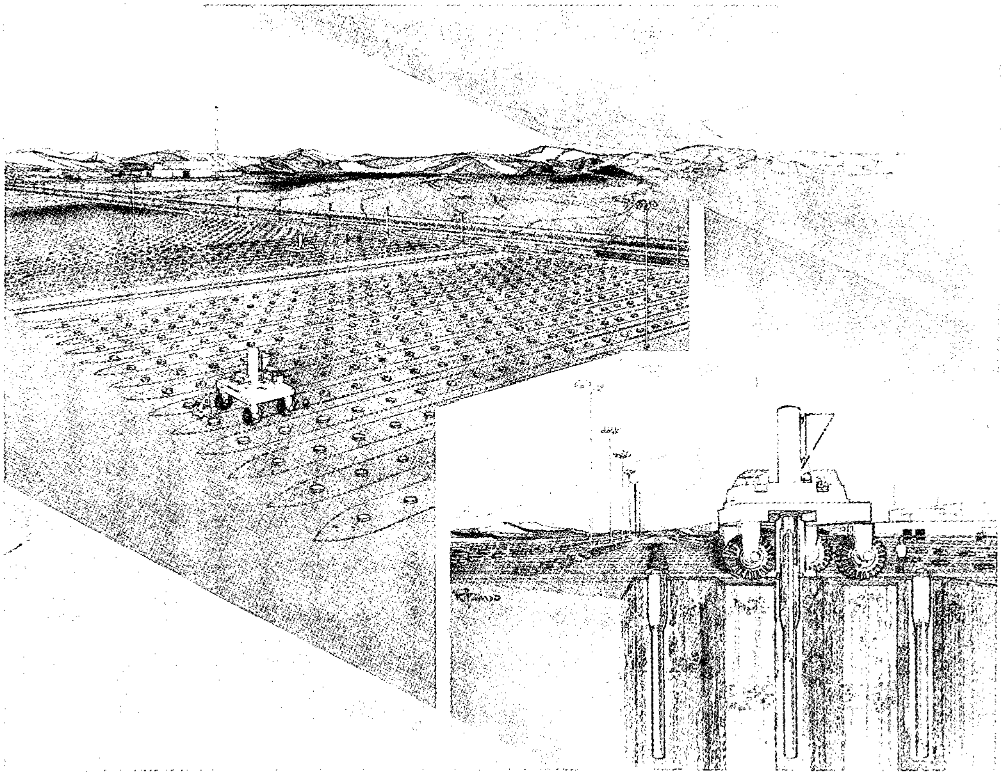

Fig. 14. Drywell Facility