EFFECTS OF AFR STORAGE LOCATION ON SPENT FUEL TRANSPORTATION

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Over the past several years, the electrical utilities, with nuclear generating capacity, have been faced with the growing problem of increased spent fuel storage. The original concept of the nuclear fuel cycles included reprocessing of spent fuel to recover unreacted uranium and plutonium. In this concept, the discharged fuel would be cooled in the reactor pools for approximately half a year prior to shipment to a reprocessing facility. Hence, most storage pools were designed to accommodate a full reactor core plus one or two discharges. Historically, reprocessing capacity has not kept pace with the spent fuel discharge rate, and in early 1977 all reprocessing activities were indefinitely deferred. The utilities have been continually re-evaluating their spent fuel storage policies in order to avoid a reactor shutdown due to a lack of storage for discharged assemblies.

Currently, several alternatives exist for handling the increasing inventory of spent fuel. These alternatives include:

1. Utilizing compact storage technology with existing storage pools,
2. Constructing new storage pools at the reactor sites,
3. Making intra-utility shipments of fuel from reactors with full pools to reactors with available storage capacity,
4. Shipping fuel to an Away-From-Reactor storage facility (AFR).

Many utilities have been pursuing the first and third alternatives. The utilization of high-density storage racks and unoccupied portions of spent fuel basins ~~have~~ has added several years' worth of storage capacity. However, there is a limit to the amount of storage capacity which can be added at an existing facility, and shipments to an Away-From-Reactor site need to be considered.

Fuel Shipment Rates

The prevailing fuel storage practice dictates the continued storage of spent fuel at the reactor sites for as long as possible. Eventually, the fuel inventor will increase to the point where the reactor would lose the capability of discharging the entire core unless some of the assemblies are removed from the storage pool.

The projected shipments of spent fuel required to maintain full core reserve over the period 1980 - 1995 are shown in Fig. 1. The upper curve represents the case in which the utilities do not expand the pool storage at the reactors beyond their current levels. The lower curve is based on increasing the reactor storage capacities to the utilities' estimate of their maximum level. Increasing the reactor storage capabilities results in approximately a 40% reduction in the fuel which must be shipped over the time period considered.

Considering the current trend in spent fuel movements, the lower curve is probably the best estimate of the amount of fuel which will be moved from the reactor sites. All the cost and transportation data discussed in this paper is based on the lower curve in Fig. 1.

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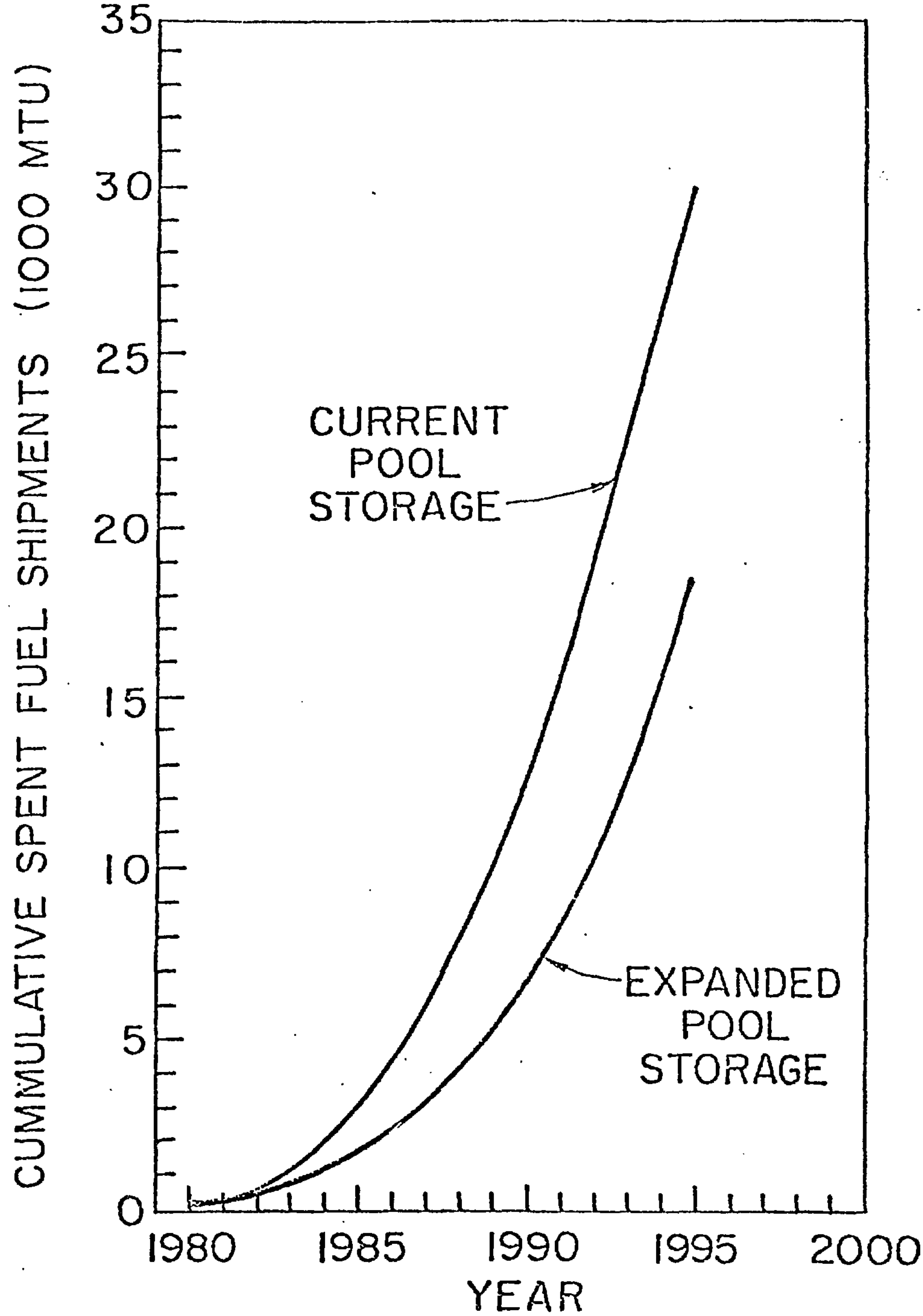

FIG. 1. PROJECTED SPENT FUEL SHIPMENTS

Possible AFR Facilities

Currently, there are three existing sites which might be developed into AFR facilities: Morris, IL; Barnwell, SC; and West Valley, NY. Some fuel is presently being stored at Morris and West Valley. Assuming the proposed expansion at Morris is completed as scheduled in the early 1980's and the AGNS facility is dedicated to a spent fuel storage utilizing high-density racks, a combined storage capacity of approximately 4000 metric tons is attainable. Referring to Fig. 2, this storage capacity would serve the needs for AFR storage until the mid-to late-1980's.

Transportation Effects of AFR Siting

Conceptually, the effect of AFR siting could have a major impact on transportation costs and cask fleet sizes. Most of the nuclear generating capacity is located east of the Mississippi River. From a transportation standpoint, it would be desirable to locate most of the AFR capacity in the eastern part of the U.S. There are many factors which must be considered before an optimal site could be identified. Some of these factors include the technical suitability of a particular site and public acceptance in the region of the AFR facility and along the major transportation routes leading to the AFR facility. Indeed, these factors will probably override any transportation considerations.

In order to assess the impact of AFR siting on the spent fuel transportation system, five different sites were studied. The selection of these particular sites is not meant to infer that an AFR is being considered at one or more of these locations. However, to estimate transportation costs, a particular site must be selected. The locations were picked to represent various geographical areas of the U.S., and are all located at existing DOE facilities. The sites

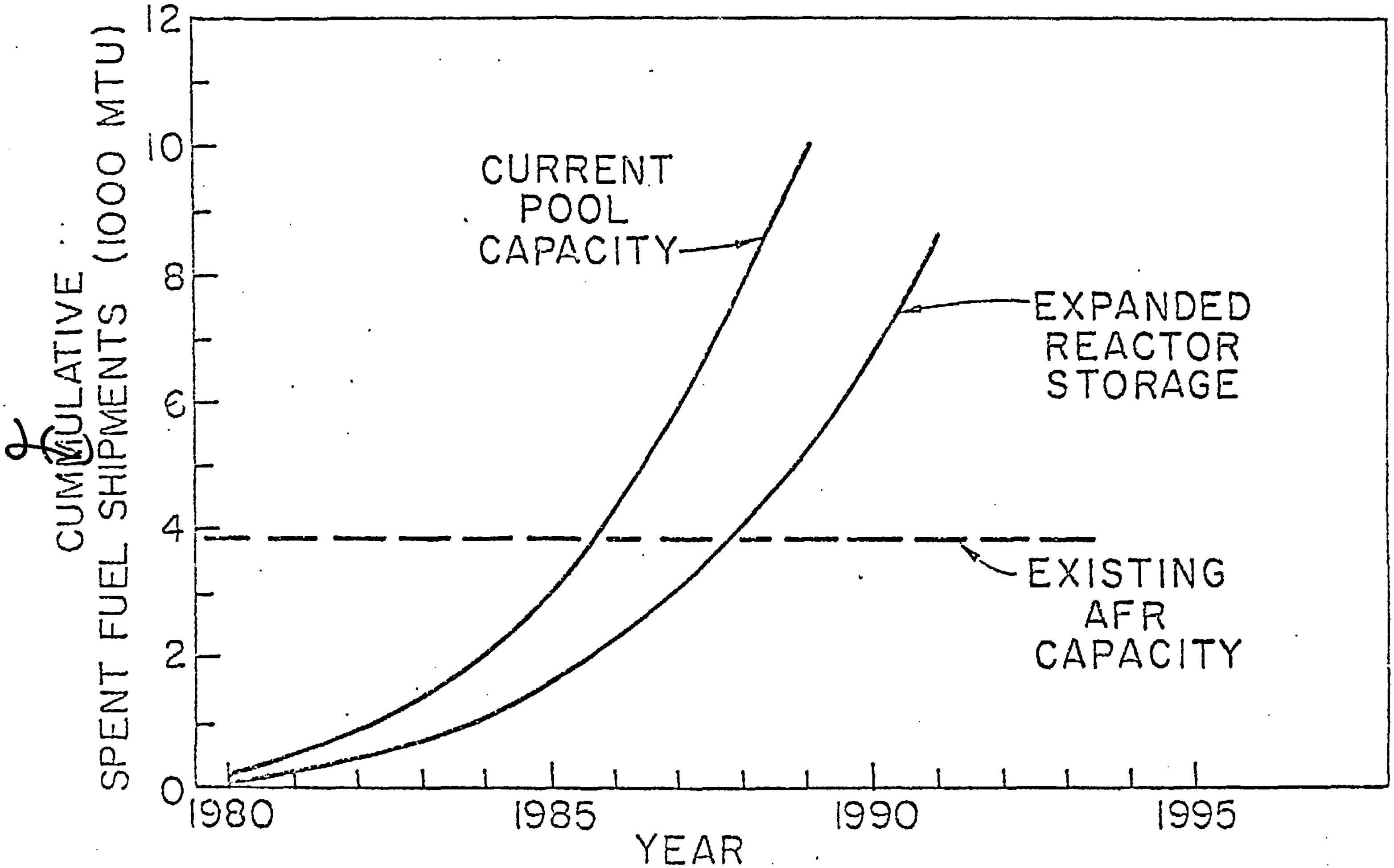

FIG. 2. PROJECTED SPENT FUEL SHIPMENTS AND AFR STORAGE CAPACITY

considered in this study, as shown in Fig. 3, were: Argonne, IL; Oak Ridge, TN; Savannah River, SC; Idaho Falls, ID; and, Richland, WA.

In order to estimate the impact on transportation, several assumptions were required.

1. All reactors will increase their onsite storage, as needed, until their respective maximum storage capacity is attained.
2. All spent fuel shipped from the reactors (assuming the maintenance of full core reserve between 1980 and 1995) would be transported to one of the sites listed below.
3. All reactors which have rail service will make all fuel shipments via rail, using a cask carrying 10 PWR or 24 BWR assemblies.
4. Reactors without onsite rail service will make all fuel shipments via a legal-weight truck cask carrying 1 PWR or 2 BWR assemblies.
5. All rail shipments will be moved as general commerce, i.e., no special train.
6. Operational considerations at the AFR facility would not restrict the amount of fuel received or stored at the facility.

Operating an AFR facility at each of the five sites would minimize the transportation requirements since the overall shipping distances between the various reactors and the AFR facilities would be minimized.

Under these assumptions, all fuel shipments from reactors located in the eastern two-thirds of the country would be sent to one of the eastern AFR's

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AFR SITES CONSIDERED

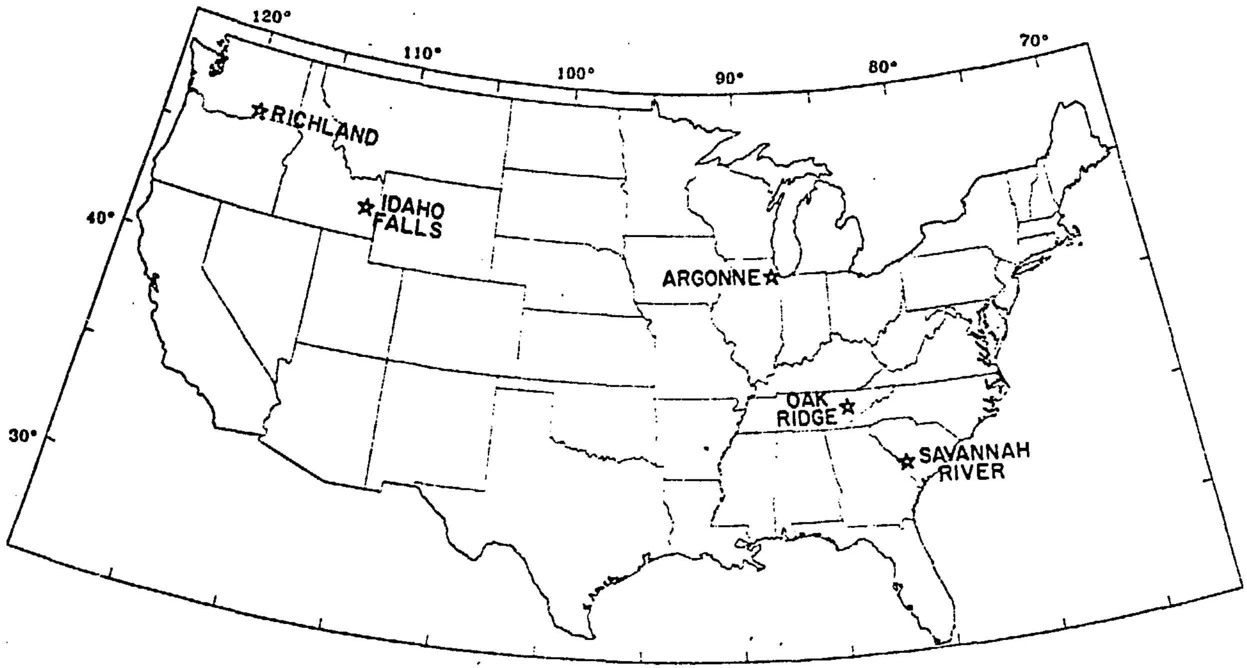

FIG. 3.

(Argonne, Oak Ridge, or Savannah River). Economic considerations for these shipments favored the utilization of Argonne or Savannah River which collected 87% of the total fuel between them. For the study period being considered (1980 - 1995), approximately 6% of the total fuel shipments are made by reactors in the western third of the country, and all of these shipments are routed to either Idaho Falls or Richland.

Since several of these sites appeared to be underutilized, a second case utilizing only three AFR sites was evaluated. The three sites picked represent the three most probable AFR sites (Argonne, Savannah River, and Richland). This scenario resulted in only a minor increase in transportation costs, and the distribution of fuel stored at the various AFR's and associated transportation costs are shown in Table 1. The second case (three AFR's) was selected as the base case for purposes of comparing the impact on the transportation system of using a single AFR site.

In order to investigate the impact of a single AFR site in the spent fuel transportation system, a series of logistics runs were made to determine the transportation costs, cask fleet requirements, and radiation exposure to the transportation workers and general population. Each of the identified sites was investigated, assuming that each site would receive all of the projected fuel shipments between 1980 and 1995.

A comparison of the transportation costs for the various AFR sites is shown in Table 2. It is immediately obvious that there is a very small difference in transportation costs for siting a single AFR in any of the three eastern sites, namely Argonne, Oak Ridge, or Savannah River. The differences reported are within the uncertainty level of the cost model. Hence, from a cost standpoint, an AFR at any of these three sites is equally attractive. The costs of shipping fuel to

Table 1

Distribution of stored fuel inventories and transportation costs for multiple AFR operation

	Case 1 (5 AFR's)	Case 2 (3 AFR's)
Fuel stored, %		
Argonne	38.3 %	40.5 %
Oak Ridge	7.0	--
Savannah River	48.6	53.4
Idaho Falls	4.8	--
Richland	1.3	6.1
	100.0 %	100.0 %
Transportation cost $\$ \times 10^6$	164	171

Table 2

Comparison of transportation costs for a single AFR

Location	Transportation cost, $\$ \times 10^6$	Percent increase from Base Case, %
Argonne	231	35
Oak Ridge	239	40
Savannah River	233	36
Idaho Falls	458	168
Richland	549	221

a single AFR located in Washington or Idaho are significantly higher. This result was expected due to the increased shipping distances encountered in moving the bulk of the fuel originating in the eastern half of the country to the western AFR sites.

Another parameter directly related to shipping distances is the cask fleet size required to transport the fuel. It was assumed that all reactor sites having rail access would make all shipments by rail. Using this assumption and the projected spent fuel schedule, rail shipments would account for approximately 75-80% of the total fuel arriving at an AFR site. However, an interesting observation was made for the base case. All the fuel shipments to Richland and approximately 92% of the shipments to Argonne were made by rail. However, rail accounted for only 45-50% of the shipments received at Savannah River between 1980 and 1986. During the later part of the study period (1987 - 1995), the percentage of fuel being shipped to Savannah River by rail increased to 60-65%. This apparent maldistribution of rail-truck mix can be accounted for by noting the geographical distribution of the reactors which lack rail service to the plant site (Fig. 4). Most of these reactors are situated in the eastern part of the U.S., and when there is a choice of AFR's, most of these reactors would opt for shipping fuel to Savannah River.

The cask fleet sizes required to ship fuel to the various AFR sites are summarized in Table 3. The values reported represent the cask fleet size at the end of the study period (1995).* Again, shipping fuel the longer distances to the

* The growth of the rail cask fleet over the study period for selected AFR locations is shown in Fig. 5.

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FIG. 4. REACTORS WITHOUT RAIL SERVICE

Table 3

Cask fleet size required in 1995

AFR Location	Rail Casks	Truck Casks
Argonne	24	26
Oak Ridge	27	23
Savannah River	27	23
Idaho Falls	42	42
Richland	50	49
Base case (3AFR)	18	22

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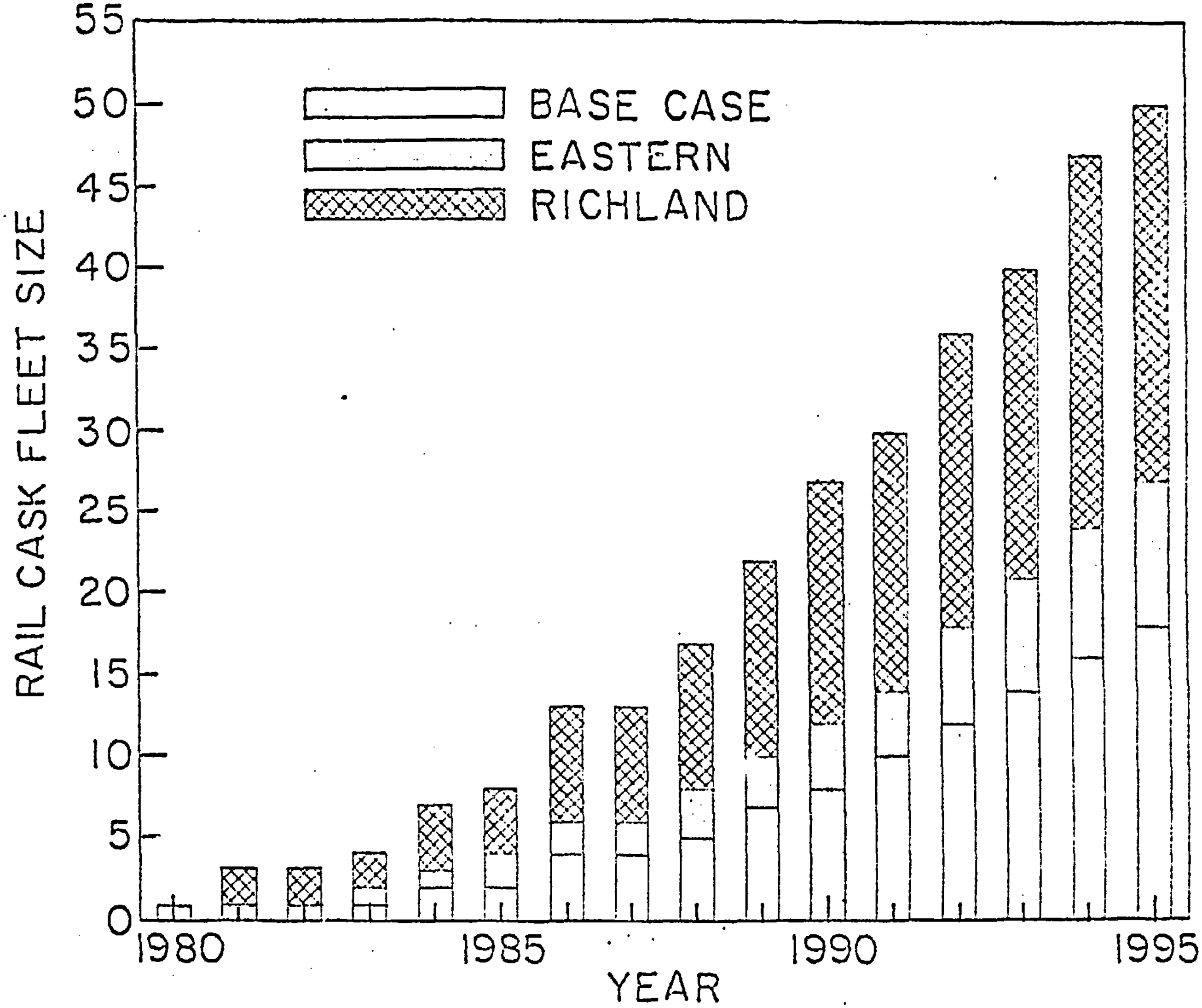

FIG. 5. RAIL CASK FLEET REQUIREMENTS FOR VARIOUS AFR SITES

western part of the U.S. requires a substantially increased fleet size. For the eastern AFR locations, the cask fleet requirements are within about 10% of each other and, as for transportation costs, there is no clear-cut distinction between those sites.

The third aspect directly related to spent fuel transportation to AFR sites is the radiation exposure received by the transportation workers and the general public. The radiation exposures received by the employees at the reactor when loading the fuel cask and at the AFR when unloading the cask were not estimated. This portion of the total radiation exposure is independent of AFR siting since the same amount of fuel was shipped in each scenario.

The major proportion of the total radiation exposure is received by the truck drivers. As shown in Table 4 for the base case, the exposure to the truck drivers is estimated to be approximately 110 man-rem over the entire study (16 years). To put this value in perspective, annual dose to any given truck driver would be in the range of 100-120 mrem/year, which is approximately equal to the typical background level.

The radiation exposure received by the total population of rail workers is much less and is estimated to be only a few tenths of a man-rem over the entire study period.

Since the radiation calculations are only approximations, the detailed exposures resulting from shipping fuel to the individual AFR sites are normalized to the base case scenario. While the uncertainty level for the radiation exposure calculations is large, the relative changes shown in Table 5 for the various scenarios do give a good estimate of the incremental increases in the exposure as a function of AFR site.

Table 4

Radiation exposure for Base Case
1980 – 1995

Transportation worker	Man-Rem
truck	110
rail	<1
General Population	7
TOTAL	117

Table 5

Relative changes in radiation exposure
for various AFR sites

Location	Radiation Exposure (Man-Rems)		
	Transportation Workers	General Population	Weighted Average
Argonne	1.87	1.84	1.87
Oak Ridge	1.32	1.89	1.35
Savannah River	1.06	1.72	1.10
Idaho Falls	4.74	2.76	4.64
Richland	5.95	3.26	5.79

Again, the same general conclusions may be drawn from this information. The higher dose rates are associated with shipments to the western sites.

The exposure received by the truck drivers showed the largest variation in the cases where the shipments are made to eastern AFR sites. As discussed earlier, most of the reactors utilizing truck shipments are located along the East Coast or in the Southeast. In the base case, essentially all of these shipments were routed to Savannah River. In the case where all shipments are sent to Savannah River, only a small portion of the total number of truck shipments are required to travel a longer distance. This change in desired destination resulted in approximately 6% increase in the radiation to the truck driver population. When all shipments are made to Argonne or Oak Ridge, essentially all the truck shipments must travel a longer distance, and the resulting increase in the radiation exposure is between 32 and 87%.

The radiation exposure to the general public is a function of the total transportation distance of all shipments (rail and truck). For the eastern AFR's, there is relatively little difference in the radiation exposure to the general population. When the shipments are made to the western AFR's, the relative increase in the exposure to the general public is much less than the corresponding exposure to the truck drivers. The greatly increased shipping distances are required and are counter-balanced by the lower population densities in the western U.S. Hence, the net overall increase is not as great as for the truck driver who stays with the truck regardless of the particular area which it happens to be traveling.