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SPENT FUEL STORAGE CAPACITY IN NEW REACTORS

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INTRODUCTION

This report is an analysis of the considerations that would enter into a utility's decision on the capacity of the spent fuel storage facilities to be constructed in a new power reactor. Capacities varying from limited to lifetime reactor discharge were assessed along with their advantages and disadvantages. The financial risk to the utility, if government policy on spent fuel changes, was evaluated, and the option most utilities would select was estimated.

SUMMARY

The standard spent fuel storage pools of the U.S. power reactors currently under construction are sized at about 1000 ft^2 and 1225 ft^2 for BWR and PWR respectively. These basins, when equipped with SS racks, will contain 11 and 13 years[1] fuel discharge respectively, each with full core reserve. With densification by fuel pin disassembly and reassembly into light SS cans, their capacity can be increased to 19 and 27 years respectively.

With moderately expanded basin size, estimated to cost $3.0 and $1.6 million, and with boron SS basin racks, estimated to cost $2.5 and $1.0 million for BWR and PWR respectively, the basin capacities could be expanded to handle 20 years of reactor discharge. With fuel rod reassembly, the capacity of these basins would increase to 40 years or full reactor lifetime discharge.

Utilities will move toward these moderately expanded size basins.

DISCUSSION

The choice of the spent fuel storage capacity to be installed at a new power reactor facility depends on a variety of factors. The factors, technical considerations, costs, safety, and political considerations are discussed in the first section below. After these factors are discussed, the actions on spent fuel storage utilities might take are addressed. This section includes alternative basin capacities, advantages, and disadvantages of the alternatives and the financial risk. The final section evaluates the option a utility might select.

Technical Considerations

Basin Capacity

Basins in existing power reactors have been constructed to contain only a limited amount of spent fuel. These basins typically have an area of ~1000 ft^2 (BWRs) and ~1225 ft^2 (PWRs). Replacement of the original aluminum racks with stainless steel storage racks allows spent fuel assemblies to be packed more closely than the originally designed lattice pitches and provides storage capacity for a little over ten years of reactor discharges - as shown in Figure 1a.[a] The use of stainless steel with boron allows an even tighter lattice pitch and will add 3-5 years of additional discharges - Figure 1a.

A further possibility is the disassembly of the fuel rods and insertion in light SS cans which will allow an additional 5-8 years storage of spent fuel - Figure 1a.

Finally the basin size can be increased. If the basins in a new reactor are made about half again larger than standard they can store the reactor's lifetime (~40 years) supply of spent fuel - with reassembly - as shown in Figure 1b. Basins a little over twice the original size are needed to store the lifetime supply of spent fuel in boron stainless steel racks without reassembly of the fuel - Figure 1c.

Other Factors

To be able to take advantage of the possibilities for increased spent fuel storage densification, basin design in new reactors should have strength allowance for the maximum fuel load that could be inserted. Seismic restraints, cooling capacity, and water cleanup facilities must also be sized to handle the largest possible spent fuel loadings.

Costs

Increased Basin Size Costs

The costs for increasing a basin size at a new reactor are based on previous studies[1,2,3] and are taken as $5000/$ft^2$ in FY-80 dollars (Table 3). For PWR fuel stored at 0.39 MT/ft^2 in SS racks, this is equivalent to $12,800 per MT of storage capacity. These costs include additional seismic bracing and extra cooling and water cleanup facility costs.

The operating costs for larger basins are considered to be about equivalent to those for small basins. The extra cooling and cleanup costs for larger basins should be roughly compensated for by the extra fuel handling costs that are avoided.

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[a]The curves in Figure 1 show the cumulative fuel discharged as a function of operating time. The intercept on the ordinate indicates a reserve for full core emergency discharge. The points superimposed on the curves indicate basin capacities for various storage methods. Information used to generate Figure 1 is included in Tables 1 and 2.

Storage Rack Costs

A detailed study[4] was made by the Nuclear Assurance Corporation of the cost of fuel storage racks. The results in FY-80 dollars are given in Table 3.

Costs for Reassembly of Fuel Rods

If the fuel elements are disassembled and reassembled in a close-packed lattice inside thin SS cans, more fuel may be stored in the racks. This is because an undermoderated array is formed which has a considerably lower multiplication factor. The BWR fuel rods are bolted in the fuel elements while most of the PWR rods are welded in place. A disassembly-reassembly cost of \$3600/MT was estimated by the Nuclear Assurance Corporation for both types of fuel.

Outside Power Costs

If a reactor is shut down because of the lack of spent fuel storage, the costs for the purchase of substitute power can be in the \$200,000 to \$400,000 per day range. At a 70% capacity factor that amounts to \$50 to \$100 million per year.

AFR Fee

The value of the government fee for the storage of fuel in an AFR is being recomputed but it appears that it will range from \$100/kg to \$150/kg with the higher value the more likely.

Safety

Criticality

There has never been an inadvertent criticality accident in a fuel storage basin. Fuel storage at reactors should be no more likely to have a criticality accident than fuel in AFR storage.

However, the fuel reassembly operations, if carried out, add an extra fuel handling step and thus a slightly higher possibility of an error leading to a criticality incident.

Heat Removal

The heat removal requirements in a reactor lifetime storage basin are larger than in a standard basin. Also the heatup following a loss of water[5] would be quicker if the fuel is compacted by re-assembly.

Radioactive Hazard

The total radioactive hazard from ingestion has been computed for both normal ($\sim$10 years) and lifetime storage pools.[6] The lifetime facility has an increase in hazard by about a factor of two.

Reassembly of fuel rods because of the extra handling would increase the possibility of spread of contaminants.

Political Considerations

U. S. Government

A number of actions, and the timing of these actions, by the Federal government can affect the size of the spent fuel storage facilities that would be built at a new reactor. These would include government policy on acquiring and/or building AFRs, on reprocessing, on geologic storage, on NRC licensing actions, and on federal regulations to override local laws restricting spent fuel storage and transportation.

Local Government

Local laws limiting storage and transportation of spent fuel are being enacted at an increasing rate.

Intervenor Actions

The intervenors to date have opposed transport and AFR storage of fuel. Lifetime spent fuel storage facilities incorporated in the reactor design would probably be opposed on the grounds that reactors should not have the possibility of becoming permanent fuel disposal facilities.

Public Utility Commissions

Public Utility Commissions are anxious for the rates to be kept as low as possible. The Commissions would have to be convinced that the increased capital costs for extra storage facilities are necessary.

Action of Utilities on Storage Capacity in New Reactors

The action of the utilities on basin size will not be identical but will depend on many factors such as the size of the utility, regulatory experiences, local laws, etc.

Alternative Basin Capacities

Three alternative basin capacities are considered in this study, (1) standard, (2) mid-size and (3) large. These are shown in Figure 1a, b, c. The mid-size (with reassembly) and the large size can accept lifetime discharges as shown on the figures.

Advantages and Disadvantages

Some pros and cons for the various size storage facilities are given below:

	Advantages	Disadvantages
Standard (small) Pool	Cheapest Most easily licensed Limited intervenor objections	Possibly could close down reactor at cost of $50 to $100 million/yr for replacement power. May need government AFRs with a fee of ∿$150,000/MT Scheduling of geologic storage and reprocessing critical
Mid-size Pool	Intermediate extra cost Can probably be expanded to lifetime storage Less intervenor objections than large size Independent of government policy of AFR, geologic and reprocessing	Adds cost (Table 4) Reassembly unproven Loss of cooling accident more severe More radioactivity at site
Large Size Pool	Lifetime storage with proven techniques Independent of government policy on AFR, geologic and reprocessing	Add cost (Table 4) Loss of cooling accident more severe than smaller sizes More radioactivity at site

Financial Risk with Government Policy Change

The financial risks of building large pools are shown in Table 4. They amount to a very small percentage of the billion dollar cost of a new reactor. If government built AFRs have storage fees of over $100,000/MT it may well be cheaper to avoid them by constructing larger reactor pools and storing fuel at the reactors to await either reprocessing or geologic disposal.

Options That the Utilities Would Select

The facts given in this report are generally known to the utilities so that the decision of a particular utility for a new reactor would depend on its weighing of the pros and cons of expanded storage pools. Some indication of their thinking is available from the following.

M.A.C. Survey[3]

The Management Analysis Company surveyed a number of utilities. Their general conclusion on storage in the reactor pools was that new reactors would have from 20 years to lifetime storage.

DOE-SR Survey

A questionnaire was sent out in May 1979 by the DOE Savannah River Operation - Spent Fuel Project Office to all utilities asking information on their spent fuel storage plans for both existing reactors and future reactors. The returned questionnaires were examined to find those that had reactors scheduled to start up in 1990 or later. (It was assumed that pool sizes in these reactors would indicate the trend that this study is trying to determine.) Three utilities had reactors scheduled in this time period. One utility had expanded pools, one utility (Duke Power) had standard pools but a transshipping plan to reactors with double size pools (Catawba I and II). The last utility had standard pools.

Vendor Survey

Checks with major reactor manufacturers were made by M.A.C. and Du Pont. Very few new reactors are being ordered, but the vendors indicated that discussions with utilities covered 20 year to lifetime storage facilities. One vendor (Westinghouse) is working on a rod reassembly station that could be used in either new or existing storage pools.

Survey Conclusions

It is concluded that reactors now being planned or to be planned in the future most likely will have mid-sized storage basins constructed to provide an option for fuel reassembly. This would potentially provide full lifetime capability should that be necessary at relatively small increase in initial capital outlay. It also postpones the decision on full lifetime capacity to a time when the basis for choice is more certain, and it changes some of the costs for full lifetime capability from capital to operating costs.

References

1. "Spent Fuel Storage Basins for New Nuclear Power Plants," H. J. Rubinstein, P. M. Clark and J. D. Gilcrest, ANS Transactions, 254, June 1977.

2. "Economics of Water Basin Storage of Spent LWR Fuel," F. E. Driggers, ANS Transactions, 331, June 1978.

3. "Spent Fuel Storage - Decision Analysis," Draft DOE/SR-10007-2, September 1979.

4. "Design Selection and Budget Estimate for AFR Spent Fuel Storage Racks," NAC-C-7836 (1979).

5. "Spent Fuel Heatup Following Loss of Water During Storage," A. S. Benjamin, D. J. McCloskey, ANS Transactions, 333, June 1978.

6. "Relative Time-Integrated Spent-Fuel Storage Hazard," J. F. Strahl, E. N. Cramer, ANS Transactions, 334, June 1978.

TABLE 1

BASIN STORAGE DENSITIES, MT/ft^2

	PWR	*BWR*
Stainless steel racks	0.39	0.47
Stainless steel racks with boron	0.52	0.58
Fuel rods reassembled in cans[a]	1.04	1.25

[a]For this type storage an ∿400 sq ft area must be available , for (1) storage of recently discharged fuel and (2) fuel rod reassembly operations.

TABLE 2

SPENT FUEL DISCHARGED IN 40 YEARS*, MT

BWR[a] = 1500 (37.5 MT/yr)

PWR[b] = 1200 (30 MT/yr)

[a] BWR element weight = 0.19 MT
[b] PWR element weight = 0.46 MT

* 1000 MWe Reactors

TABLE 3

COSTS USED FOR "AT REACTOR" STORAGE
(FY 1980 $)

Increasing basin size[1,2,3] (New Reactor)	$5000/sq ft
Stainless steel racks[4]	$4800/MT - PWR $5800/MT - BWR
Stainless steel racks with boron[4]	$5800/MT - PWR $7200/MT - BWR
Reassembly of rods in cans	$3600/MT
Shipping fuel elements within a utility[3]	$6300/MT

TABLE 4

EXTRA COSTS FOR LIFETIME (40 yr) "AT REACTOR" SPENT FUEL STORAGE
(Millions of FY 1980 $)

	Mid-size Pool		*Large size Pool*	
Capital	*PWR*	*BWR*	*PWR*	*BWR*
Basin Increase ($5000/sq ft)	1.6	3.0	5.4	8.0
Extra SS boron racks	1.0	2.5	3.2	6.6
Operating				
Reassemble in cans	4.3	5.4	-	-
Total	6.9	10.9	8.6	14.6

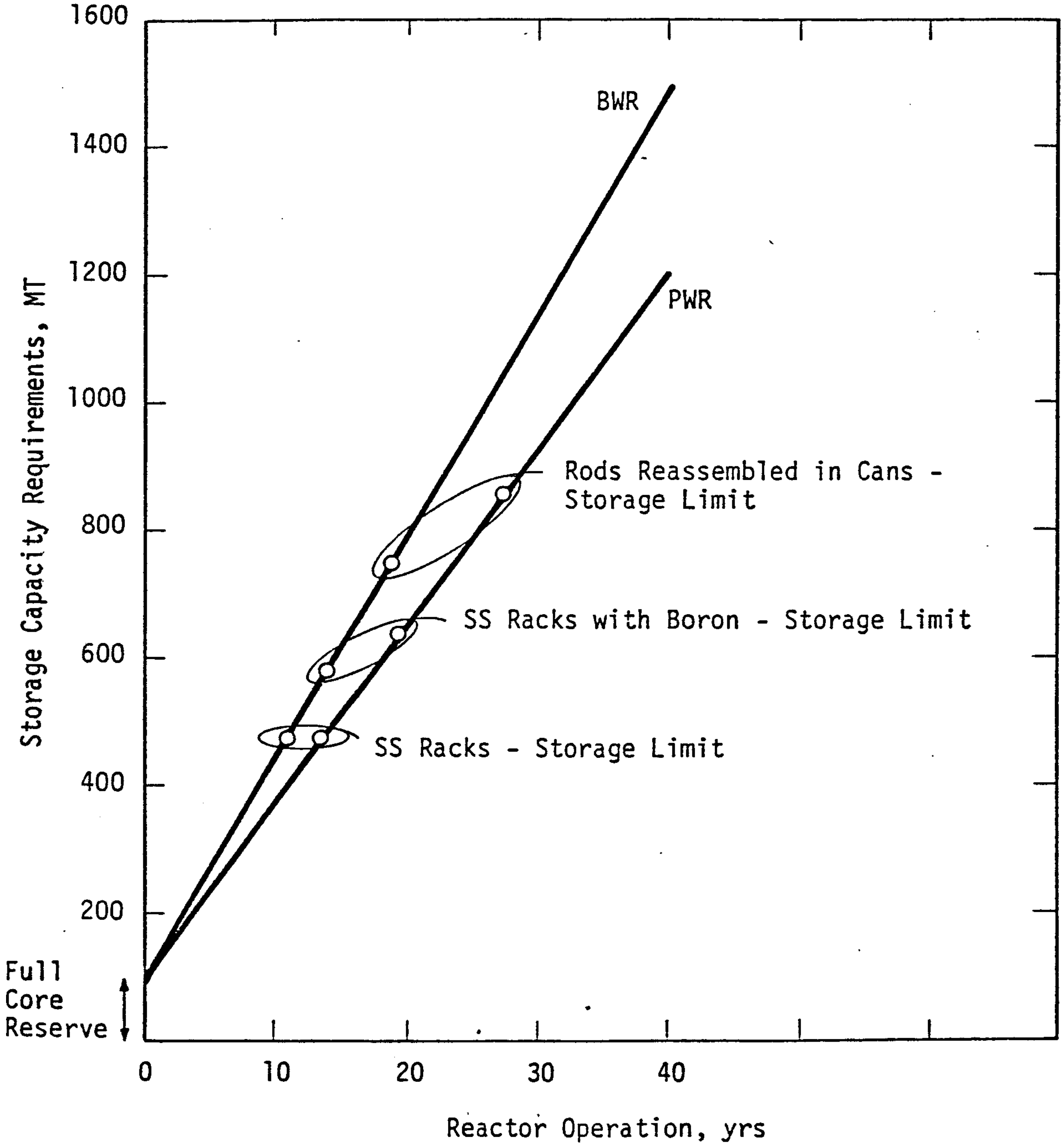

FIGURE 1a. Spent Fuel Storage Capacity - Standard Small-size Basins

Area BWR 1000 ft^2
PWR 1225 ft^2

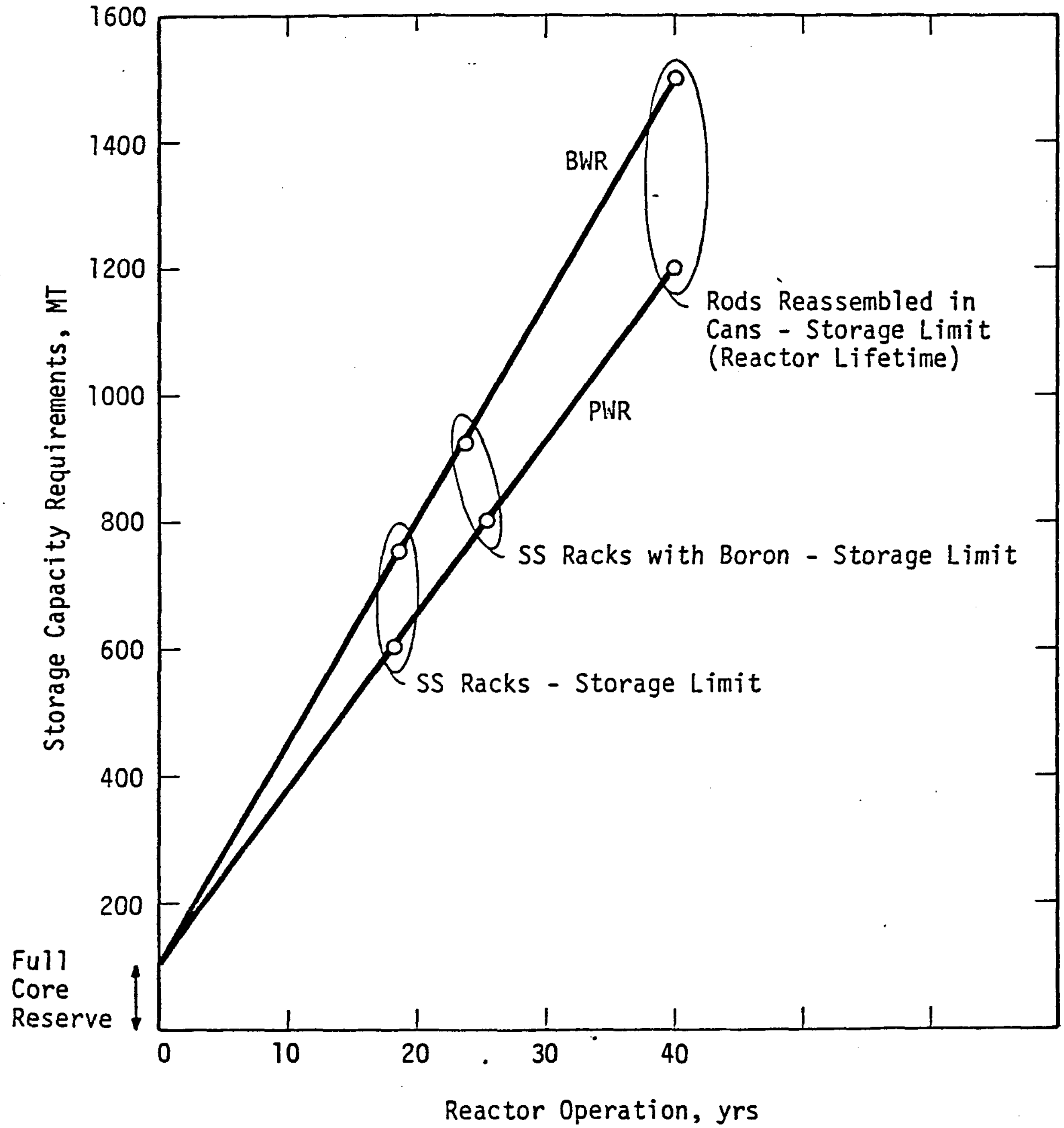

FIGURE 1b. Spent Fuel Storage Capacity - Mid-size Basins

Area BWR 1600 ft^2
PWR 1550 ft^2

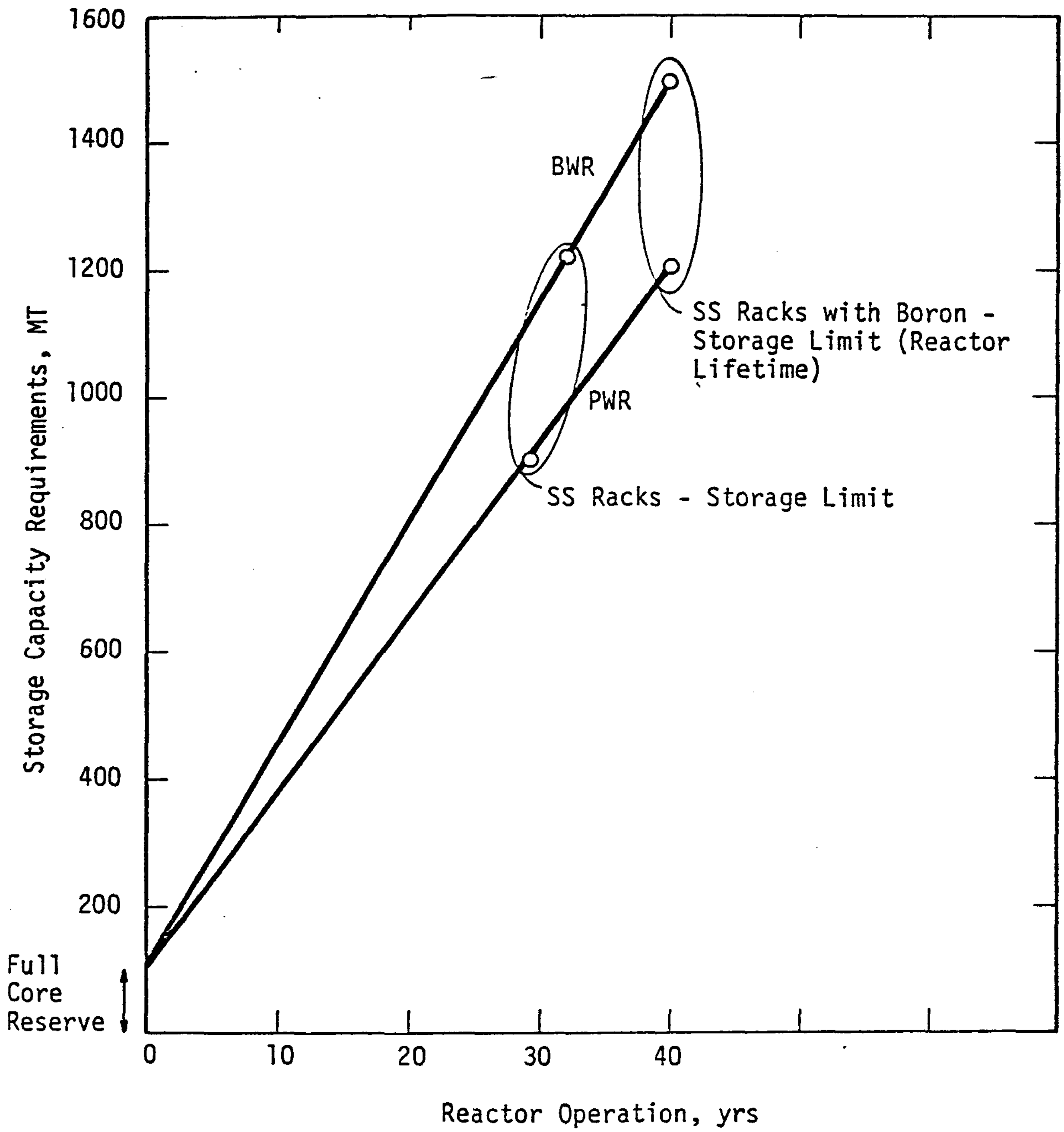

FIGURE 1c. Spent Fuel Storage Capacity - Large-size Basins

Area BWR 2590 ft^2
PWR 2310 ft^2