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ECONOMICS OF SPENT LWR FUEL STORAGE

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A power reactor operator, confronted with rising spent fuel inventories that would soon exceed his storage capacity, has to decide what to do with this fuel if he wants to continue reactor operations. A low cost option would be to ship excess fuel from the overburdened reactor to another reactor in the utility's system that has available space. The only cost would be for cask leasing and shipping. Three other alternatives all require considerable capital expenditures: reracking, new at-reactor (AR) basins for storage, and away-from-reactor (AFR) basins for storage.

Fuel storage requirements will be met best by transfer of fuel or by reracking existing reactor basins whenever these options are available. These alternatives represent not only the lowest cost storage options but also the most timely Fuel can be shipped to other storage pools for about $10/kg depending on the distance while costs for reracking range from $18 to 25/kg depending on the approach. These alternatives are recognized to face environmental and regulatory obstacles. However, such obstacles should be less severe than similar issues that would be encountered with AR or AFR basin storage.

When storage requirements cannot be met by the first two options, the next least costly alternative for most utilities will be use of a Federal AFR. Storage cost of about $140/kg at an AFR are less costly than charges of up to $320/kg that could be incurred by the use of AR basins. AR basins are practical only when a utility requires storage capacity to accomodate annual additions of 100 MT or more of spent fuel. The large reactor complexes discharging this much fuel are not currently those that require relief from fuel storage problems. This paper compares cost of reracking, AFR storage, and AR storage.

At-Reactor Reracking

Most racks used in water storage of spent power reactor fuel are open frames of steel or aluminum. These racks separate assemblies from boiling water reactors (BWR) 10 to 13 inches between centers and assemblies from pressurized water reactors (PWR) 18 to 22 inches. Such arrays result in a storage density of somewhat less than 0.25 metric ton uranium per square foot (MTU/ft^2) and prevent a critical incident even with unirradiated fuel (no ^{235}U burnup) in the rack. Fuel can be stored in a tighter array if the racks contain more stainless steel or other neutron poisons such as boron.

Stainless steel racks have been designed that can store BWR fuel at 8 inches between centers (storage density of 0.47 units) and PWR fuel at 13 inches (0.39 MTU/ft^2). Studies by the Nuclear Assurance Corporation showed that these racks would cost $4800/MTU for PWR fuel and $5800/MTU for BWR fuel.[1] Stainless steel racks poisoned with boron can store fuel 6.5 inches (BWR) and 10.5 inches (PWR) between centers to achieve densities of 0.58 and 0.52 MTU/ft^2 respectively The study estimated costs at $5800/MTU for boron-poisoned PWR racks and $7200/MTU for boron-poisoned BWR racks.[1] For a typical reactor basin, an additional $1.5 million should be anticipated for installation costs.

At-Reactor Basins

New AR basins are attractive because they eliminate an extra shipment of fuel with its accompanying environmental, political, and cost impacts. Because AR basins can be designed for a known quantity of a specific fuel, they can be optimized to an extent not available to the AFR basins, which must accept fuel of many designs and different burnups shipped in different types of rail and truck casks. AR basins also allow maximum use of facilities already provided for the reactor.

The AR basins also have distinct disadvantages in that they must in a sense be overdesigned. All storage basins must provide for fuel handling equipment including heavy transfer casks and large cranes for cask handling. The minimum handling capacity of this equipment is about 150 MTU/yr, which is far in excess of annual needs of a single reactor.

No historical data for at-reactor storage basins are available; however several cost estimates for such basins have been generated.[2] The following formula has been developed from these cost estimates:

$$C = 25 + 25\left(\frac{S}{1000}\right)^{0.75}$$

Where

C = capital cost in millions (1979 dollars)

S = storage capacity, MTU

This formula produces a cost of $50 M for a 1000 MTU facility. The 1000 MTU basin represents the condition where basin costs are about equally split between fixed and variable costs. Enlarging or reducing storage capacity would impact on only one half of the facility cost. The variable cost fraction is proportional to the 0.75 power of the storage capacity. This formula is useful for estimating AR basin costs over the range of sizes that would be anticipated.

Once a decision has been made to build an AR basin, prudent business management would dictate that the capacity of the basin be sufficiently large to provide many years of spent fuel storage. We assume that twenty-years capacity is provided for AR basins. This assumption provides the basis for the economic comparison of AR vs AFR storage shown in the table.

Away-From-Reactor Basins

The Engineering Department of the Du Pont Company designed a stand-alone basin for spent LWR fuel.[3] A preliminary fee for AFR storage of spent fuel was developed based on the Du Pont cost estimate.[4] The fee was developed to ensure that those utility customers who benefit from the use of nuclear power would pay the full cost of storage and disposal. Although the fee ($232/kg) was developed for both storage and disposal, those portions that applied to the use of an AFR could be defined separately so that only those customers that used the AFR would be subject to its costs. In the preliminary fee calculation, the AFR storage cost was $104/kg and the cost for transfer to a repository was $26/kg. These values taken together ($130/kg) represent the incremental additional cost required for use of the Federal AFR. Updating these values to 1979 dollars produces a storage fee of about $140/kg. The spent fuel storage and disposal fee is currently being recalculated to assess more recent fuel flow and cost data.

Cost Comparisons

To provide comparable information for reracking and AR storage with AFR storage, it is necessary to develop the cost to the utility customer for these services. To convert capital expenditures to an annual charge, utilities typically apply a fixed charge to the rate base. For relatively low risk industries like utilities, a fixed charge rate (FCR) of 15% is common. The total annual cost for storage includes an operating charge in addition to the fixed charge. A review of currently available data shows that the operating cost is about 5% of the capital investment. Together, the fixed charge and operating cost yield an annual charge to the customer of 20% of the invested capital. The unit cost to the customer for AR storage is the annual charge divided by the quantity of fuel stored, which otherwise would be shipped to the AFR facility.

The table shows the results of this computation. For those utilities that have small annual storage requirements, the unit cost (as charged to the customers) is much higher than the AFR charge of $140. However, because large AR basins can be built at lower unit costs than small AR basins, there is a crossover point where AR storage can compete economically with AFR storage. This unit cost is reached for a utility that has about 100 MT/yr spent fuel requiring storage. Such a large annual need will exist only for multiple reactor complexes of 3000 MWe or more. All near term requirements are for sites with one, two, or three small reactors who could not provide storage for their customers less expensively than the Federal AFR.

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LWR Spent Fuel Storage Charges, 1979 dollars

Mode	Storage Requirement, MTU/yr	Basin Capacity, MTU	Capital Cost $ millions	Capital Cost $/kg	Annual Cost* $ millions	Unit Cost, $/kg
Reracking 1**	25	400	3.0	7.5	0.45	18
Reracking 2**	25	520	4.1	7.9	0.62	25
AR						
1 Reactor	25	500	40	80	8.0	320
2 Reactors	56	1100	52	47	10.4	186
3 Reactors	96	1900	66	35	13.2	138
AFR						140†

* 15% fixed charge rate, 5% annual (operating cost not applicable to reracking).

** Each option assumes reracking of a 200 MTU basin. Option 1 reracks with stainless steel; Option 2 reracks with stainless steel containing boron.

† Published value is $130/kg in 1978 dollars.

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4. Preliminary Estimates of the Charge for Spent Fuel Storage and Disposal Services, DOE/ET-0055, U.S. Dept. of Energy, (July 1978).