Utilization of the NFS West Valley
Installation for Spent Fuel Storage

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4.3 Spent Fuel Storage

4.3.1 The Need for Spent Fuel Storage Capacity

4.3.1.1 Alternative Spent Fuel Storage Schemes

Nuclear power reactor fuel, when it is discharged, is radioactive due to the fission and activation products it contains. This radioactivity and its resulting heat generation require that spent fuel be stored carefully. The debate over its final disposition has not yet been decided, although the major alternatives include 1) reprocessing to separate the usable uranium and plutonium from the radioactive fission and activation products (referred to as high level wastes) and 2) the disposal of spent fuel assemblies in deep geologic repositories (the "throwaway" option). Interim spent fuel storage is required while this debate continues and would be necessary anyway to allow the high activity, short halflife fission products to decay and to decrease thereby the radioactivity and heat generation levels of newly discharged spent fuel.

A number of spent fuel storage schemes have been studied and are discussed in detail elsewhere.^(1,2) We will be concerned with storage of unpackaged spent fuel. Great experience has been gained over the last 30 years in the storage of spent fuel in water filled basins. This technology has been used in all power reactors and in the fuel storage pools at reprocessing plants which have operated or are planned. The advantages of water storage include:

1. The water serves as a heat transfer medium, cooling the spent fuel.
2. The water shields operating personnel around the pool from high radiation levels.

3. The water contains most of any radioactivity which manages to escape from the spent fuel.
4. The pool represents a large heat sink to mitigate the effects of some accidents.
5. Water provides a transparent medium for the handling and observation of the stored fuel.

A process summary of water basin storage of unpackaged spent fuel is shown in Figure 4-1.

A second concept for the storage of spent fuel uses forced air as the heat transfer medium, blowing over racks of spent fuel in a closed vault. The air is filtered after passing over the fuel to remove any particulate radioactivity in the air. A process summary of air-cooled storage is shown in Figure 4-2. Air-cooled storage of commercial spent fuel has not been attempted on any large scale. The method of choice remains water-filled storage basins.

Each of the nation's power reactors has a spent fuel pool. The size of these pools was at first determined by (1) the desirability of having sufficient space (called Full Core Reserve) in which to store the entire reactor core in case of an emergency and (2) the need for space to store the spent fuel discharged from the reactor during periodic (usually annual) reload. This spent fuel would cool for about 180 days before being casked and shipped to a reprocessing plant. Since one-third or one-fourth of the reactor core is discharged during reload, spent fuel pools have been sized to accomodate about 1.5 full cores of fuel assemblies. For a model 1000 MWe reactor discharging 26 MTU each year, the spent fuel pool might typically have space for 150 MTU (330 PWR or 750 BWR fuel assemblies).

Fig. 4-1. WATER BASIN STORAGE — UNPACKAGED SPENT FUEL (2, p.17.4)

Storage Description. Near-surface, water-filled cell of heavily reinforced concrete lined with stainless steel.

Development Status. Demonstrated by about 30 years experience at reactor sites and fuel reprocessing plants.

Heat Removal. Basin water circulation with rejection to atmosphere.

Materials Used. Concrete and stainless steel.

Confinement Barriers. Cladding, basin water, and carbon and HEPA filters.

Maintenance Required. Filtration systems, heat removal systems, transport systems, and radiation monitoring systems.

Waste Sources. Radioactivity collected by filter systems and secondary solid waste from facility operation and maintenance.

Primary Advantages. Low fuel temperatures, additional confinement barriers, the large heat sink and transparent radiation shield provided by the water.

Primary Disadvantages. Requirement for stainless steel basin liner, water quality control, and substantial water supply.

Fig. 4-2. AIR-COOLED STORAGE — UNPACKAGED SPENT FUEL (2, p. 17.10)

Storage Description. Near-surface, heavily reinforced concrete structure (Class 1).

Development Status. The basic technology is demonstrated by an existing facility for air-cooled storage of packaged *unsealed) assemblies from gas-cooled reactors.

Heat Removal. Forced air circulation.

Materials Used. Concrete and low carbon steel.

Confinement Barriers. Cladding and filters (HEPA and carbon).

Maintenance Required. Forced draft system including power supply and filters (HEPA and carbon), radiation monitoring system, and fuel transport equipment.

Waste Sources. Radioactivity collected by the filter system and secondary solid wastes from facility operation and maintenance.

Primary Advantages. Elimination of the secondary cooling system and water treatment system and the use of low carbon steel.

Primary Disadvantages. Lack of a heat sink in event of loss of coolant accident.

The federal government has recently chosen the policy of deferring reprocessing, raising doubts that reprocessing will ever be allowed. Thus spent fuel has accumulated at reactor sites and the problem of spent fuel storage and disposition has received great attention. Basically, two solutions are being actively pursued. Reactor spent fuel pools usually have some room for expansion, either by fitting storage racks into unused space or through "densification." The latter method utilizes storage racks which pack fuel assemblies in a tighter array. The closest packing is achieved by incorporating neutron absorbers (usually boral plates or borated stainless steel) in the rack design. Many of the nation's power reactors have expanded, or are presently expanding their spent fuel pools by using these methods. Usually an expansion to capacity of 2 or 3 full cores is achieved. As an example of such an expansion, the Calvert Cliffs Nuclear Plant recently received NRC authorization for an amendment to its operating license allowing the expansion of its spent fuel pool.⁽³⁾ This plant has two 850 MWe PWR's, and the reactors were to share one fuel pool having a capacity of 410 assemblies (1.89 full core loads). The expansion will provide space for 1,056 assemblies (4.85 full core loads) for a densification factor of 2.58. Also, fuel storage pools for reactors under construction are being designed for larger capacities. These expanded pools will eventually fill up, however, as power is produced, fuel is discharged, and the decision regarding reprocessing is deferred.

A second solution to the fuel storage problem is away-from-reactor (AFR) storage. This entails shipping spent fuel, after an initial cooling period in the reactor spent fuel pool, to a large facility designed to store many tonnes of spent fuel. The fuel would remain

there until a decision was made either to allow reprocessing or to forego reprocessing and dispose of the spent fuel in the deep geologic formations of a national repository. Such a repository has been scheduled to be available in 1985, although recent DOE announcements indicate that this date will be pushed back to 1988-1990. (16)

4.3.1.2 Projected Spent Fuel Accumulations

The amount of spent fuel discharged through the year 1985 can be accurately predicted because of the long-range nature of new reactor planning by utilities. The amount to be discharged through the year 2000 is more difficult to project because it depends on several unknown variables, e.g., demand for electricity, choice of mode of electrical production, plant designs and capacity factors. A projection was made in NUREG-0404⁽⁴⁾ based upon current nuclear power industry plans, the GESMO "super low" growth rate (414 GW in 2000), and a slight improvement in capacity factor from 0.6 to 0.7. From this demand projection and the estimation of 22.4 MT of spent fuel discharged per GW of installed capacity, the spent fuel production schedule shown in Table 4-1 was projected. Over 95,000 MT of spent fuel will require storage by the year 2000 if none of the methods of spent fuel disposal are in operation. These methods are 1) reprocessing of the spent fuel to retrieve the usable uranium and the fissile plutonium and to separate the high level wastes for volume reduction and disposal; or 2) packaging of spent fuel and burial in deep geologic formations to provide permanent disposal or perhaps retrievable storage.

The fraction of the spent fuel produced by the year 2000 which must be stored at AFR storage cannot be easily computed. It depends on several unknowns: (1) the importance of maintaining the Full Core Reserve

Table 4-1. Schedule of Nuclear Generating Capacity and Spent Fuel Discharges, Annual and Cumulated

Year	GW Discharging Spent Fuel	Annual MT Spent Fuel Discharged ^a	Cumulated MT Spent Fuel Discharged ^b
1976	39	819	2,476
1977	43	940	3,416
1978	53	1110	4,526
1979	60	1257	5,783
1980	68	1412	7,995
1981	74	1661	9,856
1982	96	1944	10,800
1983	101	2110	12,910
1984	105	2261	15,171
1985	105	2337	17,508
1986	105	2344	19,852
1987	105	2251	22,103
1988	150	3213	25,316
1989	167	3561	28,877
1990	186	3960	32,837
1991	205	4357	37,194
1992	223	4743	41,937
1993	244	5212	47,149
1994	265	5662	52,811
1995	285	6089	58,900
1996	307	6527	65,427
1997	328	6938	72,365
1998	347	7307	79,672
1999	366	7631	87,303
2000	383	7918	95,221

^aData through 1985 are from individualized reactor characteristics at 0.6 plant factor; for years 1986-2000, data are based on 0.7 plant factor (22.4 MT/GW installed capacity per year).

^bIncludes 1656 MT in storage at reactors at end of 1975. An additional 360 MT was stored at NRS and GE; total = 2016 MT.

capability; (2) the extra storage capacity that can be realized by expanding at-reactor spent fuel pools; (3) the decision on whether to allow reprocessing; and (4) the actual date that a federal waste repository will become available. Utilities are currently keeping options open by using fuel pool expansion through densification to provide needed short-term fuel storage capacity. This situation is the subject of a utility survey which formed the basis for ERDA 77-25, which stated, "Utilities and utility serving industry recognize that aggressive actions are required to assure sufficient spent fuel storage, and have identified plans to provide the needed storage."⁽⁵⁾ It should be pointed out, however, that this survey was completed before the federal government made the decision to indefinitely defer domestic nuclear fuel reprocessing. Thus, the need for AFR storage has become more critical after that decision.

The AFR storage presently available or planned for the near future consists of fuel pools at reprocessing plants. The Fuel Receiving and Storage area at the NFS plant in West Valley, N.Y. has at most about 150 MT of capacity remaining. As of September 1977, the storage pool at the General Electric site at Morris, Illinois was 43.7% filled, leaving about 400 MT of unused capacity.⁽⁶⁾ At the AGNS reprocessing plant at Barnwell, S.C. the fuel receiving and storage station, which is completed but not licensed, has a 400 MT capacity.⁽⁷⁾ A facility planned by Exxon to be available in the mid-1980's would have a 3500 MT capacity, with 3500 MT more being added when needed. ⁽⁵⁾

A study of the near-term need for AFR storage capacity was performed by the Nuclear Assurance Corporation and incorporated into ERDA 77-25.⁽⁵⁾ The study was based on the aforementioned survey of

utilities and the demand for AFR storage was considered known. The Barnwell facility was considered unavailable, and three cases were studied:

- 1) Utilities expand their at-reactor storage as planned, General Electric expands its Morris AFR pool to 700 MT (This has been accomplished) and NFS does not receive any further fuel beyond its current inventory (165 tonnes).
- 2) Same as Case 1, but General Electric constructs an additional 1000 MT pool which becomes operational in 1980.
- 3) Same as Case 2, but a planned 3500 MT pool to be built by Exxon becomes available in 1982, with an additional 3500 MT capacity being added as needed.

The study finds that Case 1 develops problems, but not until the mid 1980's; that Case 2 develops the same problems but at a later date; and Case 3 allows all fuel discharged by the year 1986 to be stored somewhere. The findings of ERDA 77-25 for the three cases are depicted graphically in Figures 4-3 and 4-4.

The Nuclear Regulatory Commission also estimated spent fuel storage requirements - until the year 2000 - in NUREG-0404.⁽⁴⁾ Separate estimates were made for the cases of (1) with or without maintaining Full Core Reserve; (2) with or without fuel pool densification; and (3) with or without the use of existing space at one reactor for storing fuel from another reactor whose pool was already filled to capacity. This last "perfect case" would eventually result in all reactors reaching the end of full storage capacity simultaneously. It contrasts with the "at-site-only" case in which fuel could be stored only at the point of generation. No utilities have actively pursued the "perfect case"

Figure 4-3
NUMBER OF REACTORS WITHOUT FULL CORE RESERVE AT
YEAR END (5)

Figure 4-4
NUMBER OF REACTORS REQUIRING ADDITIONAL SPENT
FUEL STORAGE CAPACITY TO PERMIT SCHEDULED
DISCHARGES (5)

option of searching for storage space at other utilities or of offering their own unused space. Thus, this case is not considered further. The relevant result of the NRC study is shown in Table 4-2, which gives the number of reactors which would fill at-reactor storage each year under the four cases considered. Since most utilities are densifying their spent fuel pools, the columns on the right of Table 4-2 are more realistic. They indicate that two reactors (identified in the report as Point Beach 1 and 2) would have filled their at-reactor storage space in 1976 if FCR were maintained, or in 1979 if the whole fuel pool could be used. The next filling of fuel pools would occur four or five years later at reactors scattered across the country, including Maine Yankee and Connecticut Yankee.

It is concluded that several thousand MT of capacity of AFR storage will be required in the 1980's to avert the shutting down of reactors--some of which are in the Northeast--due to lack of spent fuel storage space.

Table 4-2. Number of Reactors Discharging Fuel by 1986 (and combined GWe) Filling AR Storage for Period 1976-2000, "At-Site-Only" Storage Case (PF = 0.6)*

	Without Densification				With Densification ^b			
	Without FCR		With FCR ^a		Without FCR		With FCR	
	Number Reactors	GW	Number Reactors	GW	Number Reactors	GW	Number Reactors	GW
1976	6	3.7	27	17.5			2	1.0
1977	2	0.6	13	9.4				
1978	5	3.0	7	5.0				
1979	9	6.9	8	6.9	2	1.0		
1980	5	2.5	6	5.1			6	4.4
1981	5	4.2	8	7.7			5	3.4
1982	7	5.6	5	4.9			3	1.4
1983	6	4.3	5	5.7			7	4.6
1984	10	8.2	17	17.8	6	4.4	2	1.6
1985	8	7.3	15	15.3	4	3.4	5	4.1
Subtotal	63	46.3	111	97.3	12	8.8	30	20.5
1986	7	6.2	6	6.2	3	1.4	8	6.3
1987	6	5.9	3	3.3	6	4.2	2	1.6
1988	7	7.7			4	2.2	3	2.0
1989	8	9.0			1	0.9	3	2.6
1990	15	15.7			6	4.8	11	9.1
1991	6	6.0			4	3.2	2	1.6
1992	4	3.9			3	2.2	4	4.2
1993	3	3.0			3	2.2	8	7.7
1994	1	1.1			6	5.1	3	3.6
1995					5	4.5	10	10.6
1996					3	2.8	13	14.0
1997					7	6.9	5	5.1
1998					6	6.2	4	3.9
1999					1	1.3	1	1.1
2000					9	8.8	2	2.1
Totals	120	104.8	120	104.8	79	65.5	109	96.1

^aFCR = Full core reserve--the space kept available at reactor storage pools to store the fuel of the active core.

^bTechnique for increasing at-reactor storage, discussed in Chapter 3.

*PF = plant (or capacity) factor.

4.3.3 Existing Storage Capacity at NFS

4.3.3.1 Description of Facility⁽⁸⁾

The Fuel Storage Pool in the Fuel Receiving and Storage (FRS) area is currently operating while the remainder of the reprocessing plant is in a shutdown condition. The rectangular pool measures 75 feet by 40 feet (23 m by 12 m) and is filled with demineralized water to a depth of 29 feet (8.8 m). It sits in the impermeable silty till of the West Valley site. The pool contains 42 rows of aluminum racks, running north-south, each containing about 26 spaces for canister storage. Each of the 1,092 storage spaces can accommodate a 20 inch (0.5 m) outer diameter canister. Rows of canisters are separated by 8 inch (0.2 m) water spaces; canisters within rows are separated by 4 inch (0.1 m) spaces. Each canister could contain one PWR or two BWR fuel assemblies, although the current license allows only one assembly--of either type--per canister. Presently, the pool's stated design capacity is 489 tonnes. 756 pool spaces are occupied by 165 MT of fuel, some of which is in smaller assemblies from older reactors. Most of these assemblies are owned by utilities; Nuclear Fuel Services (NFS) owns about 24 MT of fuel in the pool.⁽⁹⁾ There are over 300 spaces remaining for fuel storage. These could accommodate nearly 150 MT of spent PWR fuel assemblies, or 60 MT of BWR assemblies.

Spent fuel is received at the FRS in heavy, shielded casks transported either by truck or train. Casks are removed using a Cask Handling Crane, a 100-ton crane with two 5-ton auxiliary hoists. This crane extends over the Cask Unloading Pool (CUP). During decontamination the external cask surface is washed by high pressure water sprays. The cask decontamination area drains to the Low Level Waste Treatment (LLWT)

system. After checking the cask's temperature and pressure and sampling its coolant, the cask is lowered into the CUP.

The CUP is 26 feet by 24 feet (7.9 m by 7.3 m) and is filled with demineralized water. A 29 feet deep (8.8 m) shelf is used for placing the cask into a shroud which prevents contact between the cask and contaminated pool water. The shrouded cask is lowered into a 44 feet deep (13.4 m) section of the CUP for lid removal and transferral of fuel assemblies to pool canisters.

The CUP is provided with several safety features. It is lined with stainless steel and the gap between the liner and the concrete wall is monitored for leaks. Any leak will be fed back to the pool by a collection-return system. A water-tight gate is available to segregate the CUP from the fuel storage pool if a cask containing contaminated coolant must be unloaded. In such a case the CUP water can be directly recirculated through the water treatment system. The Cask Handling Crane cannot be moved over the fuel storage pool. Fuel assemblies are transferred from cask to canister using a 1-ton Fuel Transfer Hoist. The canisters sit in a Canister Lift Rack, installed on the west wall of the CUP, which is raised to the 29-foot depth for transfer of the canisters to the storage pool. Each canister is moved individually within the storage pool by the Fuel Pool Canister Crane, a 2-ton capacity movable bridge. The Canister Lift Rack, The Fuel Transfer Crane, and the Fuel Pool Canister Crane have mechanical stops which prevent the raising of a fuel assembly above a minimum safe depth of 11 feet (3.4 m).

Water from the pool circulates through a 500 gpm (1900 l/min) filter which utilizes replaceable media and a 100 gpm (380 l/min) non-regenerable ion exchanger. This system maintains the activity in the pool at or below $5 \times 10^{-3} \mu\text{Ci/ml}$.

In 1971 a Low Level Waste Treatment (LLWT) plant was constructed to lower cesium and strontium levels in liquid effluents. The plant typically removes 96% of cesium and 99% of strontium from the liquid wastes. It operates similarly to a municipal water treatment plant in that it uses flocculation, clarification, filtration and ion-exchange processes. During flocculation sodium hydroxide, ferrous sulfate and clay are added to the waste water. A gelatinous precipitate of ferric hydroxide is formed which absorbs precipitated calcium and magnesium, as well as strontium and cesium. This solid material settles out in the clarifier as a sludge, while clear water overflows from the top. The sludge is removed, solidified and buried, while the clarified water is filtered through a bed of anthracite coal. The water next passes through an anion exchange filter containing a strontium-cesium-selective resin. After adjusting the pH of the water to meet New York State water quality standards, the water is released. Backwash water is returned to the head end of the plant.

The gaseous radioactivity levels around the pool are controlled by the FRS ventilation system. It was designed to minimize the concentrations of radioactivity in the building air and to maintain a dry bulb temperature of 80°F (27°C) and a relative humidity of 80%. The ventilation system provides nine air changes per hour above the pool area, taking air from the north side of the pool and distributing it along the south side. The filtration system contains prefilters and HEPA filters with a rated efficiency of $\geq 99.95\%$ (based on 0.3 μm particle diameter). The prefilters collect the larger particles and are changed according to dust loadings. The air activity in the FRS is monitored continuously; alarms are sounded

at an equivalent personnel exposure of 5 MPC hours. In the event of filter failure or significant release of activity, the FRS is evacuated. The cask decontamination area is separately ventilated by a $400 \text{ ft}^3/\text{min}$ (190 l/sec) flow of air to the Building Ventilation air washer.

The pool cooling system was modified as a first stage of the plant modification. Two 1200 gpm (4500 l/min) pumps and two evaporative coolers were installed for a total cooling capacity of 12 million BTU/hr (3.5 MW). The pumps are located and controlled so that they will be automatically shutdown if the pool water level drops more than 6 inches (0.15 m) below the normal level. If this interlock fails, the pump suction will be uncovered when the water level drops to 2 feet (0.6 m) below normal level, thereby preventing the inadvertant uncovering of the fuel.

One of the three cooling towers on the West Valley site is dedicated to fuel pool cooling. The fuel pool water circulates through heat exchangers, which are water-to-water, single pass, shell-multipass tube, U-tube type units. The secondary loop cooling water flows through the FRS cooling tower. The maximum evaporation rate of 37,400 gal/day ($142,000 \text{ l/day}$) dissipates heat at the rate of $12 \times 10^6 \text{ BTU/hr}$ (3.5 MW). Due to the unused capacity and the age of the fuel currently being stored, the cooling plant currently dissipates about $1 \times 10^6 \text{ BTU/hr}$ (0.3 MW). The FRS cooling tower represents a small fraction of plant cooling capability. The main plant cooling tower can dissipate $62.5 \times 10^6 \text{ BTU/hr}$ (40.4 MW). It should be noted that this is less than 2% of the heat dissipated by a 1,000 MWe nuclear plant, and the present heat load of the FRS area is less than 1% of the total heat load capacity.

4.3.3.2 Impacts of Using Existing Storage Capacity

Nuclear Fuel Services has ceased receiving spent fuel for storage at the West Valley site. The FRS area is, however, only 70% filled, and capacity exists for an additional 60 MT of BWR fuel or 150 MT of PWR assemblies. It has been demonstrated that a need for additional AFR storage will exist in the next decade. The use of the existing space at West Valley could fill part of that need, although capacity for 150 MT will probably not be sufficient to greatly relieve the demand for space in the 1980's. As already demonstrated, national demand for AFR space through 1986 will only be met with the addition of several thousand MT of capacity. Since the FRS area is currently in use, the impacts of continued use, to include filling the pool, can be easily ascertained. Economically, the NFS operation at West Valley employs 50 people. Only 12 of these actually operate and maintain the spent fuel and associated equipment; the remainder are maintenance personnel for the rest of the reprocessing plant, security personnel, and plant management. It is anticipated that no additional personnel would be required to maintain additional amounts of fuel. NFS management at West Valley has estimated that a fuel receipt rate of one cask per day could be handled with the present personnel, but that a faster rate would require more handlers and operators.⁽¹⁰⁾ The cost of storing spent fuel at West Valley is difficult to determine from present contractual arrangements, since the fuel now being stored is part of reprocessing contracts. NFS maintains that its fuel storage service is partially an obligation to the utilities which had shipped the fuel to West Valley with the expectation that it would be reprocessed. Hence its charges would not represent a

true storage fee based upon actual costs of storage.⁽⁹⁾

The environmental impacts can be predicted from past experience in storing spent fuel at West Valley and in other places. A recent comprehensive survey of the experience in storing reactor fuel elements in water filled storage pools ⁽¹¹⁾ gives an excellent overview of the situation. The survey involved contacts to a representative cross section of the nuclear industry with interests or direct involvement in pool storage of nuclear fuel. Discussions with and visits to various organizations within the U.S. and Canada having experience in this area were held. The survey considered a number of relevant factors including:

1. Pool size, capacity, and date placed in service.
2. Pool water chemistry and control procedures.
3. Radioactive species and their concentration in pool water.
4. Characteristics of stored fuel including type of cladding, maximum burn-up, and residence time in reactor.
5. Fuel pool storage experience, including storage experience for fuel which failed in reactor and fuel damaged during pool handling operations.

The majority of the fuel in storage is zircalloy clad type similar to the LWR fuel currently being used in the United States power reactors. Only three reactors currently use stainless steel clad fuel and the lesser storage experience with this fuel reflects this.

Fuel storage pools are relatively simple facilities which are quite straight forward to design and relatively simple to operate. Most of the pools currently in operation use a relatively simple system for maintaining pool water chemistry consisting of ion exchange resins for removal of dissolved materials and some type of filtration system for

removing of particulate material. These elements are placed on a continuous "kidney" loop which continually purifies a sidestream of water and returns it to the pool. Most of the pools maintain the water pH in the range from 5.5 to 9.5. Pool water chemistry control is simplified by the fact that pools usually have a austenitic stainless steel liner.

There is also a heat removal system which operates by removing a sidestream of water and passing it to an intermediate heat exchanger which subsequently transfers heat to a final heat removal system (heat sink).

Fuel has been stored in pools for periods up to 18 years and to date, the experience with the zircalloy clad LWR fuels is such that corrosion rates have been found to be too slow to measure. All evidence suggests that storage of the spent reactor fuel in pools is clearly very viable for times up to 100 years, from the standpoint of cladding deterioration by a variety of postulated mechanisms. This is in large part due to the fact that fuel is designed to withstand an environment within a reactor core for a period of 3-4 years that is very much more severe than the conditions encountered in a fuel storage pool. In addition to the much lower temperatures, the internal pressurization of the fuel is only a few hundred psi or less when in the fuel storage pool, resulting in cladding material stresses a fraction of those encountered within the reactor core. Accordingly, any leakage, resulting in release of gaseous fission products, has already occurred prior to the time the fuel is received at a fuel storage pool, particularly for fuel which has been out of the reactor for six months or more. Because of this, there are very few leaks encountered in the stored fuel, save an occasional accident where in the fuel bundle is dropped.

The experience outlined and summarized in (13) bears this out in that the primary fission products detected in the fuel pools are Cs-134, Cs-137 and, to a lesser extent, Sr-90. In addition there are corrosion activation products from the primary reactor cooling circuit adhering to the clad, including cobalt 60 and various isotopes of magnesium, iron and nickel. Generally speaking, it is found that Cs isotopes account for 99% of the gamma activity. Gaseous radioisotopes are a minor or non-existent contribution to radioactivity release from spent fuel once it is placed in storage in a pool.

In summary, it appears safe to say that there is sufficient experience with storage of zircalloy clad LWR fuel to form a sound judgement that this material can be stored in fuel storage pools like that currently being operated at NFS for periods up to 100 years with no particular problems. Furthermore, it can be anticipated that as longer time periods of experience are accumulated this storage period may be extended further beyond 100 years.

The quiescent nature of the fuel stored in the FRS area at West Valley has kept environmental impacts at low levels. A discussion of these levels is contained in a recent NRC Safety Evaluation Report for the reduced operations at the West Valley site (12). The radioactivity of the pool itself has averaged about $1 \times 10^{-3} \mu\text{Ci/ml}$, following its emptying and cleaning in late 1971 after reprocessing activities ended. The radiation level above the pool varies from 2 to 5 mr/hr at a height of about 1 foot above the water level. The higher rates are found at the edge of the pool, probably because of the "bathtub ring" effect. Solid wastes are composed of resins and filters from the pool water cleanup system and the filters from the ventilation system. The concentrations

of radionuclides in Cattaraugus Creek during the last available environmental report period (July-December 1976) averaged 1.7% of MPC, with the maximum and minimum observations being 3.0% and 0.4% of MPC, respectively. The principal radionuclides present were ^3H (1.0% of MPC) and ^{90}Sr (0.6% of MPC). (14)

Other effluents produced by the fuel storage operation include engine exhausts and waste treatment system discharges. An increase in the number of assemblies stored in the FRS area should not affect the levels of these non-radiological effluents. These levels are low and well within the capability of existing treatment facilities or effluent release standards. The water evaporated by the cooling towers has an undetectable effect on the humidity at the West Valley site boundary. There may be an occasional local fog or mist in the immediate area of the cooling towers under certain weather conditions, but these effects should be completely dispersed before reaching the site boundary. This assessment is for the plant operating as reprocessing center at full capacity. The effects of thermal effluents from the fuel storage pool alone would be much less than those described above.

There have been no detectable releases of radioactive noble gases in the last reporting periods for which reports are available. It is anticipated that receipt of more spent fuel for storage could result in such releases during cask venting. In the last available reporting period (14) the gaseous activities released from the plant stack have been below 1% of the Technical Specification limits (which are set at $0.1 \mu\text{Ci/sec}$).

4.3.4 Expansion of Pool Capacity

4.3.4.1 Compact Storage

The FRS area is designed to store a maximum of 489 MT of spent fuel. This is distributed by the current storage design over the floor of the pool, an area of 3000 ft² (280 m²). The storage "density" is thus only 0.163 MT/ft². The same techniques used in reactor spent fuel pools to expand storage capacity by using more compact storage racks could be employed at West Valley to increase the capacity of the pool without expanding the pool itself. This "compact storage" option could add as much as 1000 MT of additional capacity. One manufacturer of racks for spent fuel pools reported (13) that, using current designs and neutron absorbing materials (Boral or borated stainless steel), the storage densities shown in Table 4-3 have been achieved.

Table 4-3 Obtainable Storage Densities

Metric tons of fuel/foot²

Type of Assembly	W/O Absorber	W/Absorber
BWR	0.512	0.656
PWR	0.366	0.535

It would appear that expansion of the NFS fuel storage pool would be feasible, and indeed NFS management has studied several expansion options. The simplest is described in a proposal submitted to NRC in August 1975. ⁽⁹⁾ By closing up the inter canister spacing within rows and flattening the circular canisters to squeeze them together, a densification factor of 1.66 was to be obtained. This would increase the storage density to 0.270 MT/ft², still much less than the densities shown in Table 4-3. A second expansion option, using the existing pool, envisioned replacing the present racks with poisoned racks. Storage densities of 2.5 to 3 times the current density (0.408 to 0.489 MT/ft²) could be realized with this scheme. If a storage density of 0.5 MT/ft² were obtained, an additional 1000 MT of spent fuel could be stored at West Valley.

High density fuel storage racks are available from several manufacturers. The installation procedure would probably use techniques similar to those utilized in the recent capacity expansion of the fuel storage pool at General Electric's Morris operation. ⁽¹⁵⁾ Just as in the FRS area at West Valley spent fuel was already being stored at Morris. The fuel bundles were placed in one section of the pool. The new racks were installed in three sections using remote techniques of placement and joining. After the first section was installed, the fuel on hand was transferred to the

new racks and the old racks were removed from the remaining two sections, cleaned up and cut up for disposal. The new racks were installed in their place to complete the first phase of the reracking. A second phase consisted of moving all the fuel bundles out of the #1 basin (the Morris pool is divided into two parts, one small pool originally intended for spent fuel storage and a second larger basin for high level waste canister storage which was converted to fuel bundle storage in this operation), removing the old racks and replacing them with the new, higher density racks. The entire reracking operation required only a few workers. All installation was accomplished remotely from above the pool, thus avoiding problems of exposures to radiation. The operation took several months to complete, with a two month delay between phases one and two.

A number of benefits would result from increasing the storage capacity at West Valley through compaction. First, the nearly 1000 MT of additional capacity would be a more efficient use of the FRS pool space. The larger amount of fuel could probably be accommodated without improving or adding to the existing pool equipment, which is oversized for the present load. Reracking the existing pool would also provide the quickest additional AFR spent fuel storage, and this may also be the cheapest alternative although the actual cost of reracking and of fuel receipt and storage is not available. These costs would be similar to those incurred by General Electric in the Morris expansion. No additional manpower would be required for fuel receipt and pool operation. Finally, while an increase in the thermal energy generated and radioactive materials released by the fuel is expected, it should certainly be within the capacity of the cooling and cleanup systems to bring to acceptable levels.

4.3.4.2 Construction of a New Storage Pool

Additional spent fuel storage capacity could be realized through the construction of another pool adjacent to the present FRS area. Essentially this would be a compromise between using the existing pool and building a completely independent pool. The advantage of a pool addition is that some of the available equipment, notably the fuel handling equipment and perhaps the water cooling system could be used for the added pool, resulting in some savings. It has been estimated that the present utilities (pool cooling, water treatment, ventilation, steam supply) could handle another 3000 MT capacity storage pool. (17) Other benefits accrue from using the West Valley site for fuel storage in general: (1) The large West Valley site is already dedicated to nuclear use; (2) The site contains a low level radioactive waste burial site; (3) Roads and rail spurs are already in place; (4) Experienced management and technicians are on hand; and (5) The site is centrally located with respect to Northeast, Eastern and Midwest nuclear power plants.

The construction of an adjacent pool could be accomplished without disturbing the old pool until the final operation--the joining of the pools by tearing a gate from the new pool to the old pool. (The fuel pool at the Morris plant is already equipped with such a gate to facilitate this sort of expansion). The new pool would be constructed to the latest standards. In particular, the pool would be modularized, consisting of a number of 500 MT pools each of which could be segregated in an emergency. Any additional utilities could be located in the building over the new pool.

One source of problems for such a pool could be licensing. A facility designed and constructed at the West Valley site for the storage

of spent fuel would be licensed under the provisions of 10 CFR Parts 30, 40 and 70. Review of the design and construction would follow 10 CFR 70, since compliance with this regulation would automatically satisfy the requirements for a license under 10 CFR Parts 30 and 40. This would subject the design and construction to siting and licensing procedures similar to those followed for other nuclear facilities. The siting process would be accelerated by use of the West Valley site. The licensing procedure may find difficulties in the area of seismic design, however. The FRS area has been shown to be capable of withstanding earthquake induced stresses up to those produced by horizontal ground accelerations of 0.12g. ⁽⁹⁾ Part of the difficulties which halted the planned modification of the facility after 1972 was the contention by the NRC that this design earthquake was not sufficiently severe for the seismic region surrounding West Valley, and an increased acceleration for the design earthquake of 0.20g was determined. ⁽¹²⁾ Even though the new pool would be designed to meet this stricter criterion, it is difficult to assess the licensing problems resulting from continued or increased use of the old pool. Licensing could conceivably be held up indefinitely for safety reasons.

No radiation exposures would be expected during construction of the new pool. After joining with the old pool, the radiation levels above the pool would approach the levels of the old pool as fuel is placed in the new pool. The costs of constructing the new pool cannot be assessed. Use of existing equipment would probably result in a significant savings, but licensing delays may increase the ultimate cost.

An alternative to building a new pool would be the use of the now inactive processing cells of the reprocessing plant to provide dry storage with convective air cooling for older (1 year or more out of

reactor) spent fuel. The Chemical Processing Cell (CPC) in particular could be stripped of equipment and racks capable of containing 12 PWR or 16 BWR assemblies could be hung up to provide space for up to 3000 MT of fuel. (17) The disadvantage here is the loss of the CPC from other activities, such as research on the high level wastes present at the West Valley site or use of the reprocessing plant for its intended purpose. This alternative would, however, serve the purpose of demonstrating the dry storage method.

4.3.4.3 Construction of an Independent Spent Fuel Storage Installation

As a final alternative for the use of the West Valley site as an AFR spent fuel storage location, we consider the construction at the site of an Independent Spent Fuel Storage Installation (ISFSI). Although this alternative would make use of the site and thereby realize the previously mentioned site related advantages, its drawback would be the failure to use the existing and somewhat oversized equipment which supports the FRS area. Some site facilities, like the Low Level Waste Treatment system could be used for the ISFSI.

An ISFSI constructed at the West Valley site would probably resemble the design described in a recent topical report from the Stone and Webster Engineering Corporation.⁽¹⁸⁾ The design is for an ISFSI with a storage capacity of approximately 1300 MT of BWR or PWR fuel. This would accommodate spent fuel from approximately seven 1000 MWe nuclear power plants for up to ten years. The facility is designed for use at an existing nuclear power or processing plant site. The general arrangement and method of operation are nearly identical to that for the FRS area. Seismic design, waste management systems, accident analysis and radiation protection are among the topics receiving the most careful attention in the report. The auxiliary systems which are described in detail include:

1. The fuel pool cooling system
2. The fuel pool purification system
3. The facility cooling water system
4. The service air system
5. The air-conditioning and ventilation systems
6. The fire protection system

An ISFSI at West Valley would be designed to meet the standards set down in ANSI N305-1975, "Design Objectives for Highly Radioactive Solid Material Handling and Storage Facilities in a Reprocessing Plant." NRC Regulatory Guide 3.24, which provides guidance for the license application, siting, design, and plant protection of an ISFSI, specifically calls for application of standard N305, with a number of additional requirements:

1. Cask handling cranes should not pass over the fuel storage pool.
2. The ISFSI building need not be designed to withstand high winds.
3. The design of the ventilation system should include an emergency air cleanup system to accomodate ruptured fuel.
4. The heat removal system should be protected from credible accidents and have a backup power supply.
5. Onsite radioactive waste treatment facilities should be provided.
6. Provisions should be made for expected cask maintenance, repair, and modifications, as well as for receipt of casks which have suffered loss of coolant.
7. A cask drop analysis should be made.
8. The fuel storage pools should be modular in design, each module having a capacity of about 500 tonnes of spent fuel.

The license application for an ISFSI at West Valley would include a safety analysis report similar in scope and detail to the report required for a fuel reprocessing plant. Also required would be an Environmental Report and a physical protection plan outlining the methods to be employed to meet the requirements of 10 CFR 73.50.

The regulatory requirements for AFR spent fuel storage are currently being reviewed. It is generally acknowledged that some improvements must be made to account for the new interest in providing AFR storage for the sole purpose of fuel storage. The benign nature of the spent fuel may allow some easing of the regulatory requirements. A new standard N-305 is being written by a committee of the American Nuclear Society. Also, the NRC is developing new regulations, to be published as a draft 10 CFR Part 72, to cover spent fuel storage. The state of regulation of spent fuel storage is currently changing, in directions that are not yet clear.

The cost of constructing an ISFSI at West Valley is a difficult quantity to analyze. There are a number of interacting variables:

- (1) Size of the facility
- (2) Plan for loading and storage duration
- (3) Use of existing facilities and utilities
- (4) Participation by power companies
- (5) Participation by federal government
- (6) Regulatory requirements
- (7) Plant investment
- (8) Operating costs

General Electric has performed scoping calculations on an ISFSI of several thousand tonnes capacity.⁽¹⁹⁾ The costs were found to depend strongly on financing assumptions, the period of utilization of the facility, and the pattern of loading and unloading. The range of \$6000 to \$10,000 (1975 dollars) per tonne per year bracketed the results and a cost of \$7,000 per year per tonne stored was determined as most appropriate. This was only for the case, however, where utilities provided long-term storage commitments or front end money. Purely commercial storage rates

were expected to be substantially higher. The investment required is estimated to range from \$20-\$30 million for a 1000 tonne facility and from \$30-\$40 million for a 2000 tonne facility, while the annual operating costs for a 1000 tonne unit will be about \$1.3 million.⁽¹⁾ These figures contrast with the cost of \$54 million for a 1000 tonne unit estimated by a utility and the \$200 million figure quoted for storage at government sites.⁽³⁾

The parameters expected to influence the radiological and non-radiological impacts of an ISFSI constructed at West Valley include:

- 1) Capacity of chosen design.
- 2) Type of facility selected.
- 3) Protective processes, such as overpacking for dry storage.
- 4) Design and capacity of ventilation, water treatment, cask decontamination and other protective systems.
- 5) Operational assumptions such as leaker rates and behavior, postulated accidents, and release factors for various radionuclides in various situations.

Some indication of the environmental effects of an expanded fuel storage capacity at West Valley can be obtained from the Draft Environment Statement related to the operation of the Barnwell Fuel Receiving and Storage Station (BFRSS).⁽²⁰⁾ In this document, the BFRSS is treated separately from the adjacent reprocessing plant; hence, the environmental effects described therein can be directly attributed to the fuel receipt and storage functions. Similar effects should be realized at such a facility constructed at West Valley, with appropriate scaling to account for the difference in capacities (The BFRSS has a capacity of only 400 tonnes of fuel).

Land use for BFRSS presents few problems, since it is built on a large site already dedicated to nuclear service. There should be very small impact of plant operations on offsite environs and land use. Also, no adverse impacts can be attributed to the use of groundwater (at a rate of 0.83cfs, . to the low runoff to surface waters (0.68 cfs).

The radiological impacts were estimated, based upon many parameters - some site specific - and the releases of radionuclides expected from BFRSS. Estimates of these releases are summarized in Table 4-4.

Table 4-4 Estimated Releases of Radionuclides
from the BFRSS (Curies/Year)

Nuclide	Cask Venting	Storage Pool	Total
K4-85	5530	5230	10,760
H-3	214	203	417
I-129	5.78×10^{-5}	5.78×10^{-5}	1.16×10^{-4}
I-131	8.06×10^{-4}	6.14×10^{-5}	8.67×10^{-4}

These releases, which resulted from normal operation and postulated accidents, were used to estimate the annual radiation doses to workers at the plant and to the surrounding population. A summary of these doses is presented in Table 4-5.

Table 4-5 Summary of Annual Doses to the Population
within 50 Miles of the BFRSS

Category	Cumulative Dose, man-rem/yr
Population dose from background	153,000
Restricted Area	
Occupational radiation exposure	54
Unrestricted Area	
Transportation of fuel and wastes	58

Gaseous cloud	35
Ingestion	0.01
Recreation	0.01

Nonradiological impacts include soil erosion during construction, evaporation and drift from the cooling tower, and effluent from the sanitary waste treatment system. None of these were deemed unmanageable. Also, the socioeconomic costs on local residents were found to be acceptable. Thus, the BFRSS operation, as outlined, could be accomplished with acceptable impacts on the environment, indicating that this would also be the situation for a similar plant to be constructed at the West Valley site.

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