APPENDIX A

SPENT FUEL MANAGEMENT PROGRAM STUDY

SUMMARY REPORT

TENNESSEE VALLEY AUTHORITY

SEPTEMBER 1979

TVA

ACKNOWLEDGMENTS

This report was prepared principally by R. H. Davidson and J. B. Moegling, Tennessee Valley Authority Division of Fuels, and Dr. George G. Berg, University of Rochester. A number of TVA organizations provided advice and assistance in the spent fuel management study supporting this report. A draft of this report (Summary Option Paper, May 1979) was made available to interested individuals and organizations and comments were encouraged. It was also reviewed by the following six technical consultants:

Dr. George G. Berg, Associate Professor of Radiation Biology and Biophysics, the University of Rochester Medical Center.

Dr. Terry R. Lash, Staff Scientist, Natural Resources Defense Council, Inc.

Dr. Joseph A. Lieberman, Partner, Nuclear Safety Associates.

Dr. Norman H. Macmillan, Associate Professor of Metallurgy and Materials Research, Materials Research Laboratory, the Pennsylvania State University.

Dr. Karl Z. Morgan, Neely Professor, School of Nuclear Engineering, Georgia Institute of Technology.

Dr. Joel R. Primack, Associate Professor of Physics, University of California, Santa Cruz.

Comments by these consultants were considered in preparing this report. While these generally support the conclusions and the proposed action, this report does not necessarily reflect all aspects of the specific views of each reviewer.

Those interested in the reports of the six technical consultants may obtain these through the TVA Citizen Action Office at Knoxville.

Comments from the general public and from the technical consultants were a valued input in preparing this final report.

I. Proposed Action

This report is a summary of the Tennessee Valley Authority study to increase its spent nuclear fuel storage capacity. It concludes that the best alternative is to build new pools at existing reactor sites. Increased storage capacity may be needed in order to assure operation of TVA nuclear power reactors. The new storage units would be similar to the ones already in place at existing nuclear plant sites. Alternate ways of providing the needed storage, their costs, and their environmental impacts are summarized in this paper.

Construction of additional storage units at existing sites was chosen in preference to the construction of a central storage facility away from reactors. The time table for preliminary planning, design, and licensing work is geared to completing the first new storage facility by 1990, thus permitting time to review the design of additional facilities and to make further advances in ensuring a minimum of hazard to the environment and the public.

II. Need for Action

As early as the year 1990, TVA may run short of storage space for spent fuel taken out of its nuclear power reactors. TVA now operates 3 nuclear power reactors (Browns Ferry units 1, 2, and 3, all near Decatur, Alabama) and has 14 additional nuclear reactor units in various stages of construction. Spent nuclear fuel will result from normal operation of these reactors as the nuclear fuel becomes depleted and must be replaced. Because of its radioactive and thermal characteristics this spent fuel requires controlled storage.

In common with the then generally accepted concept of recycling the fuel for commercial nuclear power, TVA originally undertook its nuclear power program on the basis that spent fuel would be reprocessed to recover the useable uranium and plutonium. Shipment of spent fuel from power plants to a reprocessing facility was expected to occur within a year of its removal from the reactor.

In 1977 President Carter announced that the United States would indefinitely defer commercial reprocessing of spent nuclear fuel because of the potential for nuclear weapons proliferation as well as the fact that it had not yet been proven economical. As a result of this action, reprocessing is now precluded as an option for spent nuclear fuel.

Every existing and proposed nuclear plant has facilities for storing spent fuel. With the deferral of reprocessing, TVA recognized that very limited storage capability was provided in the original design of the spent fuel storage pools, and in the mid-1970's began to expand existing pool storage capability. This involved 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. At the present time (September 1979) high density fuel racks are being installed in the pools of 3 operating TVA nuclear reactors (Browns Ferry units 1, 2, and 3), and they are being incorporated in the design and construction of the other 14 TVA reactors.

Table 1 in the Appendix identifies the dates of storage need and storage capacity requirements for each nuclear plant until the year 2000, as well as for the estimated life of each plant, a figure which is highly speculative.[1] These computations assume that high density storage similar to that at the Browns Ferry plant will be installed as planned in all TVA nuclear plant pools. The first additional storage capacity is expected to be needed in 1990 for spent fuel from Sequoyah.

III. Options for Storing TVA Spent Fuel

TVA has examined a variety of possible options and identified two principal alternatives to provide the necessary additional storage capacity. Both alternatives involve building additional spent fuel storage facilities as described below:

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1. The TVA nuclear plant design life is 40 years from issuance of the construction permit.

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 expand its spent fuel storage capacity. Spent fuel would be stored in two stages. First, it would be moved from the reactor into the reactor's storage pool. Then, the oldest fuel in the storage pool would be moved to the independent storage facility on the plant site. The reactor pool would never be filled, because storage space would always be kept in reserve to accommodate the entire reactor core in case the reactor vessel had to be unloaded. Under this option no near-term offsite shipment of spent fuel to a storage facility 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 capacity for all of TVA's reactors. Spent fuel would be stored in the onsite power plant pools until only full core reserve storage capacity remained. The oldest stored fuel would then be transported to the centralized facility for storage as new spent fuel was generated.

In summary, the two alternatives would differ primarily in that one option involves onsite storage units while the other involves a single larger facility with the need for transport of spent fuel off the reactor site. The design and general characteristics of storage pools would be very similar in both cases, as shown in the Appendix, figure 1.

In the case of alternative B, spent fuel could 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 are used which are designed to meet road weight limitations as well as to withstand severe accidents. These casks have a rather limited spent fuel capacity, i.e., one or two fuel assemblies per cask. Rail transport utilizes casks on special rail cars that have greater spent fuel capacities (i.e., 12 to 24 fuel assemblies) than truck casks. The projected radiation dose to the population is lower in rail than in highway shipments. Barge transport may become an important future option, with a potential for lower radiation exposures. This mode could conceivably use truck casks, rail casks, or special casks designed for barge transport. At present this alternative involves uncertainties since barge transport has not been used for commercially generated spent fuel in this country. Available casks are licensed for shipment by highway or rail. Accordingly, both offsite and onsite spent fuel transport has been assumed to be made using licensed casks of existing design. Future technological developments may allow simpler methods of onsite fuel transport, further reducing transportation costs and radiological impacts for the onsite alternative.

The maximum number of personnel expected for the 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.

Each onsite facility would require about one-fourth of the operating personnel needed for the central 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 a 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 a decentralized (onsite) and a centralized facility are shown in the Appendix, figure 2.

IV. Comparison of the Alternatives

To provide a basis for a preliminary comparison between the two principal storage alternatives and the choice of a preferred alternative, TVA evaluated the most probable contributions of three significant factors:

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

The findings are summarized in this section. The uncertainties associated with the evaluations are discussed in section V below.

Technical Feasibility

The construction and operation of both alternatives would utilize existing and proven technology and equipment. Water pool storage of spent fuel has been demonstrated by 20 years' safe operating experience.[1] There appears no technical reason why storage of spent fuel under water for the life of the plant or longer cannot be accomplished using existing technology. For either alternative, facility modifications or additions of modules utilizing dry storage could extend storage for several additional decades or longer should that become necessary. Thus, there is no technological difference which would preclude consideration of either alternative.

Compliance with Environmental Regulations

TVA's studies and the Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) environmental impact statements for storage of spent fuel from light water reactors have concluded that storage of spent fuel whether in a centralized facility or in onsite facilities, can be accomplished with minor environmental impact. Such facilities would be designed and built in compliance with environmental regulations concerned both with routine releases of radioactive materials and with safeguards

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1. A. B. Johnson, Battelle-Pacific Northwest Laboratories, "Spent Fuel Storage Experience," Nuclear Technology, mid-April 1979.

against accidental releases.[1,2] Sites selected for the location of nuclear plants are satisfactory for spent fuel facilities from environmental and engineering standpoints.

TVA has handled and stored spent nuclear fuel in the past and will continue to do so in the future in a way that safeguards the environment from any significant releases of radioactive materials. Perspectives on perceived risks from radiological releases are discussed in the Appendix.

The primary environmental differences between a centralized facility and individual onsite facilities would be the impacts of transporting spent fuel to a centralized facility. The fuel transport offsite results in greater transportation impacts and costs than for the onsite option; the costs have been determined and included in the comparative results shown in the Appendix, table 2. A secondary impact would be the additional commitment of land resources required for a central facility if located at a new site. 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.

Other transportation impacts are discussed next.

Compliance with Radiological Health Regulations

If spent nuclear fuel is routinely tranported to a centralized storage facility operated by TVA, the vast majority of the public will not be near the transportation routes and will not be exposed to any ionizing radiation from that source. For the few people who might be exposed to the shipments, the dose would be about 0.01 millirem/year (mrem/yr),

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, Generic Environmental Impact Statement, U.S. Nuclear Regulatory Commission, August 1979.

which is far below radiation limits set by law. The background radiation exposure level of approximately 110 mrem/yr is discussed in the Appendix. Facility operators and shipping crews would be expected to receive higher doses of radiation than any member of the general public, but these doses would also be below the limits set for occupational exposures (up to 5,000 mrem/yr as set by Federal regulations, or up to 4,000 mrem/yr as set by the TVA). Even for the maximum case of 1,000 truck shipments per year to a central facility, the average dose to an operator would be less than 1,000 mrem/yr. The dose to workers at an onsite facility could be even less since fewer shipments would be handled at each facility and the loads would be moved over shorter distances.

Storage at the individual onsite facility would result in no additional radiological exposure to the public from offsite shipment of spent fuel.

These conclusions of radiological safety include the consideration of accidents, both onsite and during shipment. Spent fuel shipping casks are designed to withstand severe conditions including high speed collisions without significant loss of contents or increase in external radiation levels. The probability of a severe accident breaking the casks would be extremely remote as explained in the Appendix. Nevertheless public perception that transportation of spent fuel poses a potential hazard is a reality that will be considered in future actions taken by TVA.

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 operations and maintenance (O&M) costs were similarily escalated to the year of expenditure. To complete the analysis, all costs were discounted at 11 percent to obtain present value dollars (1979). TVA uses this method of accounting to reflect the cost of early capital expenditures. This method is used for comparative analysis only and is not intended to determine the actual costs for a facility.

As indicated in the Appendix, table 2, if TVA finds it necessary to complete all three (Sequoyah, Watts Bar, and Browns Ferry) or more onsite facilities to store spent fuel, then the onsite option would involve direct cost to TVA that are greater than the central storage facility option.

However, as shown in the Appendix, figure 3, economic comparison favors the onsite option in accommodating the early needs. With technological advances described in section V, such as rod consolidation, construction of facilities at Hartsville, Phipps Bend, and Yellow Creek may not be necessary if some system of further disposition becomes available. Furthermore, if final disposition of spent fuel becomes available in the 1995-2000 time frame, construction of the Bellefonte facility would also not be required. This would reduce the comparative cost of the onsite option as shown in table 2 to $131 million.

The same circumstances would not reduce the cost of the centralized facility by much, because most of it will already have been built. The final differential in direct costs would then shrink to some $20 million, or less than 20 percent, in favor of the centralized option.

V. Response to Future Developments

If TVA could be sure of the job to be done and the regulatory constraints for doing it, it could make an early choice of one of the two options for fuel storage on the basis of feasibility, economic costs, and health risks. At this time, however, both the job and its constraints are subject to future changes which TVA cannot control. Under such conditions of uncertainty, the benefits of waiting for better information may outweigh the potential savings of early decision to build a central facility. It appears that TVA could respond appropriately and safely to a wider range of future developments by starting on the path to onsite storage.

Future studies may optimize the onsite storage of spent fuel by assessing the potential for storage facilities that could provide the capacity for more than one power plant. This consideration recognizes that some power plants are located close together and transportation of small amounts of spent fuel between them may be practical. Using this approach, significant facility cost savings might be realized with minimum transportation impacts.

The key to future developments will be in national policy for nuclear power, in technology of spent fuel storage, in provision for final disposition of radioactive material, in new laws and regulations, and in State and local provisions for transport and disposal of hazardous substances.

National Policy

The current moratorium on nuclear fuel reprocessing is officially considered a temporary measure pending resolution of the proliferation and economic concerns about reprocessing. Certainly reprocessing is a possibility in the future and TVA has a large financial stake in the potential fuel value of its spent fuel if reprocessing is proven economical and safe from proliferation. Above-ground, onsite storage preserves that option. If the ban on reprocessing were made permanent, there would be time to work out a plan for longer term storage if necessary either onsite or at a central facility. Alternatively, spent fuel could be shipped for permanent disposition when such provisions are available.

If the decision is made to resume reprocessing and recycle plutonium for reactor fuel, any additional storage facilities already built on the reactor site would remain useful as a place to hold backlogs of spent fuel. While a central facility would lose its usefulness for temporary storage of spent fuel more quickly than the smaller units, the central site may be attractive for other industrial uses.

Technical Advances

Some of the developments in the technology of spent fuel storage rely on the physical fact that the fuel becomes less hazardous and easier to handle as its radioactivity decays with time.

Current designs for spent fuel facilities achieve higher density of storage with the help of racks--affording a more compact storage array and containing neutron absorbers. With older fuel, further developments may permit even more compact storage under water, which 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 dismantling spent fuel assemblies and placing individual fuel rods in close array within a canister the approximate size of an 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, it may be tested, licensed, and found economically feasible in time for application at the TVA facilities scheduled for operation after the Bellefonte Nuclear Plant. Backfitting to earlier plants would require design modifications that may offset the benefits.

Finally, spent fuel may be stored under water until it has lost so much radioactivity that the resultant internal heating is no longer a problem. Techniques could then be developed for dry storage or for embedding in a material for final disposal should this be necessary. On the other hand, since operating experience for more than 20 years is not available, a very long passage of time (i.e., several decades or longer) also may make the fuel assemblies less reliable by weakening the cladding, which means that the current methods for storing these assemblies are interim measures. Plans for very long-term storage will depend on provisions for the appropriate encasing of spent fuel as may be necessary.

As explained in section IV, each of these technological advances would favor storage onsite, which provides the option of not constructing new storage units if the existing ones can handle the load.

Hazardous Waste Regulations

State governments in the Tennessee Valley area are expected to develop regulations and procedures for safe transportation and disposal of hazardous materials with the help of guidelines which will be made available by the Environmental Protection Agency (EPA). While nuclear spent fuel shipments are now controlled by other regulations (Nuclear Regulatory Commission [NRC] and Department of Transportation [DOT]), they will be affected by the way in which the overall problem of hazardous materials management is solved. The solutions, however, may either help or hinder the shipments.

On one hand, Federal and State authorities may put together an effective system of hazardous freight control, designed to safeguard the routes, mitigate accidents, and protect passers-by from spills. The authorities for managing such a system have not been completely established, but the working components are at hand in each State. With an effective system in place, offsite shipments of spent fuel should gain in safety.

On the other hand, various levels of government in their concern for the safety of their constituents, may enact legislation that bans the passage of hazardous shipments. They may zone against repositories of hazardous and radioactive wastes. Even the insurance provisions for spent fuel shipments which are now available to nuclear power installations under the Price-Anderson insurance system may be changed by the Congress. Operation of a central storage facility would be highly vulnerable to changes that interfered with offsite shipments. Onsite storage would be less vulnerable.

VI. Conclusion

If TVA must store all of the spent fuel it will have generated 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, cost uncertainties and other considerations which cannot be fully 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 developments and design improvements.

- 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 operation.

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

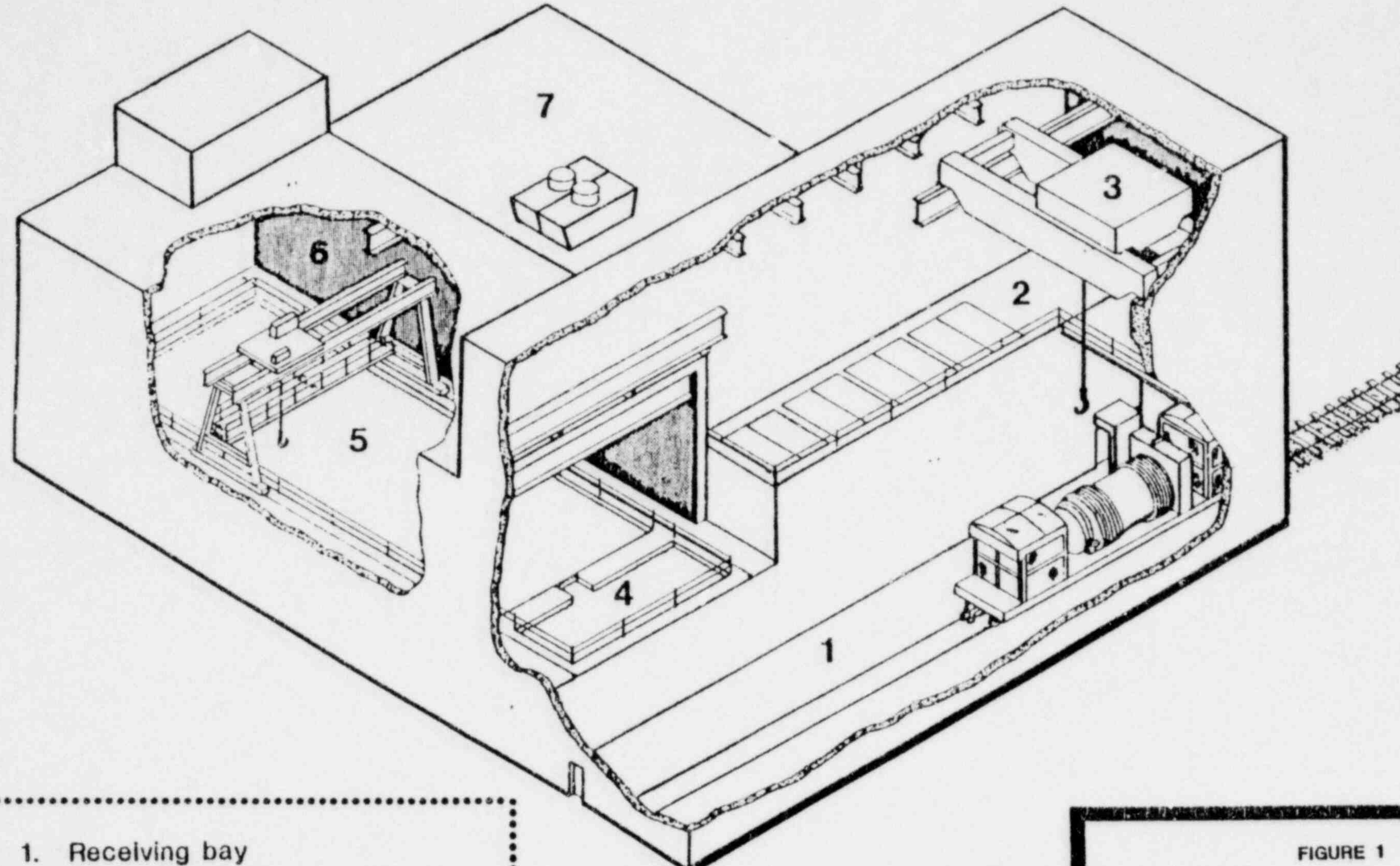
APPENDIX

A. Figures and tables

B. Notes on perceived risks

C. Notes on facilities and equipment

D. Notes on reference materials



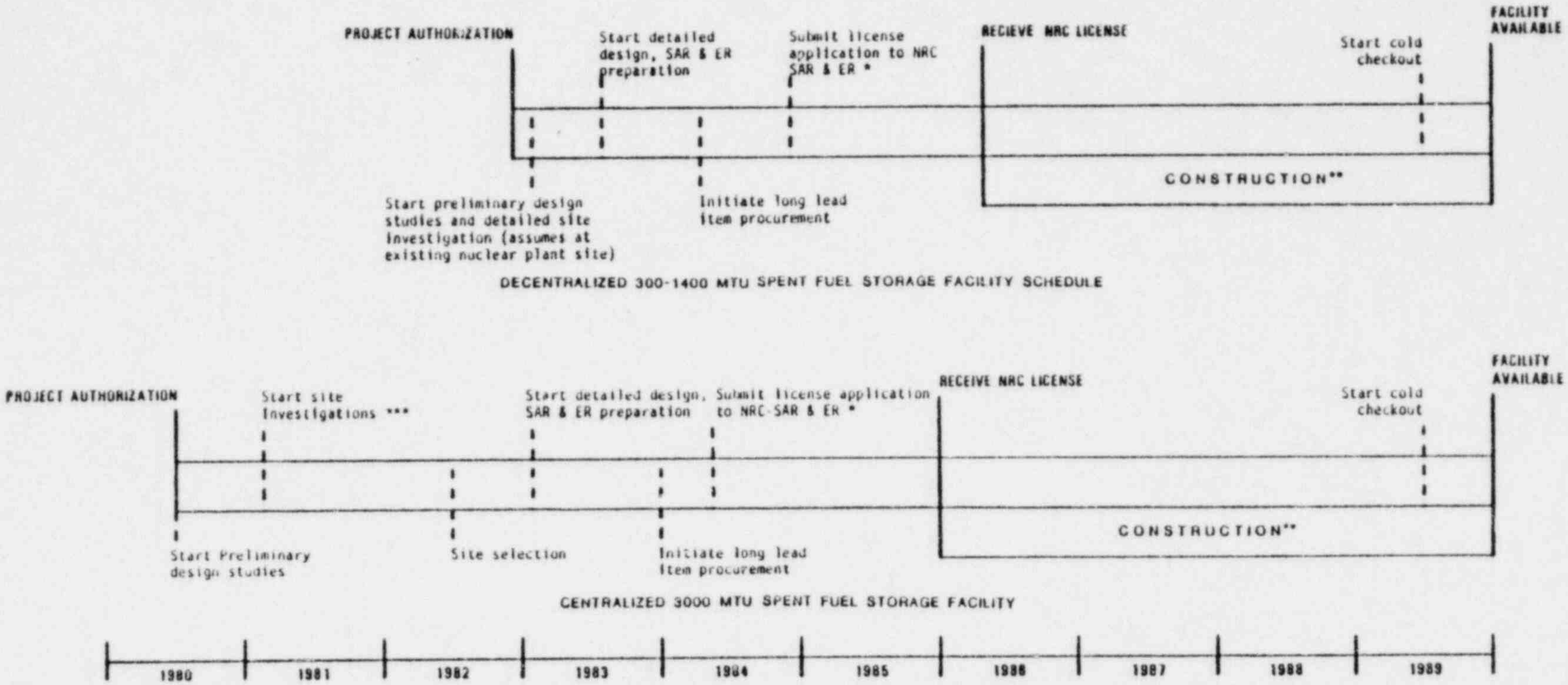
1. Receiving bay
2. Packaging and decontamination
3. Bridge crane
4. Unloading
5. Storage basin
6. Fuel handling crane
7. Auxiliary bay

FIGURE 1

CUTAWAY ISOMETRIC OF INDEPENDENT SPENT FUEL STORAGE INSTALLATION

Figure 2

TYPICAL LICENSING - DESIGN - CONSTRUCTION SCHEDULES FOR SPENT FUEL STORAGE FACILITIES



EARLIEST NEED DATES TO SUPPORT TVA REQUIREMENTS

* Must represent final design due to one-step license process.

** Construction duration based on Stone & Webster and General Electric input for 1400 MTU and 3000 MTU, respectively.

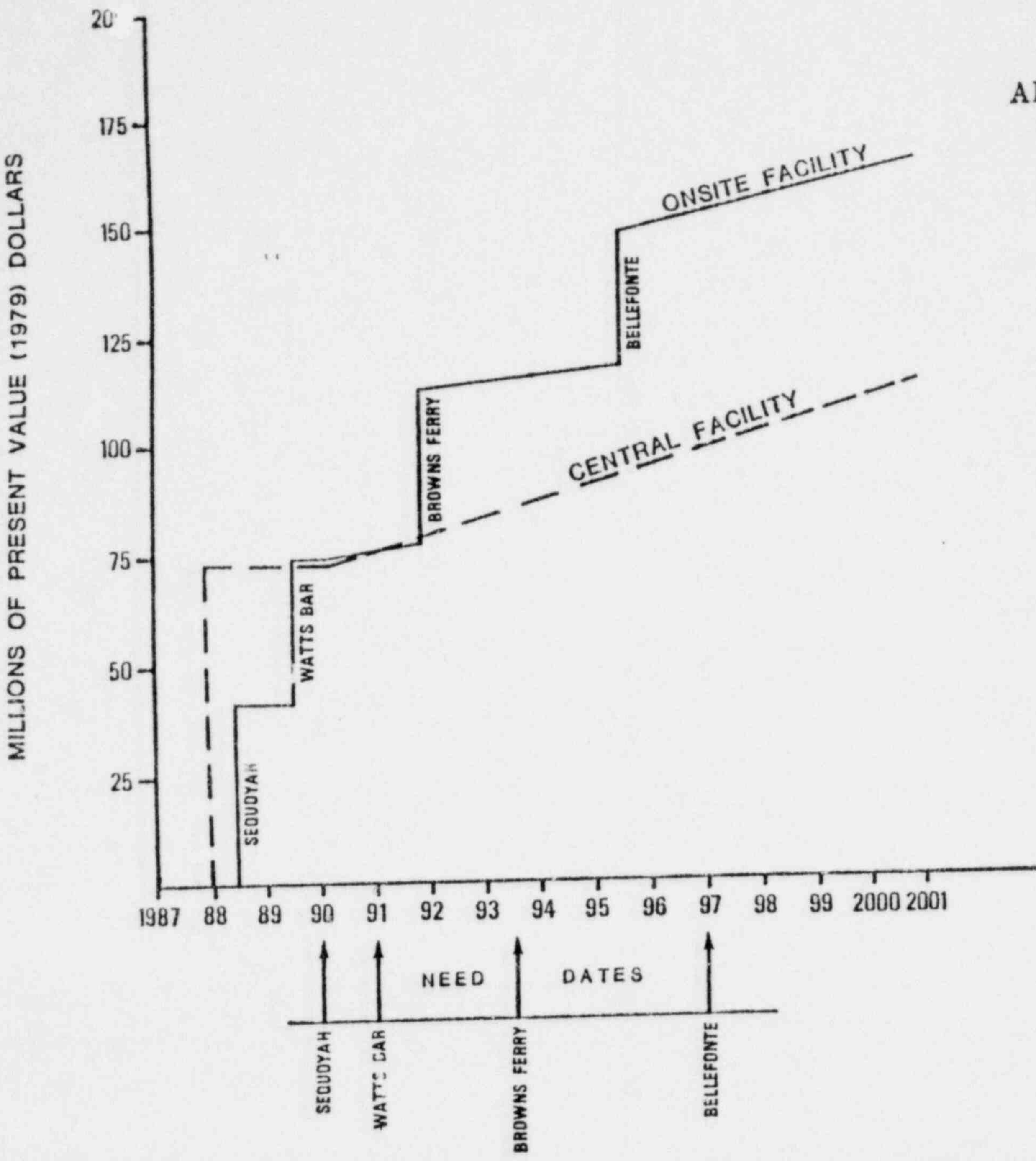
*** Assumes new site; schedule can be reduced by 23 months for existing nuclear plant site.

Figure 3

AFR YEARLY COST COMPARISON

ONSITE vs. CENTRAL

THROUGH YEAR 2000



NOTES:

The cost curves are simplified to separate facility costs (vertical lines) from O&M and transportation costs (sloping lines). Facility costs are shown at midpoint of construction. O&M and transportation costs start at need dates for each facility.

Table 1

TVA SPENT FUEL STORAGE REQUIREMENTS[1]

THROUGH YR 2000 AND ESTIMATED LIFE OF PLANT (35 YEARS)

Nuclear Plant	Spent Fuel Generated Yr 2000 MT	Spent Fuel Generated LOP 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	1140	1670	520	1990[2]	620	1150
Watts Bar	1090	1670	520	1991[2]	570	1150
Browns Ferry	2270[3]	2760[3]	1600	1993	670	1160
Bellefonte	1030	1700	760	1997	270	940
Hartsville	[4]	3850	1590	[5]	0	2260
Phipps Bend	[4]	1920	790	[5]	0	1130
Yellow Creek	[4]	1980	1020	[5]	0	960

1. All quantities and dates are based upon completing fuel pool reracking with high density storage racks as now scheduled.

2. The earliest facility need date could be extended approximately three years by interplant transfer of spent fuel if this transfer proves to be feasible.

3. The General Electric Company has ultimate responsibility for some of the spent fuel included in this amount.

4. Less than full core reserve limit.

5. 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.

KEY: MT - Metric Ton
O&M - Operation and Maintenance

B. Notes on perceived risks

Policy decisions are made by TVA on behalf of the residents of the Tennessee Valley region. Management's objective is, of course, to deliver the most benefit at least cost, but decisions made now must deal with the uncertain future. There is always the risk that benefits will be less and costs will be more than predicted. This risk, however, is perceived differently by different people. In submitting a decision to the judgment of its constituents, TVA tries to convey not only an accounting of costs and benefits but also an idea of the way management perceives the risks. Accordingly, a preliminary draft of this report was circulated not only to expert reviewers but also to over 800 individuals and organizations within the Tennessee Valley region with a request for comments and criticisms. About 50 answers came by mail and 20 by telephone. Of these responses, 25 percent represented Government agencies and electric utilities, 10 percent were industry officials or consultants, 10 percent represented citizens' organizations, 10 percent were professionals with expertise in nuclear power, and the remaining were counted as unaffiliated. On the choice of alternatives for storage, 60 percent approved the concept of storage onsite, while 10 percent came out in favor of a central facility offsite; 40 percent came out strongly in favor of nuclear power, 20 percent were strongly against, 10 percent were uncommitted, and the rest did not comment on this issue.

More useful than the simple poll of votes was a study of reasons given for each option. These comments have been a valued input to the study. Some were incorporated into this final report. Many others showed a perception of risks completely different from the unspoken assumptions of the draft report. The explanations that follow explain TVA's reasoning on points of widest disagreement. Whether or not comments were incorporated in this report, all will be considered in future actions taken by TVA.

(1) Risks of exposure

Ionizing radiation is hazardous to people. The amount of damage that can be expected increases with the dose received by each person; the dose, in turn, increases with exposure. The relation of dose to damage is known reasonably well for high doses, and progressively less so for lower doses. For example, in a population of one million people exposed to natural radiation every year, an average low dose of 100 mrem per person, the upper limit for the predicted damage is some 45 deaths from cancer each year, which amounts to about 2-3 percent of one year's death toll from cancer. The lower limit from the same exposure, however, is judged to be somewhere between zero and seven extra deaths from cancer.[1,2]

This uncertainty about low doses must not be mistaken for an uncertainty about small increases in dose. A small increase in the dose already received by a population is expected to produce a small increase in the amount of damage.[1] With this in mind information was gathered about the sources of radiation exposure to the population of the Tennessee Valley region. This section explains why nuclear power operations of TVA were not one of the significant sources of population exposure, and why the normal operation of projected additional plants will not become a significant source of additional population exposure. The next section considers risks associated with accidents.

Environmental radiation in air, water, vegetation, wildlife, and food is surveyed regularly by TVA's Radiological Hygiene Branch. The average exposure in the region was measured at 110 mrem/yr per person. This is the background radiation from soil, cosmic rays, and natural radioactivity in the body. Just by residing near certain shale or granite outcroppings a person could get up to 200 mrem/yr from natural sources. This was the high end of the distribution of natural exposures in the region. It is also close to the average background exposure level in Colorado. In some regions outside the United States, the natural background is over 500 mrem/yr.

The largest population exposures, other than background, come from diagnostic X-rays (medical, dental, and chiropractic), with an average

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1. National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (the BEIR Committee), "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," NAS, Washington, DC, 1972.
2. G. W. Casarett, "Biological Effects of Low Levels of Radiation Exposure" in "Radioactivity in Consumer Products," NUREG/CP-0001, Washington, DC, 1978.

of some 18 mrem per U.S. citizen computed for the year 1979.[1] X-ray images are used to benefit health, but they are taken with widely different efficiencies. Makers of X-ray equipment and State Bureaus of Radiological Health are working to raise the efficiency to higher standards, with a prospect of future reductions in the average annual diagnostic exposure.

Another source of exposures came to light in tests of ionizing radiation in homes. The radioactivity in the homes had nothing to do with nuclear power: it came from the decay of naturally occurring radium in the cement and other structural material used in the construction of the houses. It was known, for some time, that cement construction gives occupants of buildings an annual exposure of some five mrem above background. The recent tests, however, showed wide differences from home to home, with some of the highest exposures more than doubling the background level. The Environmental Protection Agency is now studying what advice to give the homeowners (much can be done by simple ventilation) and developing regulations for the identification and disposal of waste materials which have higher than usual naturally occurring radioactivity.

Nuclear power plants produce vast amounts of radioactivity, but they are designed to contain nearly all of it, and they are monitored to measure all the releases. The highest level of exposure calculated at the site boundaries of the Browns Ferry Nuclear Plant in the six months from January through June 1979 amounted to about 7 mrem above background or 14 mrem/yr.[2] For this whole region in the year ending June 1979 the average exposure from this source was about 0.001 mrem per person.

Exposures to ionizing radiation are an occupational hazard to workers in the nuclear industry and nuclear medicine and to x-ray and gamma ray machine operators in medicine and industry. TVA monitors the exposure of each of its workers in areas of potential radiation exposure

1. Report of the Interagency Task Force on the Health Effects of Ionizing Radiation, Department of Health, Education and Welfare, June 1979.
2. "Radiological Impact Assessment, Browns Ferry Nuclear Plant, January-June 1979," MRH-79-7-DF3, Tennessee Valley Authority, June 1979.

and does not permit the year's exposure to go over 4,000 mrem. In practice, few workers accumulate as much as 1,000 mrem of exposure in a year at work. Because these exposures are significantly greater than the background exposure and constitute a potential job hazard to the individuals, they are accounted for separately from the exposures of the general population. If the small number of exposed TVA workers was lumped with the large number of residents in the region in computing the average annual exposure, the increase caused by the occupational exposures would be relatively small.

For these reasons, the exposure to ionizing radiation of the general population of the Tennessee Valley region would not have been significantly smaller without the Browns Ferry Nuclear Plant than it was with it.

(2) Risks of Accidents

TVA operates large coal burning, nuclear, and hydroelectric power systems. It has in its territory major operations that make up both the coal fuel and the nuclear fuel cycles, and is engaged in intensive development of technology for solar applications. Each energy system is liable for some share of environmental degradation, damage to health, and long-term hazards to life because each system leans heavily on a different facet of the environment. Hydroelectric plants are land-intensive, inundating large portions of the watershed. Coal power plants are fuel intensive: a 1,000-megawatt electric power plant burns 400 tons of coal per hour. Nuclear power plants are radioactivity intensive: they pack the fuel for a whole year's production of electricity into a single reactor vessel. Solar water heaters are materials intensive: a relatively large area of collector, preferably made of copper, is needed for each low-power unit.

The resulting mix of liabilities to human health and the environment is different for each system as discussed below. It would be a mistake to conclude that nuclear power is the only form of energy generation that is the bearer of a hazard. On the contrary, each of its adverse effects is shared by other energy systems, so that after an overall comparison of liabilities, nuclear was considered to be the preferred source of additional electric power in the Tennessee Valley for the near future. With new technological developments, relative risks can change. Minimizing these risks for the benefits received is an important goal of TVA's continuing development programs.

Environmental impacts differ both in timing and in extent. The major environmental impacts of a hydroelectric installation are over and done with when a stretch of landscape has been flooded behind the dam, and the resulting pool can then be used for recreation and controlling floods. Solar energy could also claim whole areas of landscape, to mine and smelt copper for solar collectors and associated plumbing. Copper mining for solar units would also, for the most part, be over once the units were built, and the land could be reclaimed. By contrast, coal and uranium mining must continue as long as these fuels are used to generate energy. The resulting environmental impacts and the difficulties of reclamation, however, are far greater for coal mining simply because 1,000 tons of coal are needed to yield the same amount of electrical energy as 40 tons of ore containing about 0.2 percent uranium. The occupational damages to health from underground mining of coal and uranium are also roughly proportional to the amounts mined.[1]

Hydroelectric dams, coal plants, and nuclear facilities all pose some continuing risks to populations downstream or downwind.

Prevention of a flood or of a release of radioactivity is both an initial design problem and a long-term custodial problem. Dams, nuclear reactors, and spent fuel storage pools are designed to withstand extreme events such as earthquakes, and are monitored to maintain the margin of safety they were designed to have. Scenarios describing an imaginary disaster (a "design base accident") are useful as one way of promoting conservative design and vigilant supervision; they are quite disturbing both for dams and for nuclear power plants,[2,3] much less so for spent fuel storage

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1. R. L. Gotchy, "Health Effects Attributable to Coal and Nuclear Cycle Alternatives," NUREG-0322, Washington, DC, 1977.
2. A. O. Babb and T. Mermel, "Catalog of Dam Disasters, Failures and Accidents." Bureau of Reclamation, Washington, DC, 1968.
3. H. W. Lewis, "Risk Assessment Review Group Report to the U. S. Nuclear Regulatory Commission." Washington, DC, 1978.

facilities and transportation.[1] The potential for a major accident will be much smaller after these facilties are decommissioned, and future generations may find that it is less trouble to leave them in place and watch them than it is to dispose of them in any other way. Abandoned undergound mines will also remain for an indefinite future. Strip mines, by contrast, can be reclaimed when mining is ended.

Both coal and nuclear power generate troublesome wastes. Nuclear wastes are highly toxic due to natural and man-made radioactive isotopes; coal wastes, although much less concentrated, contain naturally occurring radioactive isotopes and other important pollutants. Standards for releases of toxic wastes are set by the EPA in an even-handed way, to bring risk of damages to public health from either source below approximately the same level. Normal releases from nuclear power plants have remained at a small fraction of permissible levels in air and water. Actual release of pollutants from coal power plants have been much closer to the permissible level: TVA is taking action to ensure releases from its coal power plants will all be in compliance. The most troublesome pollutant from coal is sulfur dioxide gas and its chemical derivatives (SO_x), potential sources of damage both to human health and to lake ecosystems. Fly ash, bottom cinders, precipitator, and scrubber sludge from coal plants contain radioactive radium at concentrations from 2 to 8 picocuries per gram. EPA has proposed classifying anything with more than 5 picocuries per gram as controlled radioactive material requiring special disposal. In this context the unusual feature of spent nuclear fuel is that it retains the waste products of the nuclear reaction. The bulk of the coal combustion wastes, by contrast, either goes out in the air or is appropriately disposed of with cinders, ashes, and sludge. By storing spent nuclear fuel we store waste material in order to confine pollution.

When a nuclear power plant is taken out of service, most of the slack is now taken up by coal plants. If a sufficient number of coal plants could be constructed, TVA's nuclear power plants could be phased out of operation

1. G. Yadigaroglu, et al., "Estimation of Spent Fuel Transportation Risks," Trans. Amer. Nucl. Soc. 15:74, 1972.

before there is any need for additional storage facilities for spent fuel. To do so, however, would be to replace the hazard of confined pollution with the damage done by released pollution. It would also be extremely costly and would adversely affect TVA's reserve generation capacity. This was not seen as an acceptable choice.

C. Notes on Facilities and Equipment

Spent fuel

Commercial nuclear fuel consists of short cylindrical pellets of ceramic uranium dioxide (UO_2). These pellets are stacked and sealed in a zirconium alloy tube. Fuel rods thus formed are then assembled into bundles in a square array called a fuel assembly which has dimensions of 5" x 5" x 12½' in the case of the boiling water reactors (BWR's) at Browns Ferry. While the number of fuel rods and the size of the fuel assemblies are somewhat greater for pressurized water reactors (PWR's) at some TVA plants under construction, the number of fuel assemblies is less for these reactors, making the total amount of fuel about the same for both types.

Several hundred fuel assemblies are arranged to form a reactor core. New nuclear fuel is enriched in the isotope U-235, which produces most of the energy released in the reactor. U-235 is fissionable but is not very radioactive, and new fuel is safe to handle.[1] The fission reaction is turned on or off in the reactor by means of control rods. With the reactor on, nuclear reactions generate heat and convert the fuel gradually into a wide variety of new isotopes. Most of them are radioactive. One, Pu-239, is fissionable and becomes an additional source of energy, but U-235 is depleted faster than Pu-239 is built up.

Depending upon the reactor type, about one-fourth to one-third of the fuel assemblies must be replaced each year (approximately 30-35 metric tons) due to depletion of U-235 and the buildup of isotopic fission products. The spent fuel in these assemblies contains these isotopes which are a heat source and require cooling in water to prevent damage to the fuel.

1. The word "safe" is used here to indicate that workers require no special protection to limit radiation exposure.

The spent fuel assemblies are removed from the reactor by using a remotely operated unloading machine and temporarily stored in the power plant spent fuel storage pool where they remain stored under at least 20 feet of water while radioactivity and internal heat generation decreases by radioactive decay. This radioactivity diminishes rapidly in the first year or so and more slowly thereafter.

Fuel storage pools

Each of TVA's nuclear facilities is designed to include built-in spent fuel pools, typically with storage capacity for the spent fuel resulting from 10 to 15 years' operation 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 major maintenance and inspections requiring the removal of all fuel from the reactor vessel.

Spent fuel stored in the pools is not as intensely radioactive as the fuel in the reactor, but the spent fuel does contain a large amount of radioactivity and must be carefully stored.

Table 3

TYPICAL RADIOACTIVITY INVENTORY
OF SPENT NUCLEAR FUEL
5 YEARS AFTER REMOVAL FROM A REACTOR

		Reactor Type	
		BWR	PWR
Average fuel exposure, MWD/MTU[1]		35,000	45,000
Isotopes:	Tritium (H-3), Ci/MT[2]	610	840
	Carbon-14 (C-14), Ci/MT[2]	0.7	0.9
	Krypton-85 (Kr-85), Ci/MT[2]	7,910	9,090
	Iodine-129 (I-129), Ci/MT[2]	0.037	0.049
Nonvolatile fission products, Ci/MT[2]		4.6×10^5	6.3×10^5

1. MWD/MTU = megawatt-day per metric ton unit. (This is a measure of the amount of energy drawn from each ton of fuel.)
2. Ci/MT = curies per metric ton. (A curie is a measure of the rate of radioactive disintegration.)

During a reactor refueling, spent fuel is generally transferred under water on a specially designed transport cart. This is accomplished through a fuel transfer canal connecting the reactor refueling pool to the bottom of the spent fuel pool. When moving the spent fuel from the pool to another facility, such as an independent storage facility, a fuel cask is lowered into the pool onto a specially built stand where one or more spent fuel assemblies are raised into the cask. The sealed cask can be removed via an overhead crane to a truck or railroad car for transport. The casks used for this purpose provide efficient radiation shielding and cooling during transport, and are extremely strong as described below. In the pool, the spent fuel is moved about underwater with remote handling equipment. The fuel is kept underwater because water aids in transferring heat from the assemblies and acts as a good shield against radiation. At depths normally 15 to 20 feet or more, radiation levels are quite safe for normal work activities. Water also allows the workers to see the fuel assemblies.

Prevention of criticality (chain reaction in the stored fuel) is a most important feature of pool safety. Fuel is now stored in high-density storage racks containing a neutron-absorbing material to provide appropriate separation of fuel assemblies and to increase neutron absorption assuring against a criticality accident.

A second important task is to preserve the fuel cladding from corrosion and mechanical damage for as long as possible by careful handling of the fuel assemblies and by appropriate water treatment.

The independent storage facility discussed in this report will use a water-cooled storage pool. The technology of water-cooled pool storage is well developed, and water basins have been used successfully for receiving and storing spent nuclear fuel for 20 years. The actual water pool could best be characterized as a large, steel-reinforced concrete structure with walls several feet thick having a 30- to 40-foot deep stainless steel lined pool in its middle. Supported on bedrock, the storage pool is designed to retain its watertight integrity for all design accidents, including tornadoes and earthquakes. The storage facilities are designed (1) to resist rupture and to retain adequate water to ensure safe storage of the fuel assemblies, and (2) to prevent all massive equipment, such as cranes, etc., from falling into the pools, thus causing damage to the spent fuel during a tornado or earthquake.

Shipping casks

A shipping cask holds one or more fuel assemblies and serves both as a heat exchanger to cool the spent fuel and a shield to absorb the radiation. Regulations (10 CFR 71) help ensure these casks are accident-proof containers. The cask design has been tested to withstand impact, fire, and immersion.[1]

A cask designed for truck or rail transport should be able to come through a collision at high speeds and a possible resulting fire without cracking.

This equipment may only be damaged in an highly improbable serious accident. The consequences can then be analysed in stages.[2] The liquid or cooling gas may leak out through a crack in the cask. This material could be contaminated with radioactive materials only to the extent that some fuel elements were also damaged and leaked while in the cask. Second, the fuel rods will increase in temperature from internal heat generation if the coolant is lost. This may damage the cladding and release some gases. Last, and in a most unlikely circumstance, fire from the accident may reach the fuel within the rods, releasing highly radioactive vapors. The design of the cask is intended to provide time, even in the most serious accident, to warn people downwind from the wreck and to stabilize the load. Whether this theoretical opportunity would actually be used to advantage will depend on the provisions for safeguarding hazardous shipments described in section V of this report.

Spent fuel storage installations

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

1. Proceedings of the Fifth International Symposium, Packaging and Transportation of Radioactive Materials, May 7-12, 1978, Las Vegas, Nevada.
2. "Environmental Surveys of Transportation of Radioactive Materials to and from Nuclear Power Plants," WASH-1238.

would include areas for buildings, tranportation 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 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, decontaminating loaded casks, and accommodating fuel with cladding penetrations.

D. Notes on Reference Materials

This report deals with a preliminary review of the relative merits of the two principal alternative approaches to extend spent fuel storage. Long before any new facility is built, TVA will prepare an environmental assessment of the proposed project, a detailed project design, and a report on the safety of the design. These reports will be public documents accessible through the TVA Citizen Action Office at Knoxville. These will be the source of information that interested citizens can use to confirm that the proposed facility will live up to the standards which could only be outlined in general terms in this report.

Those interested in the current record of performance of TVA's nuclear power facilities are invited to refer to the most recent report: "Radiological Impact Assessment, Browns Ferry Nuclear Plant, January-June 1979," MRH-79-7-DF3, available through the TVA Information Office at Knoxville.

A clear and simple explanation of ionizing radiation and nuclear power can be found in a compact book by E. J. Hall, "Radiation and Life" (Pergamon Press, New York, 1976).

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of	)	
	)	
Proposed Rulemaking on	)	Docket No. PR-50, 51
	)	
the Storage and Disposal	)	
	)	
of Nuclear Waste	)	

CERTIFICATE OF SERVICE

I hereby certify that I have served the original and 20 conformed copies of the following documents on the Nuclear Regulatory Commission by depositing them in the United States mail, postage prepaid and addressed to Secretary, U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Chief, Docketing and Service Section:

Tennessee Valley Authority's
Statement of Position

and that I have served a copy of the above document upon the persons listed below by depositing it in the United States mail, postage prepaid and addressed to:

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This 7 day of July, 1980.

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5

Tennessee Valley Authority

KNOXVILLE, TENNESSEE 37902

PRM50 44FR61372
PRM51 44FR61372

July 7, 1980

DOCKETED
USNRC
JUL 7 1980
Office of the Secretary

Secretary
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Attention: Chief, Docketing and Service Section

Re: In the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste - Docket No. PR-50, 51

Dear Sir:

We are enclosing for filing in the above proceeding the original and 20 conformed copies of the following document, together with the certificate of service:

Tennessee Valley Authority's Statement of Position

Sincerely yours,

Herbert S. Sanger, Jr.
Herbert S. Sanger, Jr.
General Counsel

Enclosures

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UNITED STATES OF AMERICA
BEFORE THE NUCLEAR REGULATORY
COMMISSION

In the matter of	)	
	)	
PROPOSED RULEMAKING ON	)	Docket No. PR-50, 51
THE STORAGE AND DISPOSAL	)	
OF NUCLEAR WASTE	)	

TENNESSEE VALLEY AUTHORITY'S
STATEMENT OF POSITION

INTRODUCTION AND SUMMARY

.ennessee Valley Authority (TVA) hereby submits its statement of position in the above-captioned proceeding. As stated in the Notice of Hearing, this proceeding is designed to: (1) reassess confidence that safe storage of spent fuel will be possible; (2) determine when storage or offsite disposal will be available; and (3) examine whether wastes can be safely stored onsite, if offsite storage or disposal will not be available until after the expiration of the licenses for nuclear facilities. It is TVA's position that safe storage of spent fuel resulting from the operation of TVA's reactors in operation or under construction is possible now and that spent fuel can be safely stored onsite in the event that offsite storage is not available. This is based on the following: