SPENT FUEL MANAGEMENT

PROGRAM STUDY

SUMMARY OPTION PAPER

Prepared by

DIVISION OF FUELS

TENNESSEE VALLEY AUTHORITY

May 1979

I. Need for Action

TVA now operates 3 nuclear power reactors and has 14 additional nuclear reactor units in various stages of construction. Spent nuclear fuel will result from normal operation of these nuclear power reactors as the nuclear fuel becomes depleted and must be replaced. Commercial nuclear fuel consists of short cylindrical pellets of ceramic uranium dioxide (UO_2). Typically, about 200 of these pellets are stacked and sealed in a zirconium alloy tube. These "fuel rods" are then assembled into bundles in a square array called a "fuel assembly." Several hundred fuel assemblies are arranged to form a reactor core.

Depending on the reactor type, about one-fourth to one-third of the fuel assemblies must be replaced each year due to depletion of uranium within the fuel as energy is produced. The radioactive nature of these spent fuel assemblies results in the generation of heat which decreases with time. The spent fuel assemblies removed from the reactor are temporarily stored at the power plant in spent fuel storage pools.

Typically, these onsite spent fuel pools were designed with storage capacity for the spent fuel resulting from one or two core refuelings plus sufficient additional capacity for the assemblies from an entire core unloading (full core reserve). This additional full core reserve capacity allows the performance of maintenance and equipment inspections requiring the removal of all fuel from the reactor.

TVA originally understood that nuclear spent fuel would be reprocessed to recover the useable uranium and plutonium, thereby reducing the requirements for natural uranium. Shipment of spent fuel from power plants to a reprocessing facility was expected to occur within about one year following discharge of the fuel from a plant's reactor.

In 1977 President Carter announced that the United States would indefinitely defer reprocessing of spent nuclear fuel because of the risk of nuclear weapons proliferation. As a result of this action, reprocessing is currently precluded as an option for the disposition of spent nuclear fuel.

TVA recognized that very limited storage capability for spent fuel was provided in the original design of the spent fuel storage pools and in the mid-1970's began a program to expand existing pool storage capability. This involves making more efficient use of the existing space in the plant pools by using fuel storage racks having a more compact storage array and greater neutron absorbing capability and, thus, greater capacity.

TVA estimates that 1989 is the earliest date the power system will need additional spent fuel storage capacity beyond that which will be provided by installation of high density fuel racks.

Table 1 identifies the storage need dates which begin in 1989 and storage capacity requirements for each nuclear plant until the year 2000, as well as for the life of the plant.

In the event it should become necessary to provide interim storage for spent fuel discharged after the year 2000, TVA has also considered the life-of-plant time frame in its analysis.

Other developments may also occur to enable better utilization of the existing storage capacity in power plant spent fuel pools that could defer the need dates shown in table 1. One such development, the potential for which is being studied by TVA, is fuel rod consolidation. This process would involve dismantlement of spent fuel assemblies and placement of the individual fuel rods in close array within a canister the approximate size of the original fuel assembly. Rod consolidation could provide for storing up to twice the amount of spent fuel in suitably designed high density fuel storage racks. While rod consolidation is in the conceptual stage of development, application at TVA facilities scheduled for operation after the Watts Bar Nuclear Plant may be economically feasible. Backfitting to earlier plants would require design modifications that may offset the benefits.

II. Options for Storing TVA Spent Fuel

TVA has identified two principal alternatives to provide the necessary additional storage capacity. Both alternatives involve building additional spent fuel storage facilities as described below:

A. Onsite Individual Independent Spent Fuel Storage Facilities

This alternative involves construction of an independent storage facility at each TVA nuclear power plant site designed to serve only the reactors at that site. Fuel would be stored in the onsite power plant spent fuel pools until only full core reserve storage capacity remains. As new spent fuel is generated, the oldest spent fuel would then be moved to the power plant onsite independent storage facility. Under this option no offsite shipment of spent fuel would be required and, therefore, there are no offsite impacts associated with transportation.

B. One Centralized Independent Spent Fuel Storage Facility to Serve all of TVA's Reactors

This alternative involves construction of a centralized facility designed to provide the needed additional spent fuel storage facility for all of TVA's reactors. Spent fuel would be stored in the onsite power plant pools until only full core reserve storage capacity remains. The oldest stored fuel would then be transported to the centralized facility for storage as new spent fuel is generated.

Spent fuel can be shipped through the use of three transport modes or a combination thereof: truck; rail; or barge.

Truck transport utilizes tractor-trailer rigs. Special spent fuel casks designed to meet road weight limitations as well as severe accidents are used. These casks have a rather limited spent fuel capacity.

Rail transport utilizes casks on special rail cars that have significantly larger spent fuel capacities than truck casks. The advantage of large capacity is counteracted by the disadvantage of longer transport and cask turnaround times at the reactor site and storage facility.

Barge transport may become an important future option. This mode could conceivably use truck casks, rail casks, or special casks designed for barge transport. At present this alternative is precluded because none of the commercially available casks are licensed for barge transport.

Both of the above-described principal alternatives would utilize an independent storage facility as its basic conceptual design. The only basic design difference between the two alternatives would be the storage capacity (size) of the facility(s). Since this capacity difference would not significantly affect the description or the generic nature of the facility(s), the following discussion applies to both alternatives. This discussion is intended as an overall description of the design and general characteristics of an independent storage facility. Figure 1 is an isometric impression of a typical facility.

The licensing, design, and construction lead time for an onsite independent spent fuel storage facility is estimated to be 7 years for each of the nuclear plant sites. Necessary lead time for the centralized storage facility is estimated to be 9-1/2 years at a new (nonnuclear) site and 7-1/2 years at an existing nuclear plant site. Typical schedules for an onsite and a centralized facility are shown in figure 2.

An independent spent fuel storage installation is a separate facility for storage of irradiated nuclear fuel. This type of facility could occupy anywhere from 6 to 14 acres depending on its storage capacity. The site would include areas for building structure, transportation access, and a security perimeter. Additional acreage may be required for support installations (i.e., offsite electrical power, potable water pipeline, sanitary waste facilities, and fire protection).

An independent spent fuel storage facility provides for water-cooled pool storage of spent fuel initially, with the possibility of later modules utilizing dry storage as it is perfected.

The water pools are designed to retain their watertight integrity for all credible accidents, including design basis tornados and earthquakes. They are designed (1) to resist rupture and excessive loss of water, and (2) to prevent all massive equipment, such as cranes, etc., from falling into the pools, thus causing damage to the spent fuel during the design basis earthquake.

An independent storage facility is designed to receive, handle, decontaminate, and reship spent fuel casks; to remove irradiated fuel from casks; to transfer the fuel underwater in a storage pool; and to cool and control the quality of the water. The facility is also designed for removing spent fuel from storage basins, loading the spent fuel into shipping casks, and decontaminating loaded casks. The fuel element cladding provides an effective containment for irradiated nuclear fuel during storage.

The storage facilities are designed to protect the fuel cladding against mechanical, chemical, or thermal damage. The storage facility provides for a safe arrangement of fuel assemblies and adequate radiation shielding of operating personnel from the fuel assemblies at all times. Furthermore, when spent fuel is removed from these water pools, radiation shielding is provided by special designed and licensed shipping casks.

Presently the only casks available are those licensed for shipment on the public transportation systems. Accordingly, both offsite and onsite spent fuel transport has been assumed to be made using licensed casks of existing design.

The maximum number of personnel required for operation of a central storage facility would not be greater than one-half that associated with a 2-unit nuclear generating facility which typically employs 250 to 300 people. The primary noticeable activity would be the arrival and departure of transportation vehicles carrying the spent fuel casks. For the centralized facility alternative the maximum number of cask shipments by truck would be about four a day.

An onsite facility would require about one-fourth of the operating personnel needed for the central facility.

III. Alternative Comparison

To provide a basis for a preliminary comparison between the two principal storage alternatives and the identification of a preferred alternative, TVA has considered the following potential significant issues:

1. Technical Feasibility
2. Environmental Impacts and Radiological Health Effects
3. Economic Feasibility

The actual significance of each is discussed below.

Technical Feasibility

The construction and operation of both alternatives would utilize the same existing proven technology and equipment. In either case, facility modifications or additions of modules utilizing dry storage could provide long-term storage should that become necessary. Thus, there is no technological difference which would preclude consideration of either alternative.

Environmental Impacts and Radiological Health Effects

Environmental Impacts--TVA's studies and the NRC and DOE environmental impact statements have concluded that storage of spent light water nuclear fuel, whether in a centralized or in individual onsite facilities, can be accomplished with only minor environmental impacts.[1,2] No unusual site characteristics from an

1. Storage of U.S. Spent Power Reactor Fuel, DOE/EIS-0015-D, Draft Environmental Impact Statement, U.S. Department of Energy, August 1978.

2. Handling and Storage of Spent Light Water Power Reactor Fuel, NUREG-0404, Draft Generic Environmental Impact Statement, U.S. Nuclear Regulatory Commission, March 1978.

environmental or engineering standpoint are needed. With proper design, construction, and operation, there should be little potential for significant release of radioactive material during fuel storage or handling.

The primary environmental difference between a centralized facility and individual onsite facilities would be the impacts of transporting spent fuel to a centralized facility. A secondary impact would be the additional commitment of land resources required for a central facility not sited at an existing nuclear plant. In making its decision, TVA will fully consider all environmental issues in accordance with TVA's procedures for compliance with the National Environmental Policy Act and other environmental requirements. However, TVA's studies to date indicate there are no environmental considerations which would preclude either alternative.

Whether spent fuel is moved to an individual onsite or to a centralized AFR, fuel must be transported using shielded casks and other special transport equipment. The technology for spent fuel transfer is well developed, and the impacts of this operation can be assessed with reasonable assurance based on current conditions. The longer distances associated with fuel transport offsite result in greater transportation impacts and costs than for the onsite option; the costs have been determined and included in the comparative results shown in table 2.

Other transportation impacts are not easily quantified but given current trends, represent possible increased costs which should be considered in comparing options. These include:

1. Restriction of transportation--New laws, regulations, policies, or industrial conditions related to fuel transportation may restrict transportation routes and modes and affect overall transportation considerations.

2. Liability of fuel transport--Fuel shipped today from a facility covered by the Price-Anderson insurance system is covered during transport; changes in Price-Anderson application could affect the offsite transportation alternative.

Radiological Health Effects--The routine transporting of spent fuel to a centralized facility would result in radiation exposure to the public. For the maximum number of shipments in any given year to the facility the maximum dose to any member of the public is estimated to be 0.01 millirem/year, or about 1/10,000th of that resulting from the estimated naturally occurring background radiation. The estimated occupational dose to facility operators would be higher than the public exposure but still within current regulatory allowances.

Spent fuel shipping casks are designed to withstand serious transportation accidents without significant loss of contents or increase in external radiation levels. The probability of a severe accident would be extremely remote. If such an accident occurred, some part of the population would receive some radiation with unknown effects on those involved.

The individual onsite facility alternative would result in no additional radiological exposure to the public since these facilities would be located at existing nuclear plant sites and would, therefore, have no offsite shipment of spent fuel.

Economic Feasibility

To obtain cost comparisons, three basic facility sizes were examined and the approximate base cost was determined to be $43 million for a 700-MT facility, $50 million for a 1,400-MT facility, and $90 million for a 3,000-MT facility. These base costs were then adjusted to the nominal sizes and locations actually needed. Using these adjusted base costs, each facility cost was escalated to the midpoint of construction at 8 percent. Transportation and O&M costs were similarly escalated to the year of expenditure. To complete the analysis, all costs were discounted at 11 percent to obtain present value dollars (1979). This method is used for comparative analysis only and is not intended to determine the actual costs for the facility(s).

As indicated in table 2, completion of all three onsite facilities to store spent fuel until the year 2000 or seven onsite facilities to store spent fuel for the life of the plants is more expensive than the central storage facility option in both cases. This difference could be offset by the early commitment of higher facility, operating, maintenance, and transportation costs associated with the central facility, while the onsite facility option provides greater decisionmaking flexibility by allowing commitment in increments.

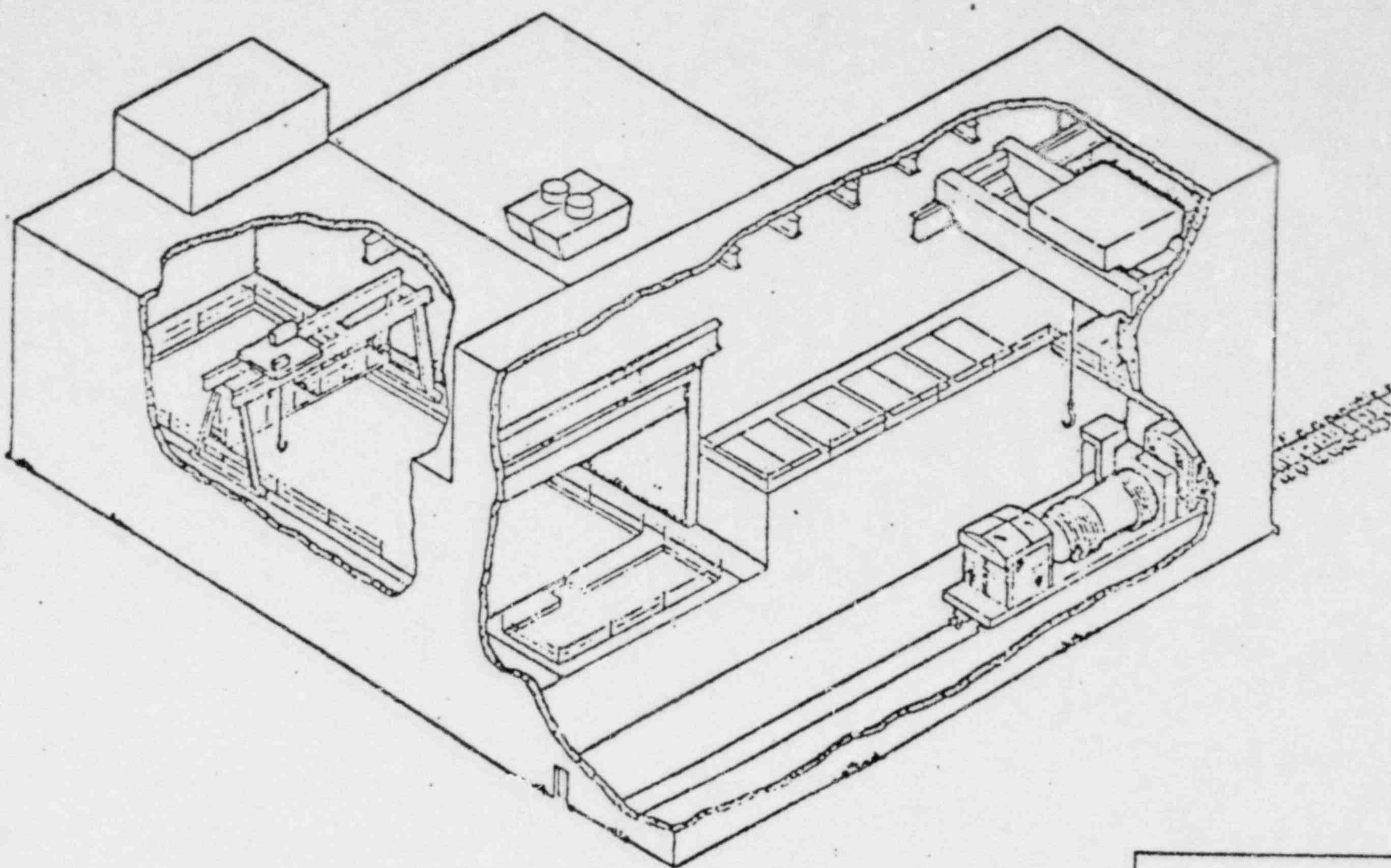
As shown in figure 3, economic comparison favors the onsite option in accommodating the early needs. With technological advances such as rod consolidation, construction of later onsite facilities may not be necessary at all. Furthermore, if final disposition of spent fuel becomes available in the 1995-2000 time frame, construction of the Bellefonte facility would not be required. This would reduce the comparative cost of the onsite option as shown in table 2 to $131 million, bringing it to within $20 million of the central AFR option. For a central facility, while technological advances might reduce the actual storage needs, the early timing for commitment may preclude application of new technologies in establishing facility size.

IV. Conclusion

If TVA must store all of the spent fuel it generates through the year 2000 or later, economic comparison of the cost factors that we can quantify for the two alternatives under present conditions favors the centralized facility. However, many other cost and considerations which cannot be quantified combine to offset this advantage. Principal among these are:

- Flexibility to avoid overbuilding, should conditions reduce requirements for storage.
- Greater potential for including future technological requirements.
- Minimized transportation impacts and the risks of possible future restrictions to offsite transport.
- Utilization of land area and security provisions already dedicated to nuclear power plant operations.

When all factors are considered, onsite storage of spent fuel appears to have more merit for TVA than storage at a centralized facility.



CUTAWAY ISOMETRIC OF

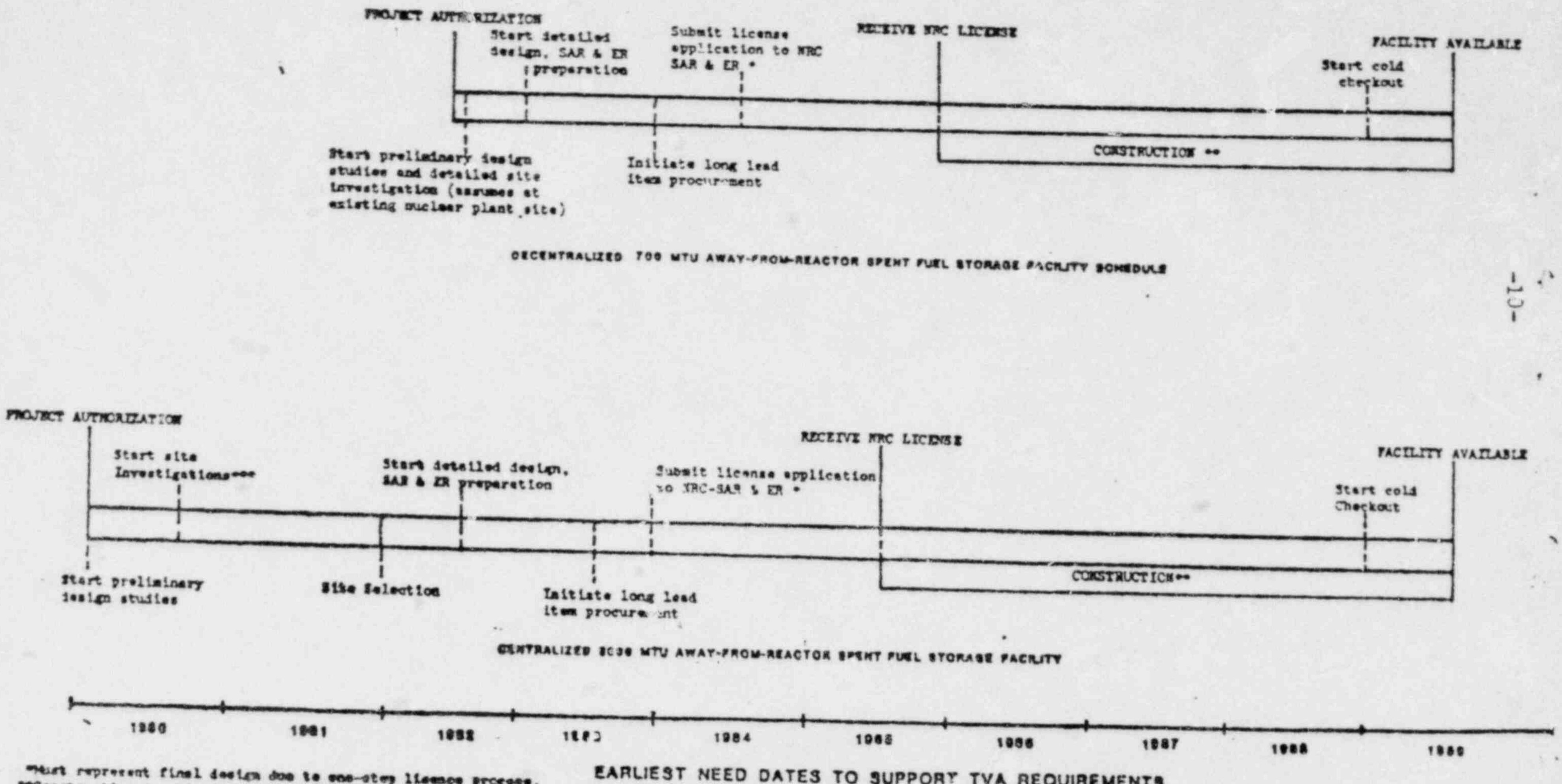
INDEPENDENT SPENT FUEL

STORAGE INSTALLATION

Figure 1

Figure 2

TYPICAL LICENSING - DESIGN - CONSTRUCTION SCHEDULES FOR AWAY-FROM-REACTOR (AFR) SPENT FUEL STORAGE FACILITIES



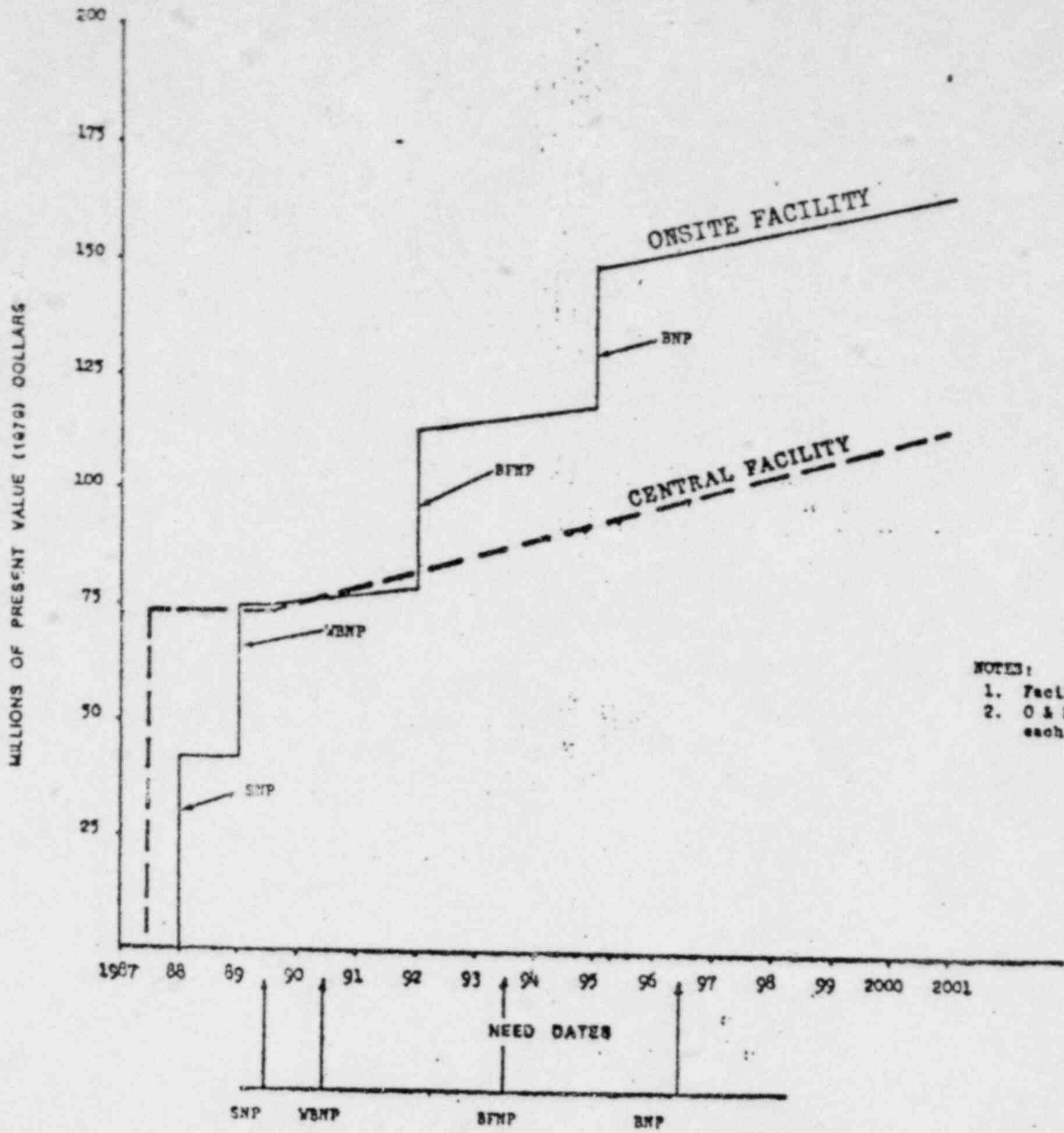
*Must represent final design due to one-step license process.
**Construction duration based on Stone & Webster and General Electric input for 700 MTU and 3000 MTU, respectively.
***Assumes new site; schedule can be reduced by 23 months for existing nuclear plant site.

Figure 3

AFR YEARLY COST COMPARISON

ONSITE VS. CENTRAL

THROUGH YEAR 2000



NOTES:

1. Facility costs are shown at midpoint of construction.
2. O & M and transportation costs start at need dates for each facility and are represented linearly for simplicity.

Table 1

TVA SPENT FUEL STORAGE REQUIREMENTS[1,2]
THROUGH YR 2000 AND LIFE OF PLANT (35 YEARS)

Nuclear Plant	Spent Fuel Generated Yr 2000 MT		Existing Fuel Pool Capacity (FCR) MT	Year FCR Limit Reached	Extra Storage Capacity Req'd (Above FCR) Yr 2000 MT	Extra Storage Capacity Req'd (Above FCR) LOP MT
Sequoyah	1190	1670	520	1989[3]	670	1150
Watts Bar	1140	1670	520	1990[3]	620	1150
Browns Ferry	2270[4]	2760[4]	1600	1993	670	1160
Bellefonte	1080	1700	760	1996	320	940
Hartsville	[5]	3850	1590	[6]	0	2260
Phipps Bend	[5]	1920	790	[6]	0	1130
Yellow Creek	[5]	1980	1020	[6]	0	960

1. All quantities and dates are based upon completing fuel pool reracking with high density storage racks as presently scheduled.
2. All values have been rounded to the nearest 10 MT.
3. The earliest facility need date could be extended approximately three years by interplant transfer of spent fuel if this transfer proves to be feasible.
4. The General Electric Company has ultimate responsibility for some of the spent fuel included in this amount.
5. Less than full core reserve limit.
6. After year 2000.

KEY: MT - Metric Ton
LOP - Life of Plant
FCR - Full Core Reserve

Table 2

ONSITE VS. CENTRAL FACILITY COST COMPARISON

(MILLIONS OF PRESENT VALUE 1979 DOLLARS; DISCOUNTED CASH FLOW ANALYSIS)

THROUGH YR 2000 AND LIFE OF PLANT (35 YRS)

Onsite Facility	Yr 2000 Facility Size MT	Yr 2000 Facility	Yr 2000 O&M, Transportation[1]	Yr 2000 Total	Life of Plant (35 Yrs) Facility Size MT	Life of Plant (35 Yrs) Facility	Life of Plant (35 Yrs) O&M, Transportation[1]	Life of Plant (35 Yrs) Total
Sequoyah	700	39.0	7.0	46.0	1200	41.0	21.5	62.5
Watts Bar	700	36.0	6.5	42.5	1200	38.0	21.0	59.0
Browns Ferry	700	36.0	6.5	42.5	1200	38.5	18.0	56.5
Bellefonte[2]	-	-	-	-	900	32.0	16.0	48.0
Hartsville	-	-	-	-	2400	52.5	26.5	79.0
Phipps Bend		-	-	-	1200	32.0	16.5	48.5
Yellow Creek	-	-	-	-	900	28.0	13.0	41.0
TOTAL	2100	111	20	131[3]	9000	262	132	394[3]
Central Facility	2400	73	38	111[3]	9000	168	140	308[3]

1. All transportation costs assume shipment by truck.

2. If final disposition of spent fuel does not become available in the 1995-2000 time frame, construction of a facility at Bellefonte would be required at an additional cost of $33.0 million.

3. These figures do not reflect non-quantifiable costs and other factors. See pages 6 and 8.

KEY: MT - Metric Ton

O&M - Operation and Maintenance