HANDLING AND STORAGE OF SPENT NUCLEAR REACTOR FUEL AT THE IDAHO CHEMICAL PROCESSING PLANT

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ABSTRACT

Spent fuel storage facilities at the Idaho Chemical Processing Plant (ICPP) are extensive, consisting of two fuel storage basins, drywells, and a dry forced air-cooled vault storage facility. All but the newest storage basin have operated for at least a decade, and the original basin for 36 years, although many improvements have been made to this basin and its water treatment system. A new pool storage area began operation in 1984, without most of the problems inherent in the original basin due to design. Fuels which cannot be processed or which cannot be stored underwater have been stored since the mid-seventies in dry wells or in a forced air-cooled vault. Both of these types of facilities have operated with few problems, although some improvements were added to additional drywells constructed since 1985. A cost estimate shows that even though costs are high for storing fuel in pools, pool storage provides the necessary flexibility and simpler handling for fueld received for reprocessing. Fuels received for storage only are reserved for vault or drywell storage, since that type of storage has lower capital and operating costs, even though handling costs are higher. New unprocessable fueld received for storage will be placed into drywells, which can be built as needed in a short time frame.

INTRODUCTION

The Idaho Chemical Processing Plant (ICPP), a part of the Idaho National Engineering Laboratory, processes various types of spent nuclear fuel for recovery of the fillile uranium and krypton-85, at the Department of Energy's request. Some spent fueld cannot be processed, and are therefore received for storage only. A variety of fuel storage facilities have been operated at ICPP to provide the necessary storage. This paper evaluates what has been learned at ICPP about safe, efficient storage of spent nuclear fuel.

Pool Storage at ICPP

The first spent fuel pool storage area at ICPP began operation in 1951. This basin provided the sole storage capacity until 1970, when ICPP began receiving certain fuels which could not be processed or stored underwater. These fuels were placed into drywells in 1970 and also into a dry shielded storage vault in 1976. In 1984, a new fuel storage basin began operation, and will eventually replace the original basin.

The original fuel storage basin consists of three separate pools interconnected by a fuel transfer canal, as described in Table I. The first fuels received were aluminum-clad test reactor and stainless steel-clad breeder development fuels. Later, zirconium-clad fuels and a variety of development-type reactor fuels were received. Fuels were stored in lines separated by 12-inch wide cement walls, so that storage densities were low. Handling was complicated by moving a whole line of bucketed fuels to reach the one intended for processing. Maximum fuel weight and height were limited by the monorail system used to transfer the fuel within the pools. In the south basin, fuels were more efficiently stored within racks, and more simply handled with a crane.

Basin water quality was maintained by a swimming pool-type diatomaceous earth filter to maintain water clarity, and by continuously purging the basin water, with the overflow water diverted to a shallow well. Microorganisms were controlled by adding chlorine, and the resulting chloride concentration was also controlled by the water purge.

Problems with Pool Storage

Most of the engineering problems at the old underwater storage facility involved the water treatment system. Since 1952, addition of substantial quantities of radionuclides, chlorides, undissolved solids, and microorganism growth, reduced operational capabilities at the basin. In summary, most of the improvements were made to control radionuclide accumulation, turbidity, and pool chloride concentration.

Radionuclide Accumulation

Figure 1 shows the steps taken to control pool water radionuclide concentrations. Before 1963 radionuclides were controlled by continuous water purging. Then in 1963 the ion removal system (IRS), containing nonregenerable clinoptilolite, started operation which with the purge resulted in the pool radionuclide concentration decreasing to 1 X $10^{-3}\mu$ Ci/ml. Radionuclide ion removal by the IRS maintained suitable levels until 1969 when increased fuel leakage completely saturated the IRS. Steps were necessary to increase removal and decrease inflow of the radionuclides.

In 1973 an Ion Exchange System (IES) with a flow of about 60 GPM and remote changeout of spent resin began operation. This system consisted of two columns in series, one containing regenerable Amberlite-200, and the other nonregenerable Zeiolon-900. Although a regenerable all-purpose resin was searched for, most could not tightly bind cesium-137 (Cs-137). Since strontium-90 (Sr-90) is preferentially exchanged over Cs, the cesium remains free. Therefore the Zeolon-900 column was included, since it preferentially absorbs cesium over strontium. But this also increased the volume of radioactive solids which must be disposed of, since approximately 175 cubic feet of Zeolon are used per year.

The IES could not sufficiently reduce the basin radionuclide content since the design water treatment rate was inadequate to handle the increased influx of radionuclides resulting from the corrosion and leakage of fuel in the basin. Therefore, in 1975 an effort was made to identify leaking fuel stored in the basin. The first analysis consisted of comparing various ratios of radionuclide concentrations found in the basin water. It became apparent that stainless-clad liquid metal breeder reactor fuels were the major source of the contamination. Selective sipping tests of suspected "leakers" confirmed this, and the leaking fuel was either processed or canned. Figure 1 shows the effect that reducing radionuclide influx had on basin water contamination.

The existing ion exchange system was upgraded in 1981 to increase the water treatment rate from 60 to 150 GPM. Figure 1 shows the basin water activity goal of 1 X 10^{-3} μ Ci/ml was met in 1981 and has since decreased to less than 1 X 10^{-4} μ Ci/ml.

Turbidity

Turbidity continued to increase in the basin water between 1963 and 1977, thus hampering fuel handling operations. Major sources of solids in the basin included external dust infiltrating the building, corrosion products from carbon steel gratings, yokes, and storage racks, diatomaceous earth from the original water filter, and calcium carbonate added with the calcium hypochlorite.

In 1977 most of this sludge was removed by vacuuming. At the same time, new fiberglass gratings, stainless steel racks and yokes were installed. A new shielded multimedia filtration system (to replace the diatomaceous earth filters) was also installed. Although some residual sludge remains in the bottom of the pool, water clarity has returned to adequate levels.

Chloride Accumulation

Originally, gaseous chlorine was injected into the basin water to control microorganisms. Although

TABLE I

STORAGE POOL DESIGN CHARACTERISTICS

DESIGN FEATURES	OLD STORAGE BASIN	NEW STORAGE BASIN
1. Layout		
Pool Volume	1,500,000 gal	3,400,000 gal
Pool Dimensions	2-39' x 59' x 21' deep 1-46' x 80' x 21' deep	2-46.5' x 31' x 41' deep 4-46.5' x 31' x 31' deep
Storage Capacity[1]	3460 units	2440 units
2. Handling & Storage		
Weight Limits	60 ton/cask & 1.5 ton/fuel unit	120 ton/cask & 10 ton/fuel unit
Storage Port Dimension	Racks, 5"Ø x 56.5" Lg, 6.5"Ø x 45" Lg, 9.75" square x 77.25" Lg, buckets, hanging from hooks	8,10,12,16" - square racks x 10' long
Transfer to Process	Cask Shipment to Process	Direct transfer to process via trans-channel.
Other Capabilities	Leak-testing	Leak-testing, leaking fuel isolation, storage pool isolation, fuel cutting
3. Water Treatment		
Filtration	Multimedia (sand) filter, 700 GPM, 500 gal backwash Filters to 10 Microns	'VACCO' filter, 1100 GPM, 100 gal backwash Filters to 5 Microns
Deionization	Cation Removal Only 150 GPM	Total Demineralizer 1100 GPM
Micro Organism Control	Ultra-violet Irradiation	Ultra-violet Irradiation, Water Chillers
Radionuclide concentration	10^{-5} μCi/ml	10^{-7} μCi/ml
Total ion concentration	200 PPM	<1 PPM
4. Waste Generation		
Liquid	70,000 gal/yr	60,000 gal/year
Solid	200 ft^3/yr	60 ft^3/yr
Airborne	No Air Control	Forced air is filtered & monitored before exhaust to stack.
5. Radiation & Contamination		
Contamination Control	Single Containment (concrete basin)	Double containment (concrete basin & stainless steel liner enveloping collection sump)

[1] The number of storage units in each basin is misleading since fuel assemblies may be double-stacked in the new basin and not in the old.

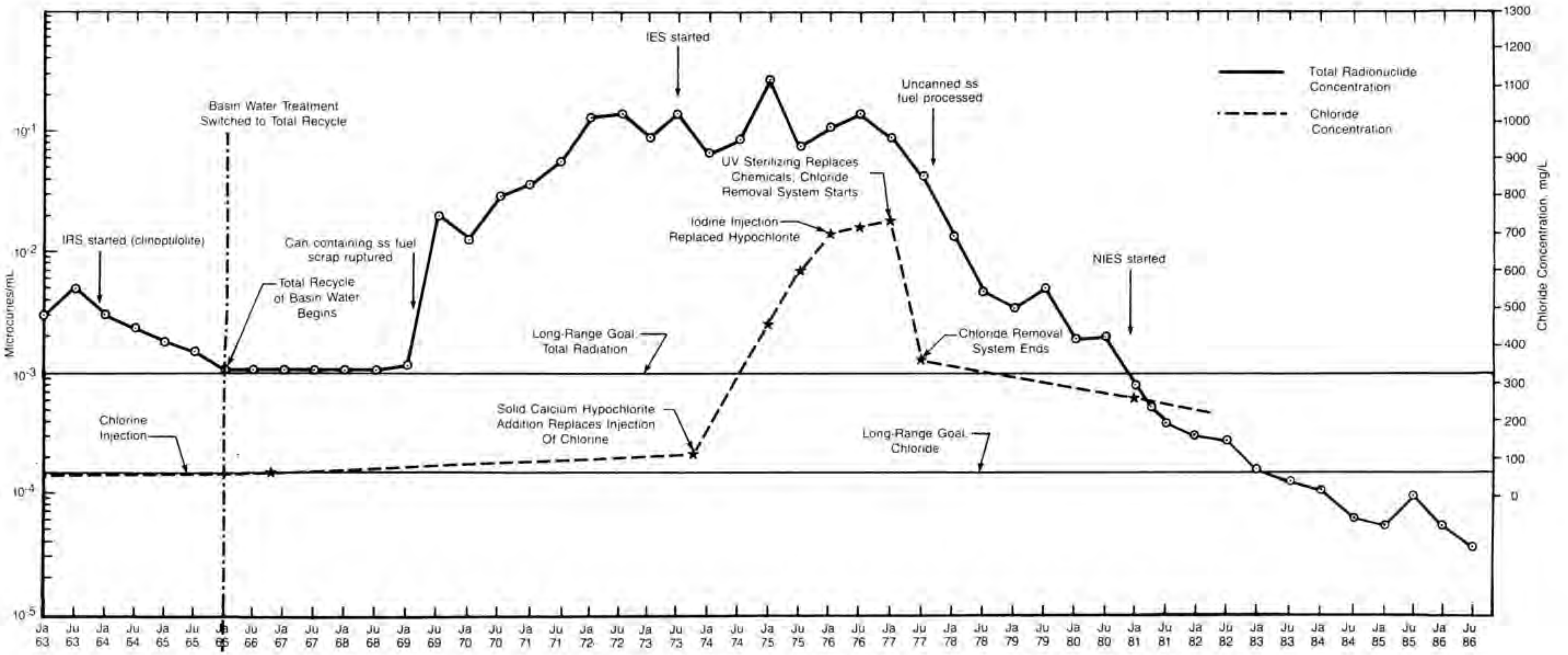


Fig. 1. Radioactivity and Chloride Concentration in Original Fuel Storage Basin Water with Time.

most of this was reduced to corrosive chloride ion, levels were controlled to less than 50 PPM by the continuous purge as shown in Fig. 1. The situation changed in 1966, when basin water recycle was instituted, resulting in a steady build-up of chloride, as well as Mg, NO_3, Ca, Na and others. Direct addition of chlorine was discontinued since its effectiveness was limited to only a portion of the basin. Instead calcium hypochlorite was added, broadcast as a solid over the entire basin. This controlled microbiological growth, but required large amounts (70kg/wk) of the solid chemical. Therefore calcium hypochlorite was largely (5 kg/wk) replaced by iodine as a biocide, which restricted total chloride concentrations to about 730 PPM.

In 1978 the addition of chemicals to the basin water for control of microorganism growth was stopped with the ultraviolet light sterilizers used instead. A system incorporating reverse osmosis and evaporation was used to reduce the chloride content in the basin water from 730 to 80 PPM.

Design Requirements for the New Pool Storage Area

The problems with the old basin emphasize the importance of maintaining water quality. This is possible only if contamination influx is minimized, and the water is treated to maintain purity. The new fuel storage area (FSA) was built to meet rigorous water quality standards, as well as to fulfill new task requirements, such as larger cask handling, fuel cutting, increased storage capacity, and more efficient fuel batching to the dissolution process. Figure 2 shows the FSA arrangement. Fuel is unloaded from the shipping cask in the unloading pool and usually placed into a dissolvable basket. The basket is then moved by crane via the transfer channel to the pool storage position. Leaking fuel may be isolated in one of two isolation pools. In addition, any of the storage pools may be isolated from the rest of the FSA. Fuel cutting may be performed in a shielded cutting pool (currently not in use). Fuel is transferred directly to the fuel dissolution process via the transfer channel.

Unlike the original basin, the FSA pools are doubly isolated from the environment. The pools themselves are constructed of concrete, and lined with stainless steel. A sump is situated to collect water leaking through the liner, where it may be monitored for contamination and removed. Above the water, two sets of doors isolate the FSA pools from the outside. Trucks enter one set of doors, which are then closed before the set leading to the pool area are opened. Ventilation inlet air is filtered, and directed towards areas of increasing contamination. Exhaust air is HEPA-filtered and monitored prior to release through the stack.

The FSA pool water treatment system was designed to eliminate problems evident in the original storage basin without resorting to the addition of chemicals. The maximum water treatment rate is 1,100 GPM; therefore the equivalent of the FSA pool volume may be treated in two days. Water flow is directed, so that water flows from areas of least contamination to areas of greatest contamination. Water is passed through two VACCO filters in parallel, and then through two sets of deionizer columns. Each deionizer set consists of one anion and one cation exchange column. The ion exchange resins are fully regenerable. Before the water is discharged to the pools, it passes through an ultraviolet sterilizer to kill microorganisms, and chillers to cool the water. Water is drawn into the treatment system from the top few inches of all the pools, in order to skim scum from the water surface. The FSA has operated reasonably well during 2 1/2 years of operation. Only one problem has developed so far. The pressure drop across the VACCO filters during backwash has increased in 2 years from 10 to 70 psi. These filters were taken out of service and cleaned, and work is underway to identify the cause of the plugging and to eliminate future problems.

Most of the problems with the old basin involved water quality. Because of the large volume of water in the facility, these problems developed slowly, until they "suddenly" produce serious consequences. Resolution of the problems and return of the basin water quality to acceptable levels occurs just as slowly after a solution is implemented. Thus, it is important to monitor the new pool storage area carefully to identify and eliminate incipient problems.

Dry Storage

Nuclear fuels have been stored in dry wells and in a forced air-cooled storage facility since 1971 and 1976, respectively. Layouts of both facilities are shown in Fig. 3 and 4. Since 1985, new drywells have been built and are being filled presently.

Drywells

Drywells have been used to store spent nuclear fuel since 1971. Drywell fissile material loadings range from 10 to 30 kg with burn-ups ranging up to 45,000 megawatt-days/metric tonne of U^{235}. Table II shows the type and quantity of fuels presently stored. Drywell design has improved since the first set was built. Between 1970 and 1976, Peach Bottom and Fermi reactor fuels were stored in drywells of the type shown in Fig. 3a. However, the design was changed in 1984 to the second type shown in Fig. 3b because of deficiencies identified in the design of the existing drywells.

Changes were made to the new drywells in order to eliminate the existing drywell deficiencies. In order to properly seal the new drywells, the drywells were constructed completely of steel as units, and leak-tested prior to installation. Holes were excavated and lined with steel pipe. Each drywell was lowered into a hole and grouted in place. Bolted flanges and rubber gaskets were used to cover and seal the new drywells in order to simplify fuel handling and leak-testing. The new drywells were also fitted with thermowells, pressure gauges and a valved sample tube to monitor storage conditions. A sump with a siphon tube was added to determine the presence of liquid water and to allow removal of the water. Together with the sample tube, the siphon tube can also be used to purge the drywell with a dry inert gas. Crush pads were placed into the bottom of each well in order to avoid the potentially hazardous consequences resulting from the accidental drop of a fuel can into the well. Finally, wells were spaced 10 feet apart in rows 30 feet apart to reduce land usage.

Despite various differences, all drywells are designed to be loaded and unloaded using the shielded Peach Bottom cask. The internal dimensions of this cask are a 25.5-inch diameter and a 155-inch length. The cask is propped on a stand, and a lift rod is inserted through a small hole in the top cover and connected to the fuel canister. A clamp is then used to grip the rod above the cover. Then the bottom cover is disconnected, and the cask is moved onto the top of

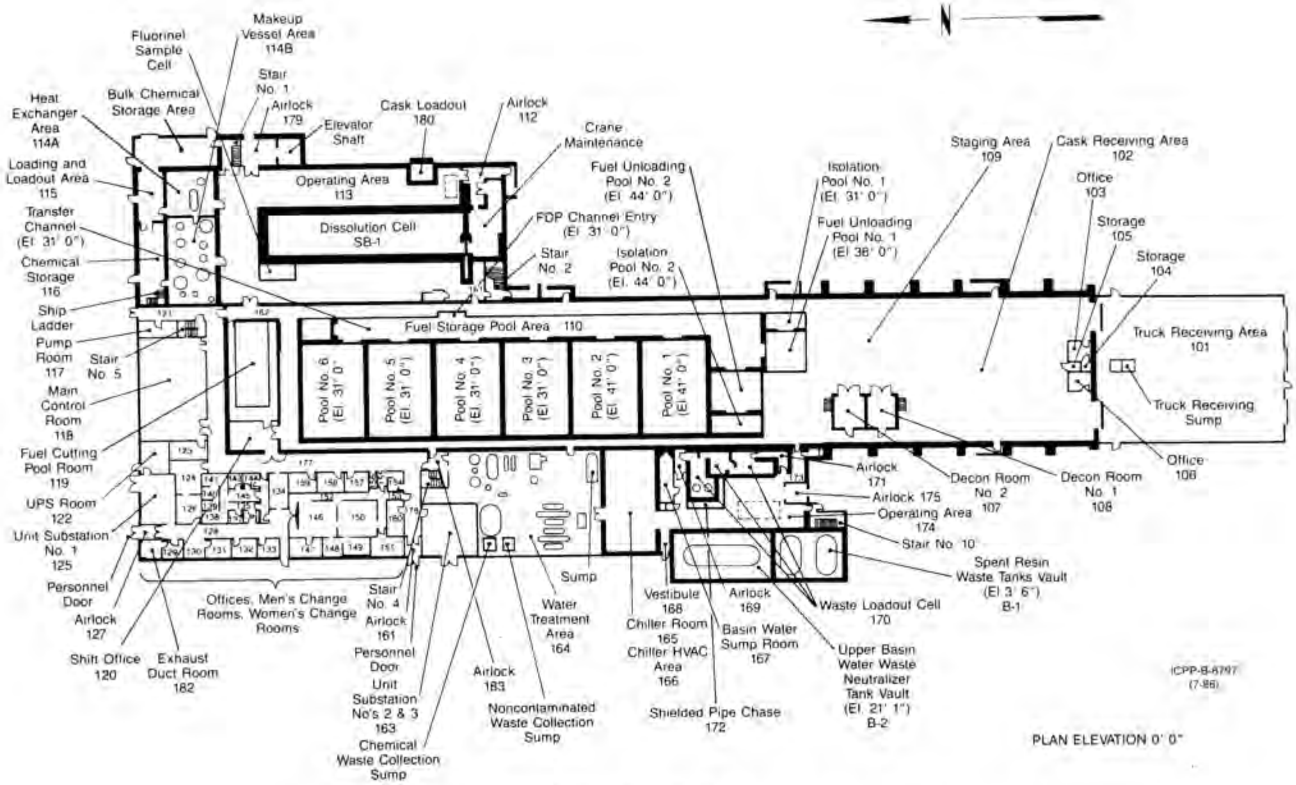
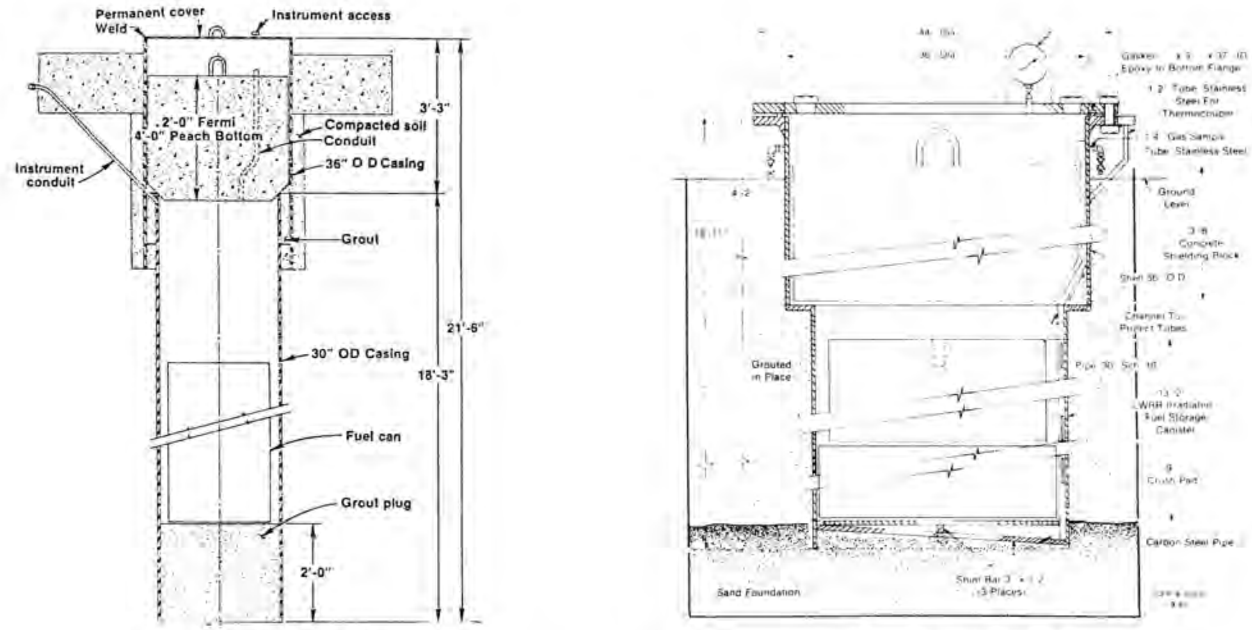


Fig. 2. Layout of the New Fuel Storage Area (FSA).

TABLE II

CHARACTERISTICS OF FUELS STORED IN DRY WELLS

DESCRIPTION	PEACH BOTTOM	FERMI	SHIPPINGPORT
Fuel Type	HTGR	LMFBR Blanket	LWBR
Composition	Thorium-uranium Carbide	Uranium-molybdenum Metal	Thorium-uranium Oxide
Enrichment %	93.15 U-235	Depleted	≤5.0 U-233
Burn-Up, Megawatt-Day/Metric Tonne			45,000
Heat Generation, Watts/Canister	900	100	2000
Canister Contents	18 elements	47 Subassemblies	1 Reactor Core
Number of Canisters	46	14	46
Canister Maximum Weight, lbs	3600	10,000	10,000
Dry Well Spacing (Center to Center), ft.	30 x 30	30 x 15	30 x 10
Placed in Storage	1971-1973	1975-1976	December 1985 and Continuing



A. Original Dry Wells.

B. New Dry Wells.

Fig. 3. Fuel Storage Drywell Cross Sections.

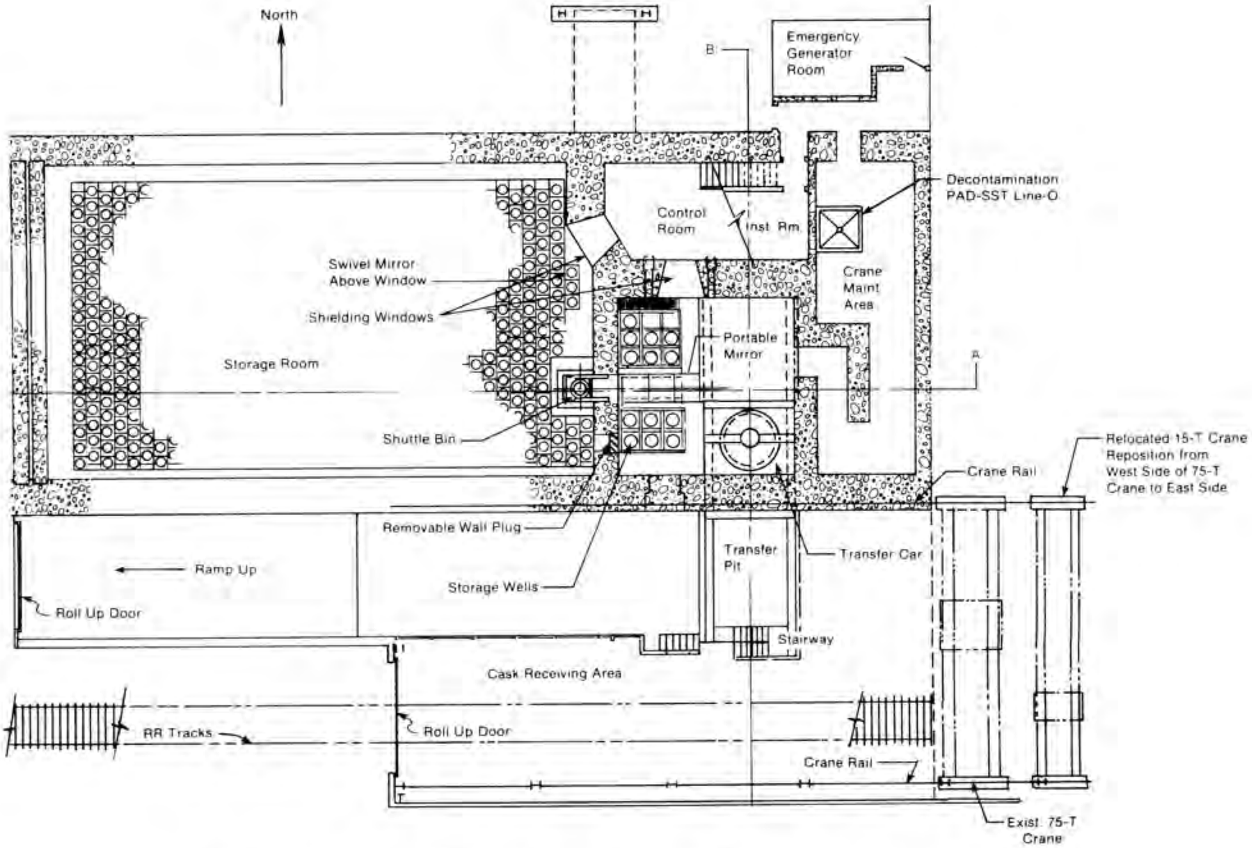


Fig. 4. Cutaway View of the Forced Air-Cooled Spent Fuel Storage Vault.

the well, with the fuel suspended inside from the lift rod. The rod is connected to a crane, the clamp is removed, and the fuel is lowered into the well. The cask is then removed and the shield plug and cover installed in the dry well.

Much concern developed about the potential personnel dose from radiation shine during dry fuel transfers. Time and motion studies were conducted of mocked-up fuel transfers. From this and radiation field calculations, total doses to personnel were estimated. Then a wide variety of steps were taken to reduce the total dose, including constructing additional shielding, minimizing time to complete some steps, and removing workers from the area during others. Mock-up testing and evaluation proved effective, because total dose to personnel was reduced from 500 mrem down to a few mrem per fuel transfer, using cask and handling equipment 18 years old. With this equipment, four operators and one health physics technician can load fuel into a drywell in four hours.

Several problems developed with the drywell's built to store Peach Bottom and Fermi reactor fuel. Drywell humidities fluctuated seasonally, and two wells purged with argon lost the gas within days. Although not a hazard in dry Idaho soils, the risk of flooding into these drywells became evident. Also, potentially dangerous volumes of hydrogen accumulated in several wells, apparently generated by radiolysis of water in some wells and by water-metal reactions in others.

The latest wells constructed were designed to provide leak-tight storage and better monitoring capabilities. These drywells are leak-tested before use and are purged with argon after being loaded with fuel. Thereafter, the loaded well is monitored for 1) argon and air, which indicates a leak in the well, 2) humidity, and 3) Krypton-85 or neon, which indicates a fuel canister seal failure. The well bottoms are also monitored for the presence of liquid water. So far these new wells have provided air-and water-tight storage for spent fuel.

A major concern with the new wells was the high storage temperatures predicted by thermal analysis studies, which exceeded 600°F. These studies were conducted for many loaded drywells arranged in regular arrays, but with different spacing. The evaluation showed that unless the well-to-well spacings were less than 10 feet, the storage temperatures were not greatly affected. Figure 5 shows predicted and actual storage temperatures for comparison. The excessive temperatures predicted arise overly-conservative assumptions about the flow of heat through soil. Therefore, future temperature estimates will be made using actual storage temperature data as a design basis in order to improve the accuracy.

Vault Storage

The Irradiated Fuel Storage Facility (IFSF) was built to provide dry storage for highly irradiated graphitetype fuels. A transport cask containing the fuel is brought into the fuel handling cell using a transfer car. The car rides in a pit underneath and between the truck bay and handling cell, and is provided with shielding to isolate the cell from the truck bay, even when moving. The cask lid is removed after the cask is brought into the cell, and the fuel is removed and placed into a storage canister. The canister is then placed in a shuttle bin, and transferred remotely into the storage cell via the bin. The canister is removed from the bin by a crane, and transferred remotely into the storage cell via the bin. The canister is removed from the bin by a crane, and transferred to a designated storage position. Operations are completely remote. Air-flows are controlled within the cell to cool the fuel, and then the air is exhausted through high efficiency filters and a stack. Very few problems have occurred since the facility was placed into operation in 1976.

Comparison of Fuel Storage Areas

A comparison between the Fuel Storage Area (pool), the Irradiated Fuel Storage Facility and the drywells is shown in Table III. The FSA contains the largest number of storage positions and the greatest variety in storage position size. This flexibility is necessary to provide storage for the large variety of zirconium-and aluminum-clad fuels received and processed at ICPP. Because of the problems incurred with the original fuel storage basin, extensive water treatment, waste handling, and monitoring systems have been included in the FSA. In contrast, the dry storage facilities have been provided with much simpler support systems.

A rough cost breakdown between these three facilities is also shown in Table III. In order to compare costs, yearly costs were estimated assuming the capital costs were amortized at 10% over 25 years. As expected, the capital cost for a pool storage position is higher than a dry storage position. However, fuel canning and handling costs for drywell storage dramatically raises the cost for drywells. The high canning cost is because the fuel must be thoroughly dried and then sealed in leak-tight cans. Fuel handling costs also increase for dry storage, since radiation and contamination hazards increase when fuel is transferred and stored in air.

Certain factors were not considered in the costs given in Table III. For example, no land costs were included, which are the highest for dry wells (300 ft^2/position) and lowest for pools. Some of these facilities are used for purposes other than storage, such as packaging and cutting fuels. Finally, security, technical support, and other service costs were not included.

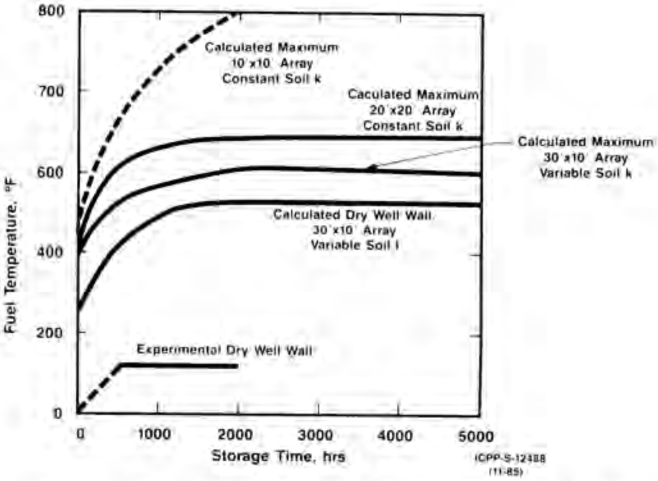


Fig. 5. Estimated and Actual Temperatures of Spent Fuel Stored in Dry Wells Built in Arrays With Different Spacings.

TABLE III

COMPARISION OF FUEL STORAGE FACILITIES AT ICPP

FEATURE	STORAGE AREA (POOL)	FUEL STORAGE AREA (VAULT	DRYWELL STORAGE AREA
Number Storage Positions	2440	636	187
Position Dimensions	8,10,12,&18" square racks by 10' long	18" square rack by 11'	14 and 30" diameter by 20' long
Area per storage position	3.54 ft^2/pos.	3.7 ft^2/pos.	300^2 ft. pos.
Type fuels stored	- Zirconium-clad - Aluminum-clad - Stainless-clad	LWR-HTGR blocks Test-Other graphite fuel LMFBR elements	- HTGR elements, - LMFBR blanket mat'l - LWBR assemblies
Required Systems	- Water treatment (include filtering, deionizing, and UV sterilizing) - HVAC	HVAC	None, Passive Facility
Required Utilities	- Power, steam, demineralized water	Power	None, Passive Facility
Required Waste Handling	- Chemical and contaminated liquid - Filter solids and spent resin - Air-borne contamination	Air-borne contamination	None, Passive Facility
Required Monitoring	Criticality & radiation, water & air treatment system parameters, and water quality.	Criticality & radiation, treatment system, storage temperature	Storage temperature, drywell atmosphere
Fixed Cost Per Position			
- Storage Position	40.0	24.0	17.0
- Cans/Baskets	0.30	0.5	25.0
- Loading/Unloading	1.25	1.0	1.8
Subtotal	41.55	25.5	38.8
Yearly Cost[1]	1.66	1.02	1.55
Operating Per Cost Year Per Position			
- Maintenance	0.275	0.02	-0-
- Utilities	0.400	0.04	0.01
- Waste Management	0.031	0.001	-0-
- Monitoring	0.100	0.005	0.05
Subtotal	0.806	0.111	0.06
Total Cost (in $1000 per pos per year)	2.5	1.1	1.6

[1] Fixed Costs Depreciated in a Straight Line Over 25 Years.

CONCLUSION

At present the new Fuel Storage Area (FSA) remains dedicated to handling and storing readily processed fuels, which form the bulk of fuel receipts at *ICPP*. Interim storage of some fuels underwater is also planned, pending design and construction of dry facilities. Drywells have been and will continue to be used for new fuels which cannot readily be processed. Additions of 20 to 30 wells every year for several years is planned to meet the projected storage capacity required for these fuels. Although drywells are individually quite expensive, they can be built in small numbers on an as-needed basis. Although relatively simple to use, existing vault storage is dedicated to certain on-going fuel receipts and no plans have been made to expand for new fuels due to the large initial cost of construction.