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STUDIES AND RESEARCH
CONCERNING BNFP

LWR SPENT FUEL STORAGE

Frank A. Shallo

August 1978

BASE TECHNOLOGY

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DEPARTMENT OF ENERGY
FUEL CYCLE PROGRAM OFFICE
UNDER CONTRACT ET-78-C-09-1040

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ABSTRACT

This report describes potential spent fuel storage expansion programs using the Barnwell Nuclear Fuel Plant = Fuel Receiving and Storage Station (BNFP-FRSS) as a model.

Three basic storage arrangements are evaluated with cost and schedule estimates being provided for each configuration.

A general description of the existing facility is included with emphasis on the technical and equipment requirements which would be necessary to achieve increased spent fuel storage capacity at BNFP-FRSS.

GLOSSARY

AE	- Architect Engineer
AFR	- Away From Reactor
AGNS	- Allied-General Nuclear Services
ASLB	- Atomic Safety and Licensing Board
BNFP	- Barnwell Nuclear Fuel Plant
BWR	- Boiling Water Reactor
CCTV	- Closed Circuit Television
cfm	- Cubic Feet per Minute
CFR	- Code of Federal Regulations
CUP	- Cask Unloading Pool
DBE	- Design Basis Earthquake
DOE	- Department of Energy
DOT	- Department of Transportation
EIS	- Environmental Impact Statement
FES	- Final Environmental Statement
FRSS	- Fuel Receiving and Storage Station
FSAR	- Final Safety Analysis Report
FSP	- Fuel Storage Pool
FTP	- Fuel Transfer Pool
GEIS	- Generic Environmental Impact Statement
HEPA	- High Efficiency Particulate Air
HVAC	- Heating, Ventilation, and Air Conditioning
kVa	- Kilovolt Ampere
LWR	- Light Water Reactor
MTU	- Metric Tons of Uranium
MWd	- Megawatt Days
NLI	- NL Industries (formerly National Lead)
NRC	- Nuclear Regulatory Commission
OBE	- Operating Basis Earthquake
P&ID	- Piping and Instrument Diagram
PWR	- Pressurized Water Reactor
QAD	- Shielding Computer Code
RMSC	- Remote Maintenance & Scrap Cell
RPC	- Remote Processing Cell
SER	- Safety Evaluation Report
TDP	- Test and Decontamination Pit
TV	- Television
TYP	- Typical

1.0 INTRODUCTION

This report has been prepared by Allied-General Nuclear Services (AGNS) for the Department of Energy (DOE) under Contract No. ET-78-C-09-1040.

The information presented herein is part of Task 1-Spent Fuel Handling Studies activities and is intended to satisfy the following objectives:

- Sub-Task 1.4.1 - Conduct a study of potential storage capacity available and related technical requirements within the existing BNFP-FRSS, limited by the existing canister storage arrangement utilizing current compaction technology. Structural and seismic requirements will be defined and preliminary criticality evaluations will be conducted. Cost estimates and schedules for engineering, licensing, and construction will be prepared. (For purposes of this report, this Sub-task will be referred to as the 830 MTU Case.)
- Sub-Task 1.4.2 - Conduct a preliminary conceptual study of potential storage capacity available within the existing FRSS, unlimited by the constraint of the existing canister storage arrangement. (For purposes of this report, this Sub-task will be referred to as the 2250 MTU Case.)
- Sub-Task 1.4.3 - Conduct an arrangement study of expansion of the existing FRSS facilities coordinated with the preliminary siting plan covered in Sub-Task 3.7, "Overall Siting Plan," prepared under the subject contract. (For purposes of this report, this Sub-task will be referred to as the 5000 MTU Case).

Each of the three cases described in this report are presented as separate expansion programs.

The cost estimates and schedules (engineering, licensing, procurement, and construction) presented in this report are based principally on AGNS' experience in constructing the existing facilities.

While the existing BNFP-FRSS has been designed as an integral part of the reprocessing facility, i.e., a holding basin for spent fuel prior to reprocessing, it was initially designed with inherent storage expansion capabilities. Thus, the BNFP-FRSS could be readily used as a model for AFR storage studies.

Use of the FRSS, either in its existing or expanded configuration, for storage of spent fuel would involve the utilization of facilities originally dedicated to the performance objectives of the BNFP and could have a beneficial impact on the utility of the plant as a spent fuel reprocessing facility. Any modification or use of the FRSS for interim storage of spent nuclear fuel should and could be done in such a manner as to retain the performance capability of the overall plant for its intended service.

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2.0 SUMMARY OF RESULTS

Potential spent fuel storage expansion capabilities at the BNFP-FRSS, along with their associated costs and schedules, are summarized in Table 2-1 and the following paragraphs.

2.1 Storage Expansion Capabilities

The existing spent fuel storage capacity of 400 Metric Tons Uranium (MTU) could be increased substantially by using high-density fuel storage equipment of the type now licensed by the Nuclear Regulatory Commission (NRC) and installed at various nuclear power plants. Replacing the present fuel storage canisters (Figures 3-5 and 3-6) with high-density canisters (Figures 3-7 and 3-8) would enable about 830 MTU of spent fuel to be stored in the present storage configuration.

Filling the existing pools with high-density storage racks (Figures 3-9 and 3-10) would enable about 1750 to 2700 MTU of spent fuel to be stored in the existing FRSS depending upon the storage configuration selected. As shown in Table 4-1, 1750 MTU of spent fuel storage could be achieved by using currently licensed high-density racks in a single-tier arrangement; 2100 MTU could be achieved by using maximum-density racks which take credit for fuel burnup and which are expected to be licensed in the near future in a single-tier arrangement; 2250 could be achieved by using high-density racks and a double-tier arrangement in the Cask Unloading Pool (CUP) and the Fuel Transfer Pool (FTP) and a single-tier arrangement in the Fuel Storage Pool (FSP); 2700 MTU could be achieved by using maximum-density racks and the double/single-tier arrangement mentioned above. The 2250 MTU fuel storage capacity arrangement has been selected as the Sub-Task 1.4.2 reference capacity for this report.

Further capacity increases to a total of 5000 MTU and beyond could be accomplished by constructing new storage pools adjacent to the existing FRSS and interconnecting them through a previously planned canal to the present FTP. Three new pool modules (each about 34 feet wide by 72 feet long by 40 feet deep, which approximates the available storage area of the existing FSP at 48 feet wide by 48 feet long by 30 feet deep) were selected for analysis. Each new pool would have a storage capacity of about 1300 MTU utilizing currently licensed rack technology. These new pools coupled with the existing FSP modified to accommodate 1100 MTU would provide an overall storage capacity of 5000 MTU. Other existing pools have been designated as fuel unloading and fuel transfer areas for the purposes of the 5000 MTU portion of this report.

Additional pool modules could be added later by expanding toward the east, where land is available for new storage pool module additions at the BNFP. In addition to storage capacity increases available from the new pool modules, further increases could be obtained by double tiering storage racks and/or using maximum-density spent fuel storage racks now under development which take credit for fuel burnup. It is expected that maximum-density racks will be licensed by the NRC in the near

future and would be available for future expansion programs. This type of rack would increase storage capacity approximately 20% in the same pool area at a cost competitive with currently licensed designs. Using maximum-density racks throughout and a double-tier arrangement in the existing CUP, the FTP and the three new storage pool modules could stretch the 5000 MTU capacity to about 7500 MTU.

Another potential improvement in space utilization for spent fuel storage is through disassembly and encapsulation of fuel rods. Fuel rods from two assemblies could be placed into a container about the same size as one spent fuel assembly. This compaction arrangement could double the storage capacity of a facility of given size. Such compaction techniques are being evaluated in the AGNS/DOE FY-1978 program and will be presented in detail in a separate report. Possible locations for fuel rod disassembly facilities include nuclear power plant sites or Away-From-Reactor (AFR) storage centers, as well as the BNFP Remote Process Cell-Remote Maintenance and Scrap Cell (RPC-RMSC) facilities now in place.

Future storage expansion programs, which incorporate new storage pool modules, double tiering, racks taking credit for fuel burnup, and fuel rod disassembly and encapsulation could be used to increase the BNFP-FRSS fuel storage capacity to 20,000 MTU or more in a cost-effective manner. Such programs could be implemented without losing the flexibility to accommodate future decisions on the ultimate disposition of spent fuel.

2.2 Cost Estimates

The present BNFP-FRSS could be expanded to 830 MTU for about \$16 million using the existing storage canister arrangement, to 2250 MTU for about \$25 million using a currently available high-density storage rack arrangement, or to 5000 MTU for about \$109 million using a currently available high-density storage rack arrangement in the existing Fuel Storage Pool and the new storage pool modules. As shown in Table 4-2, the major cost contributors would be the high-density storage equipment and the new pool modules. Dollar commitment/expenditure projections are also provided in Section 4.2.

2.3 Schedules

Either the 830 MTU or the 2250 MTU expansion programs could be completed within 30 months after full authorization to start. The 5000 MTU expansion program could be completed in 51 months after full authorization to start. The 51-month effort assumed use of the same Architect Engineering firm that was retained for the existing FRSS.

Figures 4-4 and 4-5 delineate time estimates for detailed engineering, licensing, procurement, and construction. It should be noted that the actual construction of the new storage pool portion of the project would be completed in about 21 months from the construction contract award

date. The schedule makes no provision for delays caused by protracted public hearings or court proceedings.

The schedule for the 5000 MTU program is phased so that the existing FRSS facility could be modified to store 1100 MTU and placed into operation within 30 months after full authorization to start. This would enable early fuel receipts to be accomplished should special or emergency situations arise at nuclear power plant sites. Performing new pool construction adjacent to the existing FRSS and in parallel with spent fuel receiving and storage operations in the existing FRSS has been evaluated and workable solutions can be developed.

TABLE 2-1

CAPACITY, COST, AND SCHEDULE PROJECTIONS FOR BNFP-FRSS

Capacity (MTU)	830 ⁽¹⁾	2250 ⁽¹⁾	5000 ⁽²⁾
Cost (\$ x 10 ⁶)	16	25	109
Availability (Months after full authorization to start)	30	30	51 ⁽³⁾

NOTES:

- (1) Existing BNFP-FRSS Facility.
- (2) Existing Fuel Storage Pool plus add-on storage pools adjacent to existing facility.
- (3) 1100 MTU capacity available in 30 months; 3900 MTU additional capacity available 21 months thereafter.

3.0 METHODOLOGY

3.1 General

This section describes the approaches which would be used to accomplish the objectives specified in Section 1.0. Technical requirements including design criteria, seismic analysis, and criticality considerations are covered herein. In addition, necessary equipment modifications are identified and described. The primary source of data is derived from the actual experience gained by AGNS during the design, construction, and preoperational testing of the BNFP-FRSS.

3.1.1 830 MTU Case

One expansion alternative would involve replacing the present fuel storage canisters with canisters employing current high-density technology. For example, poisoned stainless steel canisters (capacity of 27 Boiling Water Reactor (BWR) or 15 Pressurized Water Reactor (PWR) spent fuel assemblies per canister) could be used in place of the present aluminum canisters (capacity of 18 BWR or 8 PWR spent fuel assemblies per canister).

The canister support structures would be modified to accommodate the greater weight of the additional assemblies and the seismic forces imposed by the design basis earthquake conditions for the facility.

A detailed criticality analysis would need to be performed during the detailed design engineering phase of an actual project to demonstrate that fully loaded fuel canisters would remain subcritical under normal and accident conditions. Preliminary reviews by AGNS and its high-density rack consultant lead to the conclusion that such equipment could be utilized while maintaining subcritical conditions.

Ancillary equipment modifications would be performed to provide for operational efficiency of the FRSS. In addition, the installation of physical protection-related equipment would be performed. Such modifications would include the establishing of limited personnel access areas, intrusion detection equipment, and other relevant safeguards systems and procedures.

Existing cask receiving and fuel-unloading equipment would be utilized for operational activities.

3.1.2 2250 MTU Case

Another expansion alternative would involve replacing existing fuel storage canisters and their support structures with high-density fuel storage racks. The racks would be attached to framework at the bottom of the pool. Pads would be connected to the framework to distribute seismic forces to the pool walls.

The high-density racks offer improved pool space utilization over the canisters because of more space efficient storage arrangement available with the framework supports versus the canister support structures.

Also, the racks could be modularized to retain the favorable handling and operating advantages offered with canisters.

The racks to be used for this alternative would be essentially the same design as racks presently licensed in various nuclear power plant fuel storage pool expansion programs.

Spent fuel would be stored in a single-tier arrangement in the 30-foot deep FSP and a double-tier arrangement in one 60-foot deep CUP and a portion of the 60-foot deep FTP. The second CUP would be used for fuel receiving operations. This arrangement will provide about 2250 MTU of fuel storage capability while fully utilizing existing FRSS pools.

Criticality analysis, ancillary equipment modifications, and physical protection equipment would be provided as described in Section 3.1.1.

Existing cask receiving and fuel-unloading equipment would be utilized for operational activities.

3.1.3 5000 MTU Case

A third expansion alternative requires the use of new fuel storage pool modules in addition to using a portion of the existing FSP. Adding the new modules would require site preparation, excavation work, and construction of three large storage pools (each about 34 feet wide by 72 feet long by 40 feet deep) interconnected by a canal to the existing FTP.

The existing FSP would be modified to store 1100 MTU of spent fuel assemblies in a single tier, vertical arrangement with sufficient aisle way for movement of fuel racks from the CUP to the FTP. The CUP and the FTP would be designated as the fuel unloading and transfer areas for this alternative.

Each new storage pool module would be designed to store about 1300 MTU of spent fuel using currently licensed high-density racks in a single tier, vertical arrangement. (Before proceeding with detailed design, consideration should be given to deepening the new storage pool modules beyond 40 feet to accommodate a double-tier arrangement.)

Design of these new pools would consider the design and seismic criteria used for the existing FRSS. Also, the new pool modules and canal would conform to existing applicable local, state, and Federal laws, regulations, codes, guidelines, and standards for this type facility.

Existing cask receiving and fuel-unloading equipment would be utilized for operational activities. Criticality analysis, ancillary equipment modifications, and physical protection equipment would be provided for the new facility as well as for the existing FRSS.

The arrangement of the expanded facility described herein and in Reference Drawings 519D-A-5001 through 5004 is consistent with the siting arrangements covered in Sub-Task 3.7-Overall Siting Plan. (The Reference Drawings are provided in Appendix F.)

3.2 Technical Requirements

The present FRSS facility is described in Appendix A. Details covering specific systems such as pool water, off-gas, ventilation, fire protection, personnel control, and radiation monitoring are provided in addition to FRSS operation and nuclear materials control aspects. In each of the fuel storage expansion alternatives evaluated herein, the existing FRSS would be used for cask receiving, unloading, and decontamination operations.

Appendix B delineates the baseline parameters for spent fuel assemblies to be considered for storage. The storage pools to be utilized for such storage are also specified in Appendix B.

3.2.1 Design Criteria

Appendix C describes the various design criteria used in engineering and constructing the present FRSS facility. These criteria would be utilized, where applicable, for a fuel storage expansion program which would include the ancillary and physical protection modifications to the existing FRSS.

Additional design information for the 5000 MTU Case is provided below.

3.2.2 Additional Design Information for Expanded Facilities for the 5000 MTU Case

3.2.2.1 Design Criteria

Design criteria for the new storage pool modules would include the following:

- The additional storage pools and ancillary systems would be developed in accordance with the design, material, and construction specifications used for the existing FRSS (as amended to meet any changes in NRC regulations) with the following modifications:
 - Type 304 stainless wrought material or Type 316 stainless cast material may be used in lieu of Type 304L in demineralized water or other services where nitric acid corrosion is not anticipated.
 - Ball valves may be substituted for gate valves.
 - Socket weld fittings and valves may be used for pipe sized 1-1/2 inches and smaller.

(These changes have been shown to be safe and the results would be lower costs and improved schedules.)

- The depth of the new storage pools would be 40 feet to allow for transporting a spent fuel assembly over the storage racks at reduced radiation levels (see Section 3.2.5).
- Leaker detection, canning capability, and an off-gas treatment station would be provided in the new facility.

3.2.2.2 Fuel Assembly and Rack Flow Pattern

The fuel receiving, handling, and storage operations would be performed as follows:

- Receiving, handling, and unloading of casks will be accomplished in the existing FRSS facilities (see Figure 3-1).
- Fuel assemblies will be unloaded from casks located in the CUP and placed into movable spent fuel storage racks.
- The high density, movable racks will be transported into the existing FSP or to the FTP.
- The racks will be transported from the FTP through the new canal to one of the new fuel storage pool inlets (see Figure 3-2).
- New cranes located over each pool will be used to remove fuel assemblies from movable racks and place them into designated locations in fixed racks located in the new pools.

3.2.2.3 Liquid Waste Handling (Reference Drawings 519D-A-5005 and 519R-A-5007)

Liquid waste handling activities would be provided as follows:

- Liquid waste from wash-downs and floor drains would be collected in a stainless-steel lined concrete pit. This waste would be pumped by a submerged type sump pump on level control to the liquid waste collection tank.
- Pool water filter backwash would be blown to a filter blowdown tank. The liquid waste, after each blowdown, would be pumped to the liquid waste storage tank through the solids decanter.
- Demineralizer backwash water would be directed into the liquid waste storage tank through the decanter.
- The liquid collected in the waste tank would be concentrated in a reboiler type evaporator. The solids from the decanter would be pumped to a receiver tank in the waste solidification area. The

concentrated liquid would be pumped to a feed tank in the waste solidification area.

- Steam from the reboiler would be discharged to the atmosphere via a stack which discharges 93 feet above natural grade.
- The concentrated liquid waste would be pumped to the waste solidification area. The waste solidification system would be a remotely operated evaporator-extruder type unit similar to those designed by Werner-Pfliderer. The system would further concentrate the liquid waste feed stock, fix the residue in a plasticized asphalt base binder, and package the mastic in steel drums. The drums would be shipped either from the site via truck for disposal or they would be stored in berm-type vaults on site for an interim period. Costs for drum disposal or on-site storage vaults have not been included in the estimates provided in Section 4.
- The liquid waste from the existing FRSS would be rerouted to discharge into the new liquid waste storage tank.
- Interconnections to the existing BNFP service concentrator would be provided for emergency use.

3.2.2.4 Heating, Ventilation, and Air Conditioning (HVAC) (Reference Drawing 519B-A-5008)

The HVAC system for the expanded facilities would include the following:

- The supply unit for the HVAC system would be a recirculating air system located outside the new facility. It would provide a minimum of six changes of air per hour. Air would be swept from supply headers along the east and west sides of the building and returned via exhaust headers located along the pool combings. Separate supply and exhaust ducts would be provided for the mechanical equipment areas and offices.
- Heating would be provided by steam heating coils.
- Cooling would be provided by a chiller system with air-cooled condensing unit.
- The design criteria for the HVAC would be the same as used for the existing FRSS.
- Two 50% capacity HVAC units would be used.

3.2.2.5 Building

The new building would be designed as follows:

- The building enclosing the new facilities would be constructed to the design criteria of the existing FRSS.
- Tornado-resistant concrete walls extending 25 feet above grade would be used on all exposed sides.
- Steel frame metal-sided building structure would be used above the 25-foot level, on unexposed sides, and for roofing.
- The steel building would be sheathed with insulated roof decking and insulated wall panel siding.
- Both decking and panels would be designed to fully or partially detach themselves from framing under high (tornado) winds. This would limit the load on the framing structure.
- The foundations, floor slabs, storage pools, canal, and mechanical equipment areas would be of concrete construction.

3.2.2.6 Utilities

The following utilities would be required and would be provided from the existing FRSS supply lines:

- Demineralized Water (DMW)
- Medium Pressure Steam (MS)
- High Pressure Steam (HS)
- Cooling Water Supply (CW)
- Cooling Water Return (CW)
- Instrument Air (IA)
- Plant Air (PA)
- Breathing Air (BA)
- Fire Water (FW)
- Regeneration Acid (K)
- Raw Water (RW)
- Electrical

3.2.3 Seismic Analysis

The existing FRSS has been designed to meet specified seismic events. Appendix D describes the seismic analysis used in the design of FRSS structures, vessels, piping, and appendages. Any future modifications or additions to the FRSS would consider the seismic data presented in Appendix D.

3.2.4 Criticality Evaluations

The nuclear criticality safety of the FRSS relies on the design of the facility and certain of its components as well as on the enforcement of certain administrative controls.

A summary of the criticality analysis for the FRSS is provided in Appendix E. The entire analysis was submitted to NRC by AGNS as "PROPRIETARY INFORMATION" and is presented in the PROPRIETARY SUPPLEMENT to the FSAR. Therefore, it is not available for inclusion in this report. However, it is believed that Appendix E provides sufficient information for this report.

The Office of Nuclear Material Safety and Safeguards (NMSS) of the NRC reported in its Safety Evaluation on the BNFP- FRSS, NUREG-0009, dated January 1976, that their independent reactivity calculations verified the AGNS evaluation. They concluded that, "the applicant has fully considered the variables that affect nuclear criticality safety, adequately evaluated the safety of the operation of the FRSS, and has incorporated the Technical Specifications and administrative controls to operate the facility safely and protect it against inadvertent criticality."

Criticality evaluations for high-density storage equipment are discussed in Section 3.3.5. The storage density changes described in this report are based upon previously licensed high-density technology and, therefore, this experience should enable straightforward preparation and acceptance of final criticality analysis for the mode of storage increase selected.

3.2.5 Radiation Levels During Individual Fuel Assembly Handling

Radiation levels from handling a spent fuel assembly at various water depths were investigated to verify that the fuel transfer operations envisioned in an expanded storage mode would be well within prescribed operator exposure criteria.

Dose rates in millirem per hour at 3, 6, and 9 feet above the water level were determined as a function of water depth over the top of the fuel assembly. The results of this shielding evaluation are shown in Figures 3-3 and 3-4. The QAD neutron and gamma shielding computer code was used with the neutron water kernel and water dose buildup.

For these calculations the fuel burnup was assumed to be 35,000 MWd/MTU for PWR assemblies and 28,000 MWd/MTU for BWR assemblies. The post-irradiation cooling/decay time was assumed to be five years for both fuel design types.

The resultant curves show that performing individual fuel assembly loading operations in a 40-foot deep storage pool with about ten feet of water covering will provide more than adequate shielding protection for the operators.

3.3 Equipment Requirements

3.3.1 Ancillary FRSS Equipment

During extensive testing of the FRSS facility after construction completion, a number of equipment refinements were identified which would improve operational flexibility and efficiency. Potential improvements were identified in the cask and auxiliary equipment handling activities and include the following:

- Test and Decontamination Pit (TDP) Work Platform - Install a movable working platform which will provide easy operator access to spent fuel casks during various handling operations. This item will improve safety and efficiency of cask handling operations in the TDP.
- FRSS 135-Ton Crane - Modify the 135-ton crane system to provide a rotatable hook, eliminate water entry of cable, change controls from pendant to radio operated basis. These changes will provide substantial improvements in operational efficiency.
- High Efficiency Particulate Air (HEPA) Filters for FRSS HVAC - Provide HEPA filter bank to remove airborne particulate from FRSS building.
- Additional Underwater TV's - Installation is required to enable fuel identification activities to be performed in an efficient manner.
- Rail Cask Yoke - Provide a lift yoke for the NLI 10/24 rail cask.
- Rail Cask Test Equipment - Provide special test equipment for testing and handling of rail casks. Equipment includes flow simulators, thermocouples and recorders, pressure relief valves, heater power supplies, and other related tools.
- Additional Rail Trackage - Additional trackage is required for improved movement of rail casks to meet fuel handling requirements and for storage of cask internals of specific cask designs.
- Cask Internals - Provide shielded storage for truck and rail cask internals for BWR and PWR fuel assemblies.

3.3.2 Physical Protection Modifications

The physical protection system, in addition to meeting existing NRC regulations, considers the proposed upgraded NRC requirements which have been published. We believe this approach to be prudent. The equipment required would include the following:

- Explosives Detection System - Provide state-of-the-art explosives detection hardware and/or systems to perform personnel explosives searches at the entrance to the Protected Area.

- Perimeter Closed Circuit Television (CCTV) Detection and Surveillance System - Install CCTV cameras with motion detection and a videotape recording device in the Protected Area.
- Vital and Material Access Area Intrusion Surveillance and Assessment System - Install necessary intrusion detection systems in all vital and material access areas.
- Site Surveillance/Assessment CCTV - Provide CCTV systems at several elevated locations on the BNFP site.

3.3.3 Expanded Facilities

Equipment required for expanded facilities for the 5000 MTU Case (see Reference Drawings provided in Appendix F) would include the following:

- Three new pools, each about 34 feet wide by 72 feet long and 40 feet deep, would be constructed and interconnected to the existing FTP by a canal. These pools would be lined with stainless steel.
- Each pool would be designed to store about 1300 MTU of Light-Water Reactor (LWR) spent fuel assemblies in currently licensed high-density spent fuel storage racks.
- Pool depth of 40 feet would allow sufficient water shielding for fuel assembly loading and unloading operations. Section 3.2.5 discusses radiation levels during fuel handling operations. Selective fuel assembly handling sequences would be provided.
- Each pool would be serviced with a separate circulating cooling water system, and demineralizing system. Common spare pumps, filter, cooler, and demineralizer will be provided. Emergency raw water service would be provided for each pool. (Reference Drawings 519R-A-5006, 519D-A-5009, and 519D-A-5010).
- Each pool would be serviced by a 15-ton fuel/rack handling crane which would also be suitable for individual fuel assembly handling.
- Liquid waste handling system would be provided. (Reference Drawings 519D-A-5005, 519R-A-5007, and 519D-A-5011).
- Provision would be made in the new facilities for a leaker detection and canning station.
 - The station pit would be approximately 8 feet wide by 10 feet long and 30 feet deep.
 - The station would be serviced by the extended existing FTP overhead crane.

- Off-gas collection facilities would be provided at the station capable of exhausting 1000 cfm of air. The gas would be passed through an iodine scrubber and HEPA filters and dispersed to the atmosphere via a 93-foot high exhaust stack (Reference Drawing 519B-A-5008).
- A new electrical substation with a connected load capacity of 1500 kVa would be included. Distribution from the new substation would be to motor control centers located in the new facility.

3.3.4 Spent Fuel Storage Canister Support Structures

Subcriticality would be maintained within the existing canister arrangement by a rather thick water medium between assemblies (e.g., six inches of water for PWR's). During partial withdrawal of the assemblies (say several feet), the normal water separation thickness would be retained. Therefore, a partial loss of fuel assemblies from a canister in the event of support structure failure would enable a subcritical condition to be maintained.

Reactivity control with the high-density canisters would be maintained by use of a flux-trap and/or fixed poison designs. If the fuel assemblies are partially withdrawn from the canisters, they could be separated by about one inch of water. This spacing in water is essentially optimum for criticality. Such a condition makes it essential that the support structures for the 830 MTU Case be capable of retaining the high-density canisters in the DBE event and that the canisters retain the fuel assemblies in conceivable canister drop accidents onto the support structures.

The present FSP support structures are non-Q structures with the exception of Q-rack anchorage embedments in the pool floor and walls. (See Appendix C for definition and discussion of Q structures.) Therefore, the present support structures upon which canisters rest in the various pools would need to be modified for the 830 MTU Case to accommodate the necessary seismic and criticality requirements in addition to the greater weight imposed by the increased number of assemblies to be stored with high-density storage equipment.

The requisite support structure modification has been evaluated by AGNS and its Architect Engineer (AE). The result of this study is that the support structure modification is technically feasible, and the necessary engineering, procurement, and construction effort could be completed in less than one year.

3.3.5 High-Density Fuel Storage Equipment

3.3.5.1 General Description

The fuel storage canisters presently available for the FRSS are shown in Figures 3-5 and 3-6. The basic construction material is aluminum.

Minimum center-to-center spacing between fuel assembly slots is about 12 inches for BWR and 17 inches for PWR type assemblies. Up to 18 BWR or 8 PWR fuel assemblies can be stored in each representative canister.

For the 830 MTU Case, the present canisters would be replaced with high-density storage canisters such as shown in Figures 3-7 and 3-8. The basic construction material for these type canisters would be stainless steel. Fuel assembly storage could be increased to either 27 BWR or 15 PWR fuel assemblies per each representative high-density canister. Fuel assembly center-to-center spacing for high-density canisters would be about 7.5 inches for BWR and about 14 inches for PWR assemblies.

High-density fuel storage racks as shown in Figures 3-9 and 3-10 would be used in place of canisters for the 2250 MTU or the 5000 MTU Cases. A basic difference between the high-density canisters and high-density racks described herein is the manner in which they are supported in the storage pools. Canisters would be held up off the pool floor by support structures which provide the point of support in the upper section of the canister. The racks would be supported at or near the bottom of the rack with a framework located at the floor of the storage pool. The high-density racks to be used in the existing FRSS would be of the movable type and those planned for the new storage pool modules would be fixed. Fuel assembly center-to-center spacing for high-density racks would be about 6.5 inches for BWR and about 10.5 inches for PWR assemblies.

For the 5000 MTU Case, movable high-density racks would be loaded with fuel assemblies in the CUP and transferred via cranes to the entrance of a new storage pool. There another crane would be used to lift each individual assembly out of a movable rack and into a designated location in the fixed rack located in the new storage pool. Radiation levels present at the pool surface during this operation are substantially below required limits. Section 3.2.5 covers this subject in greater detail. The empty movable rack would be returned to the CUP for a refilling operation.

3.3.5.2 Design Features

The concepts, detailed engineering features, fabrication, installation, and in-service storage functions for both poisoned and nonpoisoned canister and rack designs have already been proven in nuclear power plant fuel storage installations. Poisoned canisters or racks incorporate a neutron absorbing type material such as boron in addition to the basic material of construction, generally stainless steel. Each of these installations has been fully scrutinized by the vendors and NRC as to mechanical, structural, thermal, seismic, and criticality features; has been found adequate in all respects; and has been fully licensed for unrestricted service in the respective nuclear power plants for which it was designed.

3.3.5.2.1 Structural Analysis

The high-density fuel storage canisters and racks described in this report are designed as Seismic Class I structures in accordance with NRC Regulatory Guide 1.29. Typical modules would be made up of repeating arrays of stainless steel boxes welded together in rows and columns to form a solid stainless steel honeycomb structure. The structural analysis of the high-density storage equipment has considered all the loads and load combinations specified in NRC's Standard Review Plan. The honeycomb steel structure not only provides a smooth, all-welded stainless steel box structure to preclude damage to the fuel assemblies during normal and abnormal load conditions, but also provides an additional margin of safety in the form of internal structural damping created by the large areas of bearing surfaces between boxes in the array. The modules are capable of withstanding several g's. The seismic supports and attachments provided would be designed to minimize the loads transmitted to the pools.

3.3.5.2.2 Criticality Analysis

High-density spent fuel storage equipment has been designed to prevent an inadvertent criticality event under conceivable circumstances, including accident conditions. The nuclear analysis methods used in the design and evaluation of criticality safety for the spent fuel storage equipment have been benchmarked against appropriate experimental data and have been used to successfully license similar spent fuel canisters or rack designs. The assumptions employed in the criticality analysis are consistent with applicable Regulatory Guides and industry standards. These analysis methods and assumptions combined with conservative design margins assure that spent fuel storage canisters or racks can be expeditiously licensed without delays due to criticality safety concerns.

3.3.5.3 Maximum-Density Racks

Improvements in high-density storage rack technology are under development wherein maximum-density racks may likely become an NRC licensed design in the near future. One of the important features of this improved rack concept is that about a 20% gain in storage capacity is achievable over present designs without an increase in pool space. It is expected that these racks, which include fuel burnup credit as a design criteria, would be cost competitive with current generation high-density racks. Thus, a 5000 MTU spent fuel storage facility project may be efficiently increased to 6000 MTU at a minimum increase in total cost.

3.4 Cost Estimates

Estimated costs for expanding the present BNFP-FRSS storage capacity under the 830 MTU, the 2250 MTU, and the 5000 MTU Cases are provided in Section 4.2.

Initial sizing of the new storage pools approximates the storage area of the existing FSP. This permitted the cost estimate for the new storage pools to be based upon actual cost data available to AGNS from its existing FRSS project. All pertinent cost elements of the existing FRSS were reviewed and updated as necessary to establish a 1978 dollar base for determining the costs for the new storage pools. In addition, verbal cost information was secured from suppliers of selected major components.

The arrangement of three new storage pools plus a modification to the existing FSP meets the 5000 MTU requirement. The site provides for continued expansion, primarily toward the east, for adding additional modules at a future date if it is desired.

High-density spent fuel storage equipment cost estimates were provided in writing to AGNS by an experienced vendor who has supplied these types of racks to several electric utility companies. The rack design has already been proven in NRC licensed situations and the costs are well established. Section 3.3.5 provides detailed information on the high-density storage equipment.

Cost estimates for the ancillary FRSS equipment, physical protection modifications, and the other items listed in Section 4.2 are based in large measure on AGNS' actual experience for such equipment and services.

The cost estimates, including related licensing costs, do not include any provisions for protracted intervenor actions.

Escalation is based upon 1978 dollars increased at 10% per year to the midpoint of the construction portion of the project.

Contingency is based upon 15% for the high-density spent fuel storage equipment and 25% for the balance of the items.

Projected capital commitment/expenditure information is also provided in Section 4.2.

3.5 Schedules

Based upon the assumptions and criteria presented in this report, it is technically feasible to expand the present BNFP-FRSS facility to a storage capacity of either 830 MTU or 2250 MTU within 30 months from project start or 5000 MTU within 51 months from project start. Many of the required systems are already in place and significant NRC licensing milestones have been attained. It is estimated that the already completed activities would save two to three years in overall schedule time when compared to a "greenfield" project.

Major milestones for engineering, licensing, procurement, and construction are delineated in Section 4.3. Basic assumptions used to develop these schedules include the following:

- Actual experience gained in engineering and constructing the existing FRSS would be utilized.
- Valuable time during the early stages of the project for the 5000 MTU Case could be saved by employing, on a sole-source basis, the AE who performed such services for the existing FRSS.
- Site preparation work for the 5000 MTU Case would include digging out the subsoil to a depth of about 85 feet and back-filling and compacting with an appropriate grade soil. This would improve schedule time by eliminating the need for a preconsolidation berm.
- The capability of receiving early shipments of spent fuel in the existing FRSS under special or emergency situations is desired.
- Hearings proceed and comments are resolved on the recently published NRC-Generic Environmental Impact Statement (GEIS) on "Handling and Storage of Spent Light Water Power Reactor Fuel" (NUREG-0404) in a timely manner such that the BNFP expansion program is not delayed.
- A 12- to 15-month effort by NRC would be sufficient for NRC licensing.
- Work could proceed under the existing BNFP-FRSS Part 70 license application Docket 70-1729 utilizing the documentation for the existing facility which has already been prepared and evaluated by AGNS and NRC. (The present BNFP-FRSS license application has been contested by intervenors.)
- Special nuclear material other than spent fuel will not be stored on-site during the construction phase.
- Any delays due to protracted public hearings or court proceedings are not included in the schedule development.

Although it would be possible to initiate new construction earlier than the date shown in Section 4.3, it was elected to include nine months for NRC review of licensing amendments before the start of new storage pool construction.

3.6 Licensing Considerations

Licensing activities as prescribed by NRC regulations for the BNFP-FRSS are well advanced. In July 1974, AGNS submitted an application for authorization to operate the BNFP-FRSS. NRC assigned Docket No. 70-1729 to the AGNS application. An Atomic Safety and Licensing Board (ASLB) was appointed and formal proceedings were initiated. Between 1974 and 1976, numerous detailed exchanges of information were conducted between NRC and AGNS.

Two essential documents in the NRC licensing process were prepared by the NRC staff regarding the BNFP-FRSS. Both publications, the Final Environmental Statement (FES) (NUREG-0008), and the Safety Evaluation Report (SER) (NUREG-0009), were made available in January 1976. Pertinent decisions of the NRC staff were reported in each document. In each case, the NRC staff conclusions favored operation of the BNFP-FRSS.

In addition, NRC recently published a draft GEIS on "Handling and Storage of Spent Light Water Power Reactor Fuel" (NUREG-0404).

It is assumed that the requirements requisite to expanding the BNFP-FRSS fuel storage capability could be handled as amendments to AGNS' existing FRSS license application. The present application documents include a Technical Description complete with license conditions. Also, NRC would likely need to merely supplement its FES and SER and not prepare new documents.

As noted in the schedules set forth in Section 4.3 of this report, the licensing requirements are phased into essentially two parallel schedules; one schedule covers the existing FRSS facility, while the other covers the new storage pools and their ancillary systems. Spent fuel storage could commence within 30 months after program start for either the 830 MTU or the 2250 MTU Cases.

The net result for the 5000 MTU Case would be that the existing facility could be modified and ready to receive about 1100 MTU of spent fuel within 30 months after program initiation and AE selection. A total time of 51 months would be required before the new facility could be placed into full operation. Thus, the facility could be placed into a position to receive about 1100 MTU of spent fuel by March 1981 and an additional 3900 MTU by December 1982, with an October 1978 start date.

Specific licensing assumptions used by AGNS in developing the schedules presented in Section 4.3 include the following:

- The facility would be licensed in accordance with applicable NRC regulations.
- Engineering, procurement, and construction would proceed on a timely basis for the existing FRSS modifications.
- Modifications to the existing facility would be made in conformance to the license conditions included in the present FRSS license application as amended. A license amendment covering these modifications would be prepared and submitted to NRC. (Issue for construction drawings would be included in the amendment package.)
- All NRC reviews would be conducted on a timely basis and no delays within NRC's control would be incurred. (Protracted public hearings and court proceedings are not included in the schedule development.)

- Engineering and procurement of long lead-time items for the new storage pools would proceed on a timely basis.
- Existing BNFP-FRSS license application documents would be further amended to cover modifications for upgrading the existing facility for the selected expansion program.
- An additional license amendment would be prepared and submitted to NRC to cover the new storage pools and the interconnecting canal between the new facility and the existing FRSS if the 5000 MTU Case would be selected.

FUEL RECEIVING AND STORAGE STATION (FRSS)

FIGURE 3-1

ADDITIONAL SPENT FUEL STORAGE MODULES

FIGURE 3-2

RADIATION LEVELS FOR BWR FUEL IN POOL

FIGURE 3-3

RADIATION LEVELS FOR PWR FUEL IN POOL

FIGURE 3-4

STANDARD BWR SPENT FUEL STORAGE CANISTER

FIGURE 3-5

STANDARD PWR SPENT FUEL STORAGE CANISTER

FIGURE 3-6

NOTES:

1. Overall width 21.90, including spacer.
2. Estimated weight including fuel equals 27,000 pounds (13.5 tons).
3. All dimensions are in inches.

HIGH DENSITY BWR SPENT FUEL STORAGE CANISTER

FIGURE 3-7

NOTES:

1. Overall width 29.50 including spacer.
2. Estimated weight including fuel equals 27,000 pounds (13.5 tons).
3. All dimensions are in inches.

HIGH DENSITY PWR SPENT FUEL STORAGE CANISTER

FIGURE 3-8

REMOVABLE POISON
INSERTS
(TYP. 42 PLACES)

LIFTING LUG (3 REQUIRED)

TYPICAL POISON BOX

TYPICAL FUEL
STORAGE CELL

TYPICAL REMOVABLE
INSERT

TYPICAL 96 CELL
STORAGE RACKS

TYPICAL HIGH DENSITY BWR SPENT FUEL STORAGE RACK

FIGURE 3-9

TYPICAL HIGH DENSITY PWR SPENT FUEL STORAGE RACK

FIGURE 3-10

4.0 RESULTS

4.1 Spent Fuel Storage Capacity Projections

4.1.1 830 MTU Case

The existing FRSS fuel storage canister locations would be fully utilized for this case (Reference Drawing 519D-A-5012). The present canisters would be replaced with high-density storage equipment of similar exterior configuration. Section 3.3.5 describes the high-density canisters in greater detail.

The present 400 MTU storage capacity could be increased to about 830 MTU by replacing the existing canisters with movable high-density storage equipment of the type now licensed by NRC. As seen in Drawing 519D-A-5012, about 60 BWR and 75 PWR high-density storage canisters could be used to store about 1670 BWR and 1140 PWR assemblies. Space in CUP #2 would be provided for possible fuel shuffling requirements. The FRSS operation in this mode would be essentially the same as that for the current storage configuration.

4.1.2 2250 MTU Case

High-density fuel storage racks would be attached at or near the pool floor rather than being suspended in the pool as in the 830 MTU Case. In this case the racks would be mounted inside a grid structure or framework which rests at the base of the storage pools. This arrangement would permit closer spacing of racks than available in the 830 MTU Case. The overall result would be improved utilization of available storage pool space, thereby increasing storage capacity even further.

The existing storage pools would have to be modified by removing the present canister support structures and installing new supports for mounting the high-density racks at the base of the storage pool. Replacing the canisters with racks could be accomplished without limiting fuel handling selectivity and flexibility.

To allow for storage capacity effectiveness, the high-density racks would be loaded with spent fuel in CUP #2 only and then the fully loaded rack would be moved to its designated storage location in either the FSP, the FTP, or CUP #1.

The effective storage capacity could be increased to about 2250 MTU using a double-tier arrangement and current generation high-density storage racks to store spent fuel assemblies. Fuel would be stored in a single-tier configuration in the FSP and double-tiered in CUP #1 and a portion of the FTP. The double-tier arrangement would provide space for about 500 MTU of storage capacity. Other storage configurations are available and identified in Table 4-1.

4.1.3 5000 MTU Case

The existing spent fuel storage capacity could be increased to 5000 MTU by using high-density fuel storage racks in (i) the existing FSP, and (ii) new storage pool modules interconnected to the existing FTP.

Sufficient space would be provided in the FSP for an aisle way to permit storage racks containing fuel to be moved from the CUP's through the FSP and FTP to the new storage pool modules.

Initially three new pool modules (each about 34 feet wide by 72 feet long by 40 feet deep) would be constructed. The existing FSP would be modified to contain about 1100 MTU of fuel and each new pool would contain about 1300 MTU. This arrangement would provide about 5000 MTU of total fuel storage capacity. While other existing pools could be used for storage, they have been designated as fuel unloading and transfer areas for the purpose of this case to permit a 5 MTU per day or 1500 MTU per year receiving rate.

Movable high-density storage racks would be used in the FSP and similarly designed, but fixed racks would be used in the new pool modules. Fuel would be carried in a movable storage rack from a CUP to the entrance of a new pool. Individual assemblies would then be removed from the movable rack and placed into a designated storage location in a fixed rack. The new pool depth of 40 feet permits sufficient water shielding for this operation.

4.1.4 Additional Storage Capacity Increases

In addition to storage capacity increases available from additional new pool modules, further increases for the 2250 MTU Case (as identified in Table 4-1) or the 5000 MTU Case could be obtained from using maximum-density spent fuel storage racks which take credit for fuel burnup. It is expected that these racks will be licensed by the NRC in the near future, and they could be available for future expansion programs. This type of rack would increase storage capacity approximately 20% in the same pool area and would be cost competitive with currently licensed designs.

Another potential improvement in space utilization for spent fuel storage would be through disassembly and encapsulation of fuel rods. Fuel rods from two assemblies could be placed into a container about the same size as one spent fuel assembly. This compaction arrangement could double the storage capacity of a facility of given size. Such compaction techniques are being evaluated in the AGNS/DOE FY-1978 program and will be presented in detail in a separate report. Possible locations for fuel rod disassembly facilities include reactor sites or AFR storage centers as well as the BNFP RPC and RMSC facilities now in place.

Future storage expansion programs, which incorporate new storage pool modules, double tiering, racks taking credit for fuel burnup and/or fuel

rod disassembly and encapsulation could be used to increase the storage capacity at BNFP-FRSS to 20,000 MTU or more if the need arises.

Horizontal storage of spent fuel, while beyond the scope of this report, provides still another alternative for further increasing spent fuel storage capacity.

4.2 Cost Estimates

Cost estimates for the 830 MTU, the 2250 MTU, and the 5000 MTU Cases are provided in Table 4-2 and projected capital commitment/expenditure information is provided in Tables 4-3, 4-4, and 4-5 and Figures 4-1, 4-2, and 4-3. Basic assumptions used to develop these cost estimates are specified in Section 3.4.

Expansion of the present FRSS to an 830 MTU storage capacity would cost about \$16 million using the existing storage canister arrangement and high-density canisters; increasing the present capacity to 2250 MTU would cost about \$25 million utilizing a high-density rack arrangement; and achieving a 5000 MTU expansion program would cost about \$109 million using high-density rack arrangements in the existing FSP and the new storage pool modules.

4.3 Schedules

Engineering, licensing, procurement, and construction schedules for each case are provided in Figures 4-4 and 4-5. Basic assumptions used to develop these schedules are specified in Section 3.5.

The 830 MTU or the 2250 MTU Cases could be completed within 30 months from project start. The 5000 MTU Case would require 51 months from project start. It is assumed throughout this report that project funding by DOE would be on a timely basis which is essential for meeting the completion dates specified herein.

TABLE 4-1

POTENTIAL STORAGE CAPACITY IN EXISTING BNFP-FRSS (MTU)

<u>POOL AREA</u>	<u>W/HI-DENSITY (1) (2) RACKS</u>	<u>W/MAXI-DENSITY (1) (3) RACKS</u>	<u>W/DOUBLE TIERING AND HI-DENSITY RACKS</u>	<u>W/DOUBLE TIERING & MAXI-DENSITY RACKS</u>
Fuel Storage Pool (1)	1250	1500	1250	1500
Cask Unloading Pool (4)	275	330	550	660
Fuel Transfer Pool	<u>225</u>	<u>270</u>	<u>450</u>	<u>540</u>
TOTAL:	1750	2100	2250	2700

NOTES:

- (1) Single-tier, vertical arrangement of spent fuel assemblies.
- (2) Hi-density racks have been licensed by NRC for nuclear power plant spent fuel storage expansion programs.
- (3) Maxi-density racks are expected to be licensed by NRC in the near future. This design takes credit for fuel burnup and provides about a 20% increase in storage capacity over hi-density racks.
- (4) One CUP used for spent fuel storage and the other CUP for fuel loading/unloading/transfer operations.

TABLE 4-2

COST ESTIMATES FOR LWR SPENT FUEL STORAGE
Estimated Cost - \$ Millions

<u>Item</u>	<u>830 MTU Case</u>	<u>2250 MTU Case</u>	<u>5000 MTU Case</u>
• High-Density Canisters w/ Modified Support Structures	\$3.9	--	--
• High-Density Racks w/Necessary Supports	--	11.5	24.2
• Ancillary FRSS Capital Equipment	2.7	2.7	2.7
• Physical Protection Modifications	1.5	1.5	2.8
• New Storage Pool Modules and Inter-connection w/Existing FRSS - Engineered and Constructed	--	--	36.0
Subtotal	<u>8.1</u>	<u>15.7</u>	<u>65.7</u>
• Project Management	0.8	0.8	2.4
• License Applications Preparation, Filing and Amendments ⁽¹⁾	0.4	0.4	0.7
• License Application Processing and Public Hearings ⁽¹⁾	0.7	0.7	1.0
Subtotal	<u>1.9</u>	<u>1.9</u>	<u>4.1</u>
• Escalation Based Upon Estimated Schedules ⁽²⁾	2.1	3.2	19.2
• Contingency ⁽³⁾	<u>3.9</u>	<u>4.2</u>	<u>20.0</u>
TOTAL ESTIMATED COST	\$16.0	\$25.0	\$109.0

(1) Costs due to any protracted intervenor actions are not included.

(2) Based upon 1978 \$ escalated at 10% per year to midpoint of construction.

(3) Contingency monies are based on design package and are not intended to cover scope changes.

TABLE 4-3

COMMITMENT/EXPENDITURE PROJECTIONS FOR THE 830 MTU CASE

LEGEND:

Commitment
Expenditure

\$MM

Fiscal Year by Quarters

DESCRIPTION	1979				1980				1981				TOTAL
	1	2	3	4	1	2	3	4	1	2	3	4	
EXISTING FRSS MODIFICATIONS													
Engineering	0.1	0.2	0.3	0.2									0.8
	0.1	0.2	0.3	0.2									0.8
Licensing			0.2	0.3	0.4	0.2	-	-	0.4	0.2			1.7
			0.2	0.3	0.4	0.2	-	-	0.4	0.2			1.7
Racks			6.2	-	-	-	-	-	-	-			6.2
			-	0.6	-	0.9	0.9	0.9	2.9	-			6.2
Construction				0.1	0.6	1.0	1.5	2.0	1.5	0.6			7.3
				0.1	0.4	0.8	1.8	1.8	1.5	0.9			7.3
GRAND TOTAL	0.1	0.2	6.7	0.6	1.0	1.2	1.5	2.0	1.9	0.8			16.0
	0.1	0.2	0.5	1.2	0.8	1.9	2.7	2.7	4.8	1.1			16.0

TABLE 4-4

COMMITMENT/EXPENDITURE PROJECTIONS FOR THE 2250 MTU CASE

LEGEND:
Commitment
Expenditure

\$MM

Fiscal Year by Quarters													
DESCRIPTION	1979				1980				1981				TOTAL
	1	2	3	4	1	2	3	4	1	2	3	4	
EXISTING FRSS MODIFICATIONS													
Engineering	0.2	0.4	0.5	0.3									1.4
	0.2	0.4	0.5	0.3									1.4
Licensing			0.2	0.3	0.4	0.2	-	-	0.4	0.2			1.7
			0.2	0.3	0.4	0.2	-	-	0.4	0.2			1.7
Racks				14.3	-	-	-	-	-				14.3
				-	2.2	2.2	2.2	2.2	5.3				14.3
Construction				0.1	0.4	0.7	1.2	1.9	2.4	0.9			7.6
				0.1	0.2	0.5	1.0	2.5	2.5	0.8			7.6
GRAND TOTAL	0.2	0.4	0.7	15.0	0.8	0.9	1.2	1.9	2.8	1.1			25.0
	0.2	0.4	0.7	0.7	3.0	2.9	3.2	4.7	8.2	1.0			25.0

TABLE 4-5

COMMITMENT/EXPENDITURE PROJECTIONS FOR THE 5000 MTU CASE

Legend:

Commitment
Expenditure

\$MM

DESCRIPTION	Fiscal Year by Quarters																
	1979				1980				1981				1982				1983
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1
TOTAL																	
EXISTING FRSS MODIFICATIONS																	
Engineering	0.1	0.3	0.3	0.3													1.0
	0.1	0.3	0.3	0.3													1.0
Licensing		0.1	0.2	0.3	0.3	0.2	0.2	0.1	0.1	0.1							1.6
		0.1	0.2	0.3	0.3	0.2	0.2	0.1	0.1	0.1							1.6
Racks			7.3	-	-	-	-	-	-								7.3
			-	0.1	0.1	2.7	1.4	1.4	1.6								7.3
Construction				0.4	1.2	1.5	1.1	1.0	0.8	0.3							6.3
				0.1	0.8	0.8	1.3	1.6	1.2	0.5							6.3
Subtotal	0.1	0.4	7.8	1.0	1.5	1.7	1.3	1.1	0.9	0.4							16.2
	0.1	0.4	0.5	0.8	1.2	3.7	2.9	3.1	2.9	0.6							16.2
NEW FUEL STORAGE POOLS																	
Engineering	0.1	0.3	0.6	0.8	1.2	1.4	1.3	0.8									6.5
	0.1	0.3	0.6	0.8	1.2	1.4	1.3	0.8									6.5
Licensing					0.1	0.2	0.2	0.1	0.1	0.1						0.1	0.1
					0.1	0.2	0.2	0.1	0.1	0.1						0.1	0.1
Racks							26.5	-	-								26.5
							-	0.1	0.1		8.0			2.6	5.2	5.2	5.3
Construction											10.0	11.5	9.0	7.0	8.3	8.0	5.0
											2.0	13.5	7.5	13.0	10.0	5.3	7.5
Subtotal	0.1	0.3	0.6	0.8	1.3	1.6	28.0	0.9	0.1	0.1	10.0	11.5	9.0	7.0	8.3	8.1	5.1
	0.1	0.3	0.6	0.8	1.3	1.6	1.5	1.0	0.2	0.1	10.0	13.5	7.5	15.6	15.2	10.6	12.9
GRAND TOTAL	0.2	0.7	8.4	1.8	2.8	3.3	29.3	2.0	1.0	0.5	10.0	11.5	9.0	7.0	8.3	8.1	5.1
	0.2	0.7	1.1	1.6	2.5	5.3	4.4	4.1	3.1	0.7	10.0	13.5	7.5	15.6	15.2	10.6	12.9

COMMITMENT/EXPENDITURE FLOW
FOR THE 830 MTU CASE

FIGURE 4-1

COMMITMENT/EXPENDITURE FLOW
FOR THE 2250 MTU CASE

FIGURE 4-2

FISCAL YEAR

COMMITMENT/EXPENDITURE FLOW
FOR THE 5000 MTU CASE

FIGURE 4-3

SCHEDULE FOR THE 830 MTU OR 2250 MTU CASES

FIGURE 4-4

SCHEDULE FOR THE 5000 MTU CASE

FIGURE 4-5

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5.0 CONCLUSIONS

Spent fuel storage expansion programs are technically feasible at the BNFP-FRSS. Present storage capacity could be increased from 400 MTU to about 2700 MTU in the existing facility or to 5000 MTU with three additional reasonably sized storage pool modules and high-density storage equipment.

Storage expansion capabilities beyond 5000 MTU are inherently available at BNFP by using additional storage pool modules and/or next generation high-density storage equipment and/or spent fuel disassembly and fuel rod encapsulation techniques.

Cost estimates to implement spent fuel storage expansion alternatives at BNFP vary from \$16 million to \$109 million. The advanced status of the BNFP-FRSS could save two to three years in overall schedule time. The 830 MTU or the 2250 MTU Cases could be implemented within 30 months from project start or the 5000 MTU Case within 51 months. For the 5000 MTU Case, the project could be scheduled to utilize the existing FRSS within 30 months for spent fuel storage while construction of the new storage modules would be in progress.

The BNFP-FRSS has inherent fuel storage expansion capabilities and it is uniquely suited as a model for on-going advanced spent fuel storage expansion evaluations.

APPENDIX A

to

Report No. AGNS-1040-1.4-20

FACILITY SYSTEM DESCRIPTION

August 1978

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1.0 GENERAL DESCRIPTION

The Fuel Receiving and Storage Station (FRSS) is shown in Figure A-1 and Drawings 519E-A-5012 and 5013. Structurally the FRSS is a concrete and steel building housing stainless-steel-lined pools and related facilities. The systems in the FRSS and related facilities are provided for the safe receipt and storage of irradiated nuclear fuel assemblies commonly called "spent fuel" from light water nuclear power reactors. The FRSS building houses the fuel unloading, storage and transfer pools, service areas, and associated cooling, filtering, deionizing and circulating equipment. Service areas immediately adjacent to the pools are employed for handling, preparing, and decontaminating the casks in which the fuel is transported to the Barnwell Nuclear Fuel Plant.

The FRSS building contains five interconnected pools of water. Two of the pools, Cask Unloading Pools (CUPs) #1 and #2, are primarily used for unloading the spent fuel from the casks. The Fuel Storage Pool (FSP), serves as the primary pool for storage of the spent fuel. The Fuel Transfer Pool (FTP) contains a transfer conveyor system from which spent fuel assemblies could be safely moved out of the water storage and into a concrete shielded cell or room for fuel preparation for disposal or reprocessing. A fifth pool, the Failed Fuel Pool (FFP) is provided for use in segregating and handling damaged or leaking spent fuel assemblies, if any.

Immediately south of the entrances to the two cask unloading bays lies an outdoor parking area where incoming over-the-road tractor-trailers and railcars will be parked during the unloading operations. This area also includes a washdown station for rinsing of the transport equipment to remove surface road dirt and space for storage of spare cask internal baskets.

FUEL RECEIVING AND STORAGE STATION

FIGURE A.1

2.0 PHYSICAL DESCRIPTION

2.1 Protected Area

The protected area (Drawing 519E-A-5014), which comprises the FRSS, is encompassed by a chain-link fence and the exterior walls of the FRSS building. Within this protected area all operations associated with handling radioactive and/or contaminated materials will be controlled.

The parking area is asphalt-paved and covers roughly 100,000 ft². Entrance to this parking area may be gained through a road gate, three railway gates, or a pedestrian portal. In each case these entrances will be locked until opened by the Security Department which then supervises ingress and egress until the entrances are again locked. There are parking spaces within the parking area for about twenty trailers of the type used to transport spent fuel casks.

The outdoor washdown station is a concrete pad (100 feet by 24 feet) in the parking area. A railroad spur terminates on this pad. Utility services at this pad include utility air, utility water, 100-psig steam and electric power. Drainage from this pad collects in a 3-foot by 4-foot mud settling basin and then joins drainage from the parking area. Part of the parking area is dedicated to two rail spurs, one for switching out rail cars to permit exchange of a delivered railcar with one to be shipped, and the other leading into the east unloading bay in the FRSS building. The balance of the paved area is available for maneuvering of tractor-trailers and other mobile equipment.

Also located within the protected area are the ventilation and return air fan, situated east of the FRSS building and on top of the berm at elevation 272 feet and 0 inches.

2.2 FRSS Facility

Entrance into the FRSS building with spent fuel casks is gained through an 18-foot by 20-foot roll up door on the parking lot end (south) of each of the two unloading bays. The west unloading bay, during initial operation of the FRSS, will contain the FRSS waste solidification system and will not be used for spent fuel cask receipt. It will be usable, however, for the tractor-trailer trucks which will be employed to ship the low-level waste, in DOT approved containers, to a commercial waste burial contractor. The east unloading bay is the bay which will be used for spent fuel cask handling of both truck and rail casks.

Opening off the west bay is the water treatment room which contains the pool recirculation pumps and the pool filtration system. Access to the waste water sump pump is gained from this area.

Located between the two bays is the Test and Decontamination Pit (TDP) at elevation 252 feet and 0 inches. Equipment access is through doors from either bay. In this area, incoming casks will be prepared for the fuel unloading operation in the CUP. Outgoing casks are prepared and checked

before being loaded on the transport vehicle in the truck bay for shipment. Two stairwells at the south end of the building, with access from the unloading bays, connect the ground level facilities with those at poolside elevation.

The poolside level of the building is at elevation 274 feet and 0 inches. It is from this elevation that access is gained to the fuel pools. The building is generally "T" shaped. The cross of the "T" contains the two unloading bays, the Cask Cooldown System, the Test and Decontamination Pit, the Decontamination Pit and the two Cask Unloading Pools. This high bay portion of the building has a ceiling at elevation 337 feet and 0 inches. The stem portion of the "T" contains the Fuel Storage Pool, the Fuel Transfer Pool, and Failed Fuel Pool. The low bay stem portion of the building has a ceiling at elevation 315 feet and 0 inches.

West of the low bay portion of the FRSS building is the Deionization Area. Floor elevation is at 274 feet and 0 inches and provides direct access from the poolside level of the FRSS building. The deionization area contains the pool deionizer unit and the heat exchangers which provide pool cooling.

The pools have been constructed of reinforced concrete 4 to 5 feet thick and are installed to "Q" requirements.⁽¹⁾ They are lined inside with non-Q 304L stainless-steel 3/16 inch thick to form an impervious liner. The concrete behind the liner has been poured with depressions in the surface which form channels or water conduits to convey any water leakage to sumps or collection points. Some floor plates in areas such as gate slots and transfer lanes are 1/2 inch 304L stainless steel. The plates are welded to form a leak-tight barrier.

The pools are interconnected by means of opening isolation walls which have "drop-in" gravity gate slots. The slots are deep enough that canisters loaded with fuel may be moved underwater from one pool to another while normally maintaining sufficient water shielding over the active portion of the fuel assembly. The canister transport elevation is controlled by administrative procedures and a limit switch on the hoist. As further backup, there are mechanical stops which prevent raising the canister above a safe elevation.

The gates which provide pool separation are normally stored in the pools. They are tapered or "V" shaped as are the gate slots so that the gate can be inserted in the slot without lifting the gate completely clear of the water. It is only necessary to lift it high enough to clear the slot edge before lowering it into the slot.

(1) Structures, systems, and components designated herein as "Q" are those items that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public. These items are identified and documented as safety-related. The application of a Quality Assurance Program, based on compliance to Title 10 Code of Federal Regulation Part 50, Appendix B, Quality Assurance Criteria, is mandatory.

On the edge of each gate is an inflatable rubber gasket. This gasket is constrained in a slot so that when pressurized with at least 25-psig compressed air, it is forced out against the facing portion of the slot forming a water tight seal between the gate and gate slot. Gates used during liner leak testing have shown the gate seals to function satisfactorily.

2.3 Pool Water System

The water inventories of the fuel pools are given in Table 2.1 below.

TABLE 2.1
POOL WATER INVENTORY
(Estimated with no fuel in storage)

<u>Pool</u>		<u>Inventory (gals.)</u>
Cask Unloading Pools		
No. 1 and No. 2	230,000 gal. each	460,000
Fuel Storage Pool		540,000
Fuel Transfer Pool (incl. Failed Fuel Pool)		<u>285,000</u>
	TOTAL	1,285,000

NOTE: Water inventory will decrease as fuel inventory increases. Water displaced by cask immersion will be accommodated by water level fluctuations between elevations 275 feet 6 inches and 276 feet 6 inches.

The water in the fuel pools of the FRSS is channeled and treated to promote clarity, to control temperature, and to minimize corrosion and radioactivity. This is accomplished by filtration, demineralization, and cooling of the pool water. By the use of isolation gates, piping and valving, individual pools can be isolated and cleaned (filtration and demineralization with cooling of the water).

Pool cooling is accomplished using pool cooling heat exchangers. The two heat exchange units have a combined capacity of 14 million Btu's per hour at a mean ΔT of 14°F. The normal flow of the system is 1000 gallons per minute per unit. The normal temperature of the fuel storage pool was projected to be approximately 105°F based on 250 MTU with 160 days cooling, 27,000 MWd/MTU and specific power of 35 kilowatts per kilogram. Aged fuel will substantially reduce pool cooling requirements and, therefore, considerably greater quantities of aged spent fuel could be stored without affecting the overall pool cooling capability.

There is valving provided in the heat exchanger loop to isolate one heat exchanger at a time for maintenance. Administrative controls are employed to

ensure that normally no more than one heat exchanger is isolated at any given time; however, should the need arise, the time during which both pool cooling systems are shut down will be kept to a minimum. If required, additional cooling capacity could be provided as necessary by expanding the capacity of the plate-type heat exchangers through addition of plates. Cooling water for the pool heat exchangers comes from the closed-loop cooling system.

The pool filtration system is a bypass loop off the main cooling recirculation loop. Three hundred gallons a minute of pool water is passed from one or both CUP's through the pool filter and returned to the fuel storage pool; about one-half of this water also goes through the deionizer. Valves in the system provide for alternative routings as may be determined by operating experience. The water flow is supplied by the pool filter pump. The pool filter is an etched disk-type filter which has a 95% removal efficiency for 5-micron size particles. The filter is monitored for differential pressure.

The demineralizer system is supplied with water as a bypass loop off the pool filter loop. The same pump (the filter pump) provides the motive force for both systems. One half of the 300-gallon/minute filtration loop flow is valved through the demineralizer unit. This flow is intended to maintain the radioactivity level in the pool at reasonably low levels by the removal of the radioactive ions.

2.4 Off-Gas System

Gaseous emissions from the cask cooldown system and failed fuel, if any, stored in the pool or in leaker cans in the pool are vented to atmosphere via the temporary off-gas system. Cask off-gas passes through a "tee" to a treatment and exhaust system composed of a HEPA filter, silver zeolite absorber bed, a blower, and an exhaust stack that discharges 10 feet above the roof of the FRSS high bay (354 feet above mean sea level). This system will have a capacity of 25 scfm. The exhaust flow will be maintained in the headers at a negative pressure of more than 1 inch of water.

2.5 Ventilation

During operation of the FRSS, the ventilation system is essentially one of full recycle of the conditioned air within the FRSS. Atmospheric pressure in the FRSS may be maintained by isolating the exhaust duct to the main plant stack through the closing of a damper valve. With no exhaust, the inflow and outflow from the FRSS will result from normal building leakage because of external wind pressures. Ventilation will also result from air passing through doors into the FRSS because of wind pressures over the openings. This will be especially true when a large roll-up door in the unloading bay is open. These doors will normally be opened only during the entrance or exit of a transport carrier engaged in handling a spent fuel cask. Because of the large volume of air in the FRSS and the small number of people active within the area, normal building infiltration and exfiltration are considered adequate to provide satisfactory ambient conditions. The filtration that has been provided on the recycle air flow in the FRSS consists of a roughing filter with an 80% NBS spot test efficiency. Temperature conditions within the area are controlled by heating and cooling coils in the HVAC unit.

Since the ambient pressure within the FRSS is normally held at atmospheric, there is little requirement for makeup air; however, if makeup air should be required, the HVAC unit will automatically provide this from outside the FRSS to bring the pressure within the FRSS back up to atmospheric.

Condensate from dehumidification of the building air is potentially contaminated and will be routed to low-level waste via the waste water sump.

2.6 Change and Personnel Decontamination

The change room and sanitary facilities in the Separations Building will be used by the FRSS operating personnel. The Hot/Cold Laboratory (HCLA) decontamination facility will be used when required for personnel decontamination. Established policies for control will be followed.

2.7 Fire Protection

The substantial materials of construction of the FRSS and the limited quantity of flammable materials required for operation present a very low probability for fires. Significant sources of fuel for support of fires are motor vehicles present to emplace or remove a truck cask, unreacted reagents used for liquid solification, and fires of electrical origin.

Fire fighting appliances for use in the FRSS consist of fire hose cabinets and strategically located extinguishers. An enforced flame permit procedure is used throughout the facility.

2.8 Personnel Control

2.8.1 Radiation Dosimetry Program

The personnel Radiation Dosimetry Program is described in Section 4.2.2 of this Appendix.

Exposures in excess of specified Administrative Exposure Limits will be investigated and the results reported and corrective actions taken as necessary.

2.8.2 Clothing

Protective anticontamination clothing will be worn by all personnel while working in contaminated or potentially contaminated areas. The types and amount of anticontamination clothing will be determined by the radiation/contamination survey prior to entry.

The used disposable anticontamination clothing will be discarded by the individual when exiting a contaminated area and disposed of as solid radioactive waste.

The reusable anticontamination clothing will be packaged, monitored, properly labeled, and sent to a contractor for laundering.

2.9 Radiation Monitoring

A complete radiation protection and surveillance program will be in operation when fuel is received at the FRSS to ensure that personnel exposures are maintained within the limits established by 10 CFR 20. This program is described in Section 4.2 of this Appendix.

3.0 FRSS OPERATION

Spent fuel assemblies are received in heavily shielded, gas or water-cooled, shipping casks transported either by rail or truck. Upon receipt, the cask system (cask and rail car or truck trailer and auxiliary equipment) are moved to the protected fenced area established for the FRSS. Each cask system is inspected for possible shipping damage and monitored for radioactive surface contamination and radiation level upon arrival at the plant. Road dirt is washed from the cask system in an outdoor washdown station and the water discharged to the storm sewer. If the cask system is contaminated, it is moved into the Vehicle Unloading Bay where road dirt is washed from the unit and channeled to the liquid-waste disposal system. Contaminated is defined as any smearable contamination equal to or greater than permissible limits as defined in DOT regulations Title 48 CFR, Part 173.

Figure A-2 illustrates a typical rail cask being unloaded from the rail car.

Following the cask monitoring and washing operations, the cask system is moved into the vehicle unloading bay. There the hold-down bolts, any additional protective covers, and the impact limiters are removed.

An overhead 135-ton cask handling crane is used to remove and transfer the cask from the rail car or truck trailer to the TDP. The cask's primary coolant temperature and pressure are checked to determine the coolant and fuel conditions.

The cask cooldown equipment is then connected, if required, to the cask and high-pressure, heated water introduced, the gas and steam vented, and the cask cooled to an acceptable temperature for further handling. The cooldown coolant is sampled and may be flushed into the liquid-waste disposal system to reduce the concentration of radioactivity to a level acceptable for the CUP.

Through use of a handling yoke, the cask is transferred to a CUP and lowered to the bottom. The fuel storage area of the CUP is separated from the cask set down area by heavy structural beams which prevent a cask from swinging into a canister during the lowering operation.

Operating personnel identify each spent fuel assembly as it is removed from the cask with the 10-ton cask unloading crane (a semi-gantry type). The assembly's identification number is compared with the shipping records. The operator then records the identity of the fuel assembly and the storage canister into which the assembly is placed.

Should a discrepancy be found between the shipping papers and the visual assembly identification number, the shipper will be notified immediately and the fuel assembly placed in a canister designated for this fuel until its proper documentation has been received. The NRC will likewise be informed that the proper documentation has not been delivered for the material shipped. The cause of the discrepancy will be determined and corrected. (See Section 5.0 of this Appendix.)

The fuel-handling grapple is attached to the cask unloading crane and used to remove the spent fuel assemblies from the cask. The spent fuel assemblies are

transferred to a multiple assembly storage canister located in a rack in the CUP.

These portable storage canisters are moved to the FSP with the 15-ton canister handling crane. Positive mechanical and electrical stops on the canister handling crane prevent fuel canisters from being raised above the safe shielding depth of the water. The canisters are placed in the appropriate canister racks of the FSP.

The FSP, CUP, and FTP are available for the storage of spent fuel assemblies. Water from the FSP, CUP, and FTP is circulated through a treatment system to remove soluble radioactive material and undissolved particulate. The latter is backwashed to the liquid-waste disposal system. Heat exchangers remove fuel decay heat.

After the cask has been unloaded in the CUP, the cask interior is inspected visually to ensure that all fuel assemblies have been removed. As the cask is removed from the pool, the operator rinses it with demineralized water to remove pool water from the cask exterior. The cask is then removed from the CUP and lowered into the TDP for routine decontamination. If extensive decontamination is required, the cask may be moved to the Decontamination Pit for additional decontamination.

In the TDP, the cask head cover is replaced and the bolts are tightened to the design-specified torque. Pool water is drained from the cask. The exterior surface of the cask is washed. Smear tests of the dry cask determine whether contamination is within requirements of DOT, 49 CFR. Following a visual inspection of the various portions of the cask, including the vent valves and lifting points, the cask is picked up, moved to the unloading bay, and mounted on and coupled to the transport vehicle.

Space is planned within a fenced area outside the FRSS, but within the protected area, for storage of cask inserts, special handling tools, and other fuel handling tools and equipment. The equipment is decontaminated or enclosed in a protective cover before being placed in this area.

NL 10/24 RAIL CASK BEING UNLOADED FROM RAIL CAR IN BNFP-FRSS

FIGURE A.2

4.0 RADIOLOGICAL SAFETY

4.1 General Description

The objective of the Radiological Safety Program at BNFP is to conform to the radiation protection requirements of Title 10, Code of Federal Regulations. These requirements apply to employees and the general public, and include measures necessary for protection of the environment. A fundamental principle of this program is that radiation exposure of personnel shall be maintained at levels as low as reasonably achievable.

Policies and procedures employed for implementing the above stated objectives embody the following basic elements of radiation protection practices:

- Personnel monitoring and dosimetry
- Contamination control
- Respiratory protection - Radiological
- Personnel training
- Authorization of work activities involving exposure potential
- Control of radioactive sources
- Record keeping and reporting.

Additional policies and procedures are promulgated as dictated by operational needs and in accord with the objective for Radiological Safety at BNFP.

Facilities are provided for sample preparation, analysis, and evaluation. Instrumentation for these facilities include alpha, beta, and gamma detection systems. Instruments shall be routinely calibrated to assure efficacy of generated data.

Shielding of equipment and major facility components is utilized to reduce personnel exposure potential where appropriate. Work performed in areas where contamination or elevated external radiation levels exist is conducted in accord with posted instructions or a radiation work permit, either or both of which prescribe protective measures that shall be taken.

4.2 Radiation Monitoring

The radiation protection and surveillance program which will be in operation when fuel is received at the FRSS includes the following.

4.2.1 Area Control and Monitoring

4.2.1.1 Area Radiation Monitors

Three area radiation monitors are strategically located in the FRSS. These monitors alarm in the continuously manned control room. When they alarm, an area alarm is actuated by the control room operator to evacuate the FRSS.

Seven locally alarming area radiation monitors are located as follows: three over the FRSS pools, and one each in the dionization room, water treatment

room, TDP, and the waste solidification area. In event of an alarm, personnel shall leave the immediate area in which it is being sounded.

4.2.1.2 Continuous Air Monitors

Continuous air monitors (CAM's) shall be located in the FRSS to ensure accurate and comprehensive air sampling. The CAM's shall have detectors capable of measuring beta-gamma emitting airborne particulates.

Although alpha activity is not expected in the FRSS, alpha detecting CAM's will also be used to obtain a complete history of airborne activity.

In the event of an alarm, personnel shall leave the immediate area in which it is being sounded.

4.2.1.3 Portable Radiation Detecting Instruments and Surveys

Portable alpha, beta-gamma, and neutron radiation instruments are provided for the FRSS. To ensure total control over the area, surveys shall be taken at routine intervals and recorded on a radiation/contamination survey form. These surveys shall include, as appropriate, smearable contamination, airborne activity, and radiation levels. Signs and rope shall be used to designate and isolate locations where high contamination or radiation levels exist.

4.2.2 Personnel Radiation Dosimetry

4.2.2.1 External Dosimetry

A program of personnel dosimetry for external radiation exposure shall be instituted for FRSS activities. This program will be implemented by use of a commercial dosimetry service augmented by BNFP dosimetry devices.

- Thermoluminescent dosimetry (TLD) badges shall be provided for all personnel working in the FRSS.
- Personnel routinely assigned to the FRSS shall wear a dosimetry service TLD badge, a BNFP TLD badge and, if required, a direct-reading dosimeter and neutron badge.
- Authorized personnel not routinely assigned to the FRSS who are expected to receive a quarterly radiation dose $\geq 25\%$ of the permissible quarterly radiation dose set forth in 10 CFR 20 shall wear a visitors dosimetry service TLD badge, a BNFP TLD badge and, if required, a direct-reading dosimeter and a neutron badge.
- Authorized personnel who infrequently enter the FRSS and who are not expected to receive a radiation dose $> 25\%$ of the permissible radiation dose shall be provided, at a minimum, with direct-reading dosimeters.

Dosimetry service TLD badges shall normally be read on a monthly basis. Where the incurred exposure for the wearer is expected to be minimal, these badges may be read quarterly.

BNFP TLD's shall be read at least weekly. If the results indicate an unexpected exposure, the dosimetry service TLD's and neutron badges (if appropriate) shall be processed immediately.

4.2.2.2 Internal Dosimetry

All regularly assigned FRSS workers shall have preassignment urinary bioassay and/or in vivo count evaluations. Subsequent in vivo counting of these individuals shall be performed at least annually. Urinary bioassay samples shall be obtained at least quarterly.

In the event of known or suspected internal exposure from FRSS operations, special in vivo counting and/or bioassay sampling may be used, as dictated by the circumstances, to obtain estimates of the dose or dose commitment resulting from the exposure.

Personnel that occasionally work in radiation control areas and have a history of potential internal exposure may also be subject to in vivo counting and/or urinary bioassay sampling. The type(s) of evaluation and frequency will be determined by the Safety and Environmental Control Department personnel.

4.2.3 Environmental Monitoring

The AGNS-BNFP environmental monitoring program, which has been in effect since 1971, will provide sufficient air sampling and direct radiation measurements to assess potential exposure of personnel in the vicinity of FRSS as well as the off-site population.

5.0 NUCLEAR MATERIALS CONTROL

The FRSS is designated as Material Control Area (MCA) No. 1 and Item Control Area (ICA). Control of nuclear material is based upon piece-count and fuel assembly identification.

Each receipt of spent fuel is checked against the shipping papers prior to the fuel being placed into the storage pool. Shipments are not accepted without accompanying shipping papers. In addition to piece-count, the shipment will be verified, recorded, and identification numbers on each assembly compared with the data on the shipping papers. Also, verification will be made by two persons that each shipping cask has been emptied prior to replacement of the lid.

The results of the verification by operating personnel is reported to Nuclear Materials Control Department personnel. If there is a discrepancy between the shipping papers and the physical check, the shipper is promptly contacted and the difference reconciled.

The pre-irradiation and post-irradiation compositions of the fuel, irradiation history of the fuel, and estimated quantities of special nuclear materials (SNM) present as provided by the shipper are recorded. The quantity of special nuclear material reported by the shipper represents the inventory value for material in the FRSS.

Material control in the FRSS is based on individual assemblies. The identification of each assembly will be verified when transferred within the FRSS (MCA-1).

A centralized perpetual inventory control system of the FRSS is maintained and consists of:

- Maintenance of fuel assembly identity and location in storage pool. This is maintained by location within a canister and by canister location within the pool.
- Recording and reporting of all transfers into or out of the FRSS. Transfer records contain assembly identification, reactor discharge batch identification, and shipper's special nuclear materials value.

A centralized accounting system using double-entry bookkeeping is maintained for the entire facility. This control area (MCA-1) is one of several control areas handled as a subsidiary accounting unit within the system.

A Computerized Inventory Control System will be utilized which provides real-time inventory status and locations. Input/output devices for direct communication to the computer are located in the FRSS and an interactive dialogue is maintained, i.e., conflicting data are immediately rejected. Inventory status by locations, SNM quantities, reactor discharge batch, etc., are available on demand from the computer.

6.0 PHYSICAL PROTECTION

The Physical Protection System consists of equipment and personnel (security officers and other employees) to accomplish the following:

- Control access into the protected area.
- Prevent entry of firearms, incendiaries, and explosives into the protected area.
- Protect against industrial sabotage.
- Prevent theft.
- Ensure compliance with applicable laws and regulations.

Means by which these measures are implemented in the FRSS fall into the following major subject areas:

- Physical and administrative control of access to the protected area and the FRSS.
- Selection and retention of reliable personnel and detection of aberrant behavior of authorized personnel.
- Monitoring the status of the protected area, vital area, and isolation zone.
- Augmentation of the security force in the event of threats or actual or potential industrial sabotage.

The requirements for physical protection of special nuclear materials (SNM) are specified in Title 10 CFR Part 73. To meet these requirements, a security organization is maintained, and security procedures prescribing the security requirements for the FRSS and the method of dealing with various incidents are promulgated and maintained. Procedures cover such subjects as overt threats, civil disturbances, employee security training, duties and responsibilities of security officers, visitor control, record requirements, and other subjects necessary for adequate physical security.

The security plan for operation of the FRSS covers security measures during the period when spent fuel is received and stored.

The following sections briefly describe the systems, equipment, procedures, personnel, and facilities used to provide physical protection of the FRSS.

6.1 Barriers

The protected area is enclosed by a chain-link fence and other physical barriers as shown in Drawing 519E-A-5014.

The railroad and truck gates are manned only when vehicles are being admitted to or leaving the area. At other times, the gates are locked and protected by intrusion alarms on active status.

To the extent facility arrangement and construction activities permit, an isolation zone is maintained around the perimeter of the protected area. The fence and isolation zone around the protected area is lighted. The entire fence is alarmed.

Personnel (except those with Department of Energy (DOE) security clearances) entering the protected area are routinely searched for weapons and explosives. Those with DOE clearances are searched on a random basis. Metal and explosive detectors are located in an access passageway at the personnel entrance to the protected area. If either the metal or the explosive detector alarms, entry into the protected area is prohibited by an automatic locking of the door into the protected area. The passageway doors are interlocked such that both doors cannot be opened simultaneously. Vehicles are checked, and packages on vehicles are checked for identification and authorization.

6.2 Access Controls

Only personnel whose names appear on an approved access authorization list and visitors escorted by authorized personnel are allowed access to the protected area. Such personnel (except escorted visitors), including all plant employees, are issued specially coded photo-identification badges. Authorized personnel enter the fenced area through passageways at the personnel access points. Hand-carried packages are searched before being allowed into the protected area.

Personnel access to the FRSS complex is controlled through the use of card readers, alarm doors, and closed-circuit television. All other portals are alarmed and are for emergency use or equipment transfer only.

Employees of rail carriers transporting spent fuel will not routinely enter the protected area. Rail cars will normally be disconnected from their prime movers outside the gate and the cars moved into, and out of, the protected area by operating personnel. Motor vehicles transporting spent fuel are either driven into the protected area by employees of the carrier, or the trailers are disconnected and moved into the area in the same manner as rail cars. A security officer checks the vehicle prior to entry and mans the gate during entry and exit. Other vehicles, such as maintenance and delivery vehicles, are checked and packages are checked for identification and authorization.

6.3 Intrusion Alarms, Communications, and Card Key Systems

Fence gates and FRSS exterior doors are alarmed. Alarms for intrusion detection devices and metal and explosive detectors annunciate in a continuously manned Central Alarm Station within a protected area and a remote Secondary Alarm Station.

6.4 Security Personnel

Security personnel are employees trained and qualified in first aid, health physics, firefighting, safety, etc., as outlined in NRC Regulatory Guide 5.20, "Training, Equipping and Qualifying of Guards and Watchmen".

6.5 Auxiliary Services

Intrusion alarms and metal and explosive detectors are powered by an uninterruptible power supply (UPS) system, backed up by an emergency power generation system. Upon loss of primary power, the alarm system operates on UPS battery power until the emergency generators start; therefore, the alarm system operates without interruption in the event of commercial power outages. Security lighting is directly powered by commercial power backed up by the emergency generators.

APPENDIX B

to

Report No. AGNS-1040-1.4-20

BASELINE PARAMETERS
FOR
LIGHT WATER REACTOR (LWR) SPENT FUEL STORAGE

August 1978

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1.0 DESCRIPTION OF LWR SPENT FUEL ASSEMBLIES

Sub-Task 1.4 studies are based upon storing in a vertical arrangement current generation LWR spent fuel assemblies which meet the following nominal parameters:

	<u>BWR</u>	<u>PWR</u>
1.1 Enrichment (% ²³⁵ U) (nominal)		
• initial	2.8	3.5
• final	0.9	0.9
1.2 Average Burnup (MWD/MTU)	25,000	28,000
1.3 Average Specific Power (MW/MTU)	25.0	35.0
1.4 Cooling Time at Reactor Site (years) (minimum)	5.0(1)	5.0(1)
1.5 Assembly Cross-Section (inches) (nominal)	5.5	8.7
1.6 Active Length (feet) (nominal)	12.0	12.0
1.7 Overall Length (feet) (nominal)	15.0	14.0(2)
1.8 Fuel Content per Assembly (kilograms) (nominal)	190.0	450.0
1.9 Shipping Weight (pounds) (nominal)	700.0	1600.0
1.10 Quantity of Assemblies Shipped and Received (%)	60.0	40.0
1.11 Leaking Assemblies (% of the total number of Assemblies)	1.0	1.0
1.12 Removable Non-Fuel Bearing Items Included with Assemblies	No	No
1.13 Rail/Truck Receiving Mix (% on MTU Basis)	70.0 R 30.0 T	70.0 R 30.0 T

(1) Relative quantities of spent fuel cooled less than five years could be accommodated on a case-by-case basis.

(2) Does not include CE System 80 fuel assemblies.

2.0 AREAS TO BE USED FOR SPENT FUEL STORAGE

Fuel storage areas considered in the Sub-Task 1.4 studies include the following:

	<u>Sub-Task 1.4.1</u>	<u>Sub-Task 1.4.2</u>	<u>Sub-Task 1.4.3</u>
2.1 Existing Fuel Storage Pool	Yes	Yes	Yes
2.2 Existing Cask Unloading Pool #1	Limited	Yes ⁽¹⁾	No
2.3 Existing Cask Unloading Pool #2	Limited ⁽²⁾	No	No
2.4 Fuel Transfer Pool	Limited	Yes ⁽¹⁾	No
2.5 New Facilities Adjacent to Existing FRSS	No	No	Yes

NOTES: (1) Double Tier arrangement for spent fuel storage racks.

(2) Provided truck cask barrier is included.

APPENDIX C

to

Report No. AGNS-1040-1.4-20

DESIGN CRITERIA FOR FRSS STRUCTURES,
COMPONENTS, EQUIPMENT, AND SYSTEMS

August 1978

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1.0 GENERAL CODES AND STANDARDS

Design, construction, maintenance, and operation of the BNFP-FRSS conform to all existing applicable local, State, and Federal laws, regulations, requirements, codes, guidelines, and standards for this type facility.

Structures, systems, and components designated herein as Q are those items that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public. These are identified and documented as safety-related. The application of a Quality Assurance Program, based on compliance to Title 10 Code of Federal Regulation Part 50, Appendix B, Quality Assurance Criteria, is mandatory.

1.1 Site Requirements

The site is an exclusion area as defined in 10 CFR Part 100. The site boundary is fenced and is posted to notify persons of trespass restrictions.

1.2 Site Evaluation

A thorough evaluation was made of the demography, hydrology, seismology, meteorology, geography, and biological factors of the site and adjacent areas to ensure that the facility is designed, constructed, and operated, and that it and other effluents released from the facility and site comply with existing applicable governmental requirements.

2.0 WIND CRITERIA

Wind loads for Q and non-Q structures (and vessels, equipment, etc., where applicable) conform to the design methods and loadings described in American Society of Civil Engineers (ASCE) Paper 3269, "Wind Forces on Structures," dated 1961.

The maximum recorded gust peaks in the last 80 years in the Barnwell area were approximately 100 mph and represent an extreme hurricane for this area.

Shape factors, variation of wind velocity with height, and formulae of converting wind velocities into loads to be resisted by the structures are based on said ASCE Paper No. 3269. This publication assembles, correlates, and summarizes existing information on the factors that determine wind forces in structures and considers technical literature extending back to the early 1800's. Since wind and earthquake are not assumed to act simultaneously, for structures where seismic forces exceed the wind loads, no further analysis is performed. For structures where wind load governs, the load is combined with other appropriate loads as required by the various load equations, as described in Sections 7.1.5 and 7.1.6.2.

Wind loads are applied to the structures as uniform static loads on the vertical or horizontal projected areas of the structure walls and roof. Roof loads due to wind are treated the same as roof dead and live loads with the direction of loading taken into account. Only dead load is considered as resisting uplift. Horizontal wind loads are distributed by the walls to the floor and roof diaphragms which, in turn, transfer the loads to the lateral load carrying elements of the structures.

All Q structures are designed for tornado winds of 300 mph; therefore, the 100-mph hurricane winds do not control the design of Q structures of this facility.

All non-Q structures not protected by Q confinement structure are designed for the following wind forces:

<u>Elevation (above-grade feet)</u>	<u>Wind Pressure (psf)</u>
0-50	25
50-150	35

A shape factor of 0.8 was applied to round or octagon shapes.

3.0 TORNADO CRITERIA

Tornado criteria are applied to the design of all Q structures, and all Q equipment, piping, and vessels not protected by a Q confinement structure. Parameters of the design tornado are:

- A wind force on the structures having a uniform static load calculated on the basis of 300-mph horizontal wind applied over the full height of the projected area.
- Depressurization of 3 psi occurring in three seconds, followed by a two-second steady state, followed by return to ambient pressure in three seconds.
- Impact of tornado-generated missiles.

These events are applied separately, or simultaneously, to achieve the most severe loading conditions on the structure of component.

3.1 Tornado Wind

The design basis tornado model consists of a tornado with a uniform wind velocity of 300 mph. The realistic wind-loading criterion for the typical low-profile structure of the FRSS is established as a 300-mph uniform wind applied over the entire surface of each structure from grade to the highest point of the structure. The 300-mph wind is conservative, because wind

velocities increase with height, and estimated velocity for the design tornado at a height of 80 feet above grade is only 160 mph (all Q structures are less than 90 feet).

3.2 Depressurization

Uniform loading, resulting from atmospheric depressurization about vented and unvented structures is added algebraically to the uniform load due to the 300-mph wind velocity.

3.3 Tornado Missiles

Two design missiles, the wooden plank and automobile, are applied to the design of unprotected Q structures.

3.4 Tornado Design Basis

Q structures (and their applicable components) are designed to remain elastic even under the most severe combination of tornado wind loadings, except missile impact. This design further increases the conservatism and structural safety. See Section 7.0 for design criteria of structures.

Non-Q structures or components (excluding light steel siding) adjacent to the fuel pools are designed to remain in place during tornado wind loading. Possible failure of other non-Q structures will not affect the function of adjacent Q structures.

3.5 Tornado-Induced Loss of Water from the Fuel Pools

The two potential means of water removal from a fuel pool are the direct removal by the tornado, and water leakage, caused by missile impact. The direct removal of water by the tornado is limited by an eddy formation over the pool and the pool location with respect to building protection. Accordingly, the pool will not lose a critical amount of water during a tornado, and water removed in this way would leave adequate coverage of the fuel assemblies.

The second possibility of gross water loss is from a rupture of the pool by tornado missiles. The pool structure consists of thick walls and base, capable of withstanding tornado-induced missiles. The possible angles of impact and the energy absorption characteristics of the water add to the protection of the pool structures and their contents. These conclusions, which are supported by observation, are conservative.

3.6 Tornado Missile Design of Fuel Storage Canisters

The fuel assemblies are stored in canisters submerged in the fuel pools. These canisters are designed to withstand the impact of tornado missiles and maintain proper fuel spacing.

4.0 MISSILE PROTECTION CRITERIA

This section describes the design basis pertinent to internal and external missiles for which the plant is analyzed and protected. The discussion considers: (i) missiles that might be generated within the structure, (ii) tornado-generated missiles, and (iii) missiles that might result from activities particular to a given site location (such as airports, etc.).

For each missile, consideration has been given to the design parameters of origin, impact velocity or energy and orientation, density and other pertinent assumption, along with bases for each.

4.1 Missiles Generated Within Structures

The systems located inside the structures have been evaluated to identify and classify potential missiles. The basic approach in the design was to take necessary precaution to protect against the generation of missiles rather than assume that missiles would occur and then try to contain their effects.

Possible sources of missile generation would be the failure of mechanical equipment. For example, the failure of the non-Q engine in the pumphouse was considered to have the potential to generate a missile with the following characteristics:

- A 100-pound component hitting with an impact area of 20 square inches and a velocity of 40 feet per second.

Missile barriers provided to protect Q components are designed to preclude missile penetration.

4.2 Tornado Generated Missiles

Q structures, systems, and components, not protected by Q confinements, are designed to sustain the combined tornado wind, depressurization, and missile loading without loss of function. The following design tornado missiles are representative of the postulated missiles.

- The 4-inch by 12-inch by 12-foot wood plank missile striking end on at 300 mph.
- The maximum wind velocity combined with the wood plank missile striking end on at 200 mph, and the maximum pressure differentials.

The maximum wind velocity combined with a 4000-pound automobile flying through the air at 50 mph and at not more than 25 feet above ground with a contact area of 30 square feet, and the maximum pressure differentials.

Local yielding, crushing, or partial penetration of materials at the point of impact of the missile is allowed, providing there is no loss essential confinement or other essential function.

Fuel canisters are designed to resist (without loss of function) the impact loadings due to any of the postulated missiles (Table 4.1) entering the pool water surface and passing through the water and striking the canisters or support racks. The fuel canisters will maintain the fuel in favorable geometry both before and after the impact. Weight, minimum impact areas, and equivalent free-fall loading of these missiles are shown in Table 4.1.

4.3 Aircraft

The closest major airport near the facility is in Augusta, Georgia, over 50 miles away. Therefore, the facility is not designed against aircraft.

TABLE 4.1

POSTULATED MISSILES AFFECTING FUEL SUPPORT RACKS AND CANISTERS

Missile*	Size	Minimum Impact		
		Weight (Pounds)	Area (Square Feet)	Free Fall from Above Grade (Feet)
Wood Plank	4" x 12" x 12' long	125.00	0.33	300
Street Light Fixture	1' x 4' x 6"	25.00	0.50	300
Rock Debris	1-1/2"	0.25	0.01	500
Metal Siding	2' x 16'	100.00	0.50	300
Vent Ducts		160.00	0.40	300

*Typical missiles as defined by NRC design guides.

5.0 WATER LEVEL (FLOOD) DESIGN CRITERIA

Due to the topographic characteristics of the site, flooding is not possible. The site does not include or bound any waterway.

6.0 SEISMIC CRITERIA

Appendix D describes the seismic criteria used in the design of the FRSS.

7.0 DESIGN OF Q AND NON-Q STRUCTURES

Design bases, criteria, codes, and specifications, appropriate for the intended service and loading requirements, were selected or developed for the design and construction of FRSS structures.

7.1 Description and Design Basis

The FRSS structure encloses the fuel pool system and is adjacent to the Separations Facility. The lower portion of the structure is composed of Q concrete walls rising to a minimum of 25 feet above final grade. Atop the walls is a Q steel-frame structure (braced walls and roof), covered by light-gauge siding. The structure supports the fuel cask unloading crane and canister-handling cranes.

7.1.1 Design Basis

- The lower concrete barrier is designed to resist all applicable Q loadings, including tornado missiles.
- The structural steel confinement structure is designed to resist Q loadings, except that only one-third of the light steel siding (not a structural element) is assumed to remain in place during a tornado.
- All elements heavier than light-gauge siding will remain in place during any design basis event.
- Crane rails, girders, and support columns and components which retain the cranes on the rails are designed for Q loadings. The crane support system for the cask handling crane is designed to support a 135-ton crane and a 40-ton crane (both cranes loaded and operating simultaneously).
- Crane supports are designed as integral components to the FRSS structure and will support all structural loadings (in addition to crane loadings) in the most severe combination with a design basis earthquake (DBE).
- Crane rails and supports are designed to maintain their structural integrity and remain intact after tornado loadings or DBE. Cranes are not required to be operational after a tornado or a DBE.

- Crane runout space for operation of present and future cranes is not provided in the confinement construction.
- Craneway building foundations are carried to approximately five feet below natural grade.
- Other foundations are founded in the berm, and their influence on the pool has been accounted for in the design of the pool system.
- All structures comprising the FRSS are structurally separated from the Separations Facility.
- Access doors into the FRSS are non-Q.

7.1.2 Non-Q Structures

- Design of structures adjacent to the FRSS ensures that no elements or components will become dislocated and pose a potential threat to the fuel pools.
- Floors are designed for a minimum live load of either 100 psf, uniform, with reductions allowed for area, or a 2000-pound concentrated load applied anywhere -- whichever governs.
- All floors and roofs are designed to support all temporary storage, transport, or letdown loadings safely.

7.1.3 Design Loadings for Q and Non-Q Structures

The following individual loadings have been considered in the design of structures for each classification:

<u>Type</u>	<u>Description</u>
Dead Load	Dead weight of structure and permanent equipment, vessels and piping, cranes storage -- plus any other permanent loads such as soil and hydrostatic pressures on walls.
Live Load ⁽¹⁾	Lifted crane loads, maintenance loads, code design loads for roofs and floors.
Operating Loads	Weight of contents in operating or shutdown conditions.
Thermal Forces	Forces due to temperature variation and gradients.
Dynamic Forces	Forces resulting from any dynamic source, <u>except</u> earthquake.

(1) Minimum live load for roof of Q structures is 20 psf, with no reduction permitted.

Live load is not combined with earthquake, wind load, tornado load, and missile load, except for FRSS cranes.

7.1.4 Design Basis Events for Q Structures

Structures are designed to remain functional while sustaining the following loadings, where applicable.

Type	Description
Design Wind Load	Pressures exterior to and inside structures resulting from a 100-mph wind gust velocity. Also, vortex excitation is considered.
Tornado Wind	Pressure resulting from a tornado wind velocity of 300 mph.
Differential Pressure	Atmospheric pressure drop that is combined with tornado wind pressure.
Missile Impact During Tornado	Force(s) created by the impact of tornado-generated missiles.
Abnormal Operations or Upper-Limit Accident	Pressure wave and/or thermal or radiation effects (and forces due to such occurrences) as stipulated for individual structures.
Operating Basis Earthquake (OBE), DBE	Seismic accelerations and displacements and resulting shears and movements.

7.1.5 Design Loading Combinations for Q Structures

Q structures are designed for the most severe of the following loading combinations:

- (1) $D + L + T$
- (2) $D + L + T + P$
- (3) $D + T + (E \text{ or } W)$
- (4) $D + T + E'$
- (5) $D + T + W'$

where:

D = Dead loads of structures and components, operating loads of components

L = Live loads, dynamic forces, and internal pressure loads

P = Pressure due to abnormal operations or upper-limit accidents

T = Thermal forces

E = Operating basis earthquake

E' = Design basis earthquake

W = Design wind load

W' = Tornado wind, missile, and differential pressure loading as specified in Section 7.1.4.

7.1.6 Strength Design for Q Structures

7.1.6.1 General Requirements

Computed design stresses do not exceed the elastic stress range of the materials where the upper limit of elastic behavior is the yield strength of the material.

For reinforcement steel and structural steel, yield strength is taken as the guaranteed minimum values established by the latest ASTM Specification at time of design.

For concrete, yield strength is taken as $0.85 f'_c$ where f'_c is the concrete compressive strength per ACI 318-71.

7.1.6.2 Concrete Structures, Foundations, and Elements

For concrete, the ultimate design strength of the structure or element under consideration is based on ACI 318-71, Ultimate Strength Design, except Section 9.3 which is replaced by the provisions of this section. The load factors listed below are more severe than ACI-318 (i.e., 2.0 instead of 1.25 for E or W).

Final design satisfied the most severe of the following loading combinations and load factors: (Refer to Section 7.1.5 for explanation of the following terms.)

- (1) $U = 1.5 (D + L + T)$
- (2) $U = 1.25 (D + L + T + P)$
- (3) $U = 2.0 (D + T + [E \text{ or } W])$
- (4) $U = 1.1 (D + T + E')$
- (5) $U = 1.1 (D + T + W')$, for this condition only, the computed concrete stress does not exceed 75% of the concrete yield strength ($0.85 f'_c$).

Where U = ultimate load capacity of the structure.

Reinforced concrete structures are designed for ductile behavior, that is, with steel controlling.

7.1.6.3 Steel Structures

Under OBE or wind loading combinations, computed stress is limited to normal allowable American Institute of Steel Construction or Uniform Building Code working stresses (latest issue at time of design), with no increase for wind or earthquake loadings. Under DBE or tornado loading conditions, computed stresses are limited to 90% yield.

7.1.7 Q Structures with Light-Gauge Steel Siding

Design of this type structure is based on the requirement that -- under any condition of loading set forth in these criteria -- elements, equipment, and

appendages (other than light-gauge metal siding and roofing) will not become separated from the building.

Design provides that building frames, including purlins, girths, and all similar structural appendages will remain in place under any condition of loading.

Main framing design is based on the applicable loadings given in Sections 7.1.3 and 7.1.4 for Q structures; however, differential pressure is not applicable; and under tornado wind, one-third of the siding and roofing of light-gauge material is assumed to remain in place. This is conservative because the roofing and siding are designed to blow away at approximately 80 psf.

Permissible design stress levels conform to criteria for Q steel structures.

7.1.8 Non-Q Structures and Components

7.1.8.1 Structures

Design of non-Q structures is based on applicable loads listed under Section 7.1.3 in combination with design wind load as defined in Section 7.1.4 or earthquake provisions of the Uniform Building Code (UBC) (latest issue at time of design).

Design procedures and permissible stress levels conform to normal practice in accordance with provisions of the latest issue of UBC, AISC Specifications for Design and Construction of Building, and ACI 318-71.

In order to ensure that no potential missiles can be generated from nearby areas and enter fuel storage pools, structural elements heavier than light-gauge metal are designed to remain in place under tornado wind.

7.1.8.2 Foundations

The soil reports are the basis for allowable and ultimate soil stresses used. "Stability Ratio" is the same as for Q structures.

7.1.9 Material and Construction

7.1.9.1 Reinforcement

Material conforms to ASTM A615-Grade 60. In general, lapped splices will be used for No. 11 bar and smaller. Mechanical butt splicing may be required in some areas as defined on the drawings. Mechanical butt splicing shall be used for No. 14 and No. 18 bar. Splicing shall be in accordance with Job Specification 9211-Q-4. In the event mechanical or lap splicing is impractical, welded splices may be used only with prior approval of the Engineer. Welded splices shall be made in accordance with AWS D12.1.

Splices are avoided in zones of maximum tension stress. Special attention is given reinforcement details for crack control in containment structures that provide a source of radioactive or toxic emission (or leakage) of dangerous liquids or gases. Reinforcement is continuous through construction joints.

7.1.9.2 Concrete

Concrete mixes for Q structures are proportioned for minimum drying shrinkage characteristics and maximum density. An approved testing laboratory (Froehling and Robertson, Inc., Inspection Engineers, Richmond, Virginia) made recommendations concerning design and control of mixes and additives for plasticizing, improved weathering, increased density, control of setting, etc. Minimum dry density of concrete containing conventional aggregates is 142 pounds per cubic foot. Minimum dry density of high density concrete is 230 pounds per cubic foot (or as required to meet shielding requirements). Concrete design strength (f'_c) is 3000 psi (minimum).

High strengths, consistent with low shrinkage, density, weathering, or other requirements pertaining to specific structures or elements are allowed for non-Q structures at the option of the designer subject to AGNS' approval.

7.1.9.3 Structural Steel (Carbon Steel)

Shapes and plates conform to ASTM-A36. High-strength bolts conform to ASTM-A325 (or equivalent). Welding conforms to AWS D1.0-69, with minimum strength of filler equal to 70,000 psi.

7.1.9.4 Stainless Steel

Plates conform to ASTM A276-70, Type 304L. Bolts conform to ASTM A193-70 (Grade BB, Class 1).

7.1.9.5 Welding

Type 304L stainless steel to stainless steel welding conforms to AWS A5.4, Type E 308L. Stainless steel to carbon steel welding conforms to AWS A5.4, Type E 309.

7.1.10 Shielding

Concrete walls, floors and ceiling, hatches and doors, and viewing windows are designed to provide adequate shielding for protection of plant personnel. Where structural requirements are exceeded by shielding requirements, the latter controls. High-density concrete or other high-density material was sometimes substituted for normal density concrete, where geometrical restraints limit structural thickness. Concrete construction includes provisions to minimize shrinkage and crack generation to ensure maximum leak tightness.

7.1.10.2 Piping and Electrical Penetrations

Penetrations of all Q lines and penetrations of all lines through a Q liner are designated Q. All other penetrations are non-Q. Penetrations for future lines through present walls are provided. Penetrations through structural separations are designed to sustain all differential seismic motion and settlements without loss of function.

7.1.10.3 Liners

Welded stainless steel liners in the pools provide secondary confinement to vessels or piping and leakage control. Sumps to collect any leakage or wash-down fluids are provided. Liners and sumps are designed to safely collect and direct liquids to appropriate locations.

The liners in the FRSS pools are classified as non-Q.

7.1.10.3 Structural Steel

All steelwork, below the maximum holdup level of a cell liner, is constructed of 304L stainless steel. All other steelwork (including crane rails, clips, fittings, anchorages, and embedded metal items) is constructed of stainless steel or carbon steel with proper protective coating.

7.1.11 Design Basis for FRSS Pools

The pools are connected to form one monolithic structure. The pool system is structurally connected to the FRSS building structure.

Pool structure is designed for the following loading conditions, and combinations, that result in the highest possible stresses:

- Pool empty, and dead load soil pressures acting
- Pool full, net soil reaction on base, and no lateral soil pressures on walls
- Pool full, all vertical and lateral pressures acting, plus OBE (DBE).

The FRSS confinement system is composed of the following major components:

<u>Components</u>	<u>Design Classification</u>
Cask Unloading Pools (CUP)	Q
Failed Fuel Pool (FFP)	Q
Fuel Storage Canisters	Q
Fuel Storage Canister Racks	Non-Q
Fuel Storage Canister Rack Embedments	Q
Fuel Storage Pool (FSP)	Q
Fuel Transfer Pool (FTP)	Q
Pool Isolation Gates	Non-Q
Pool Liners	Non-Q
CUP Leakage Collection Sump	Q
FFP & FTP Leakage Collection Sump	Q

The base slab and pool structure, as a whole, are designed as a ridge (as opposed to elastic) system on an elastic foundation. Soil pressures are based upon a transient saturated condition of surrounding soils to approximately

natural grade. The influence of foundations of surrounding structures is also included in the design. Earthquake-induced pressures were computed as described in Section 2.0 of Appendix D.

The pool storage system is designed to remain functional during and after extreme natural phenomena, including the DBE and tornado wind loadings. The building is Q to 25 feet above berm level and the crane supports are Q. The roofing and wall covering have been evaluated and determined that failure of these during a tornado would not compromise safety in the fuel pool.

The pool system is not subject (directly) to tornado winds, except through interaction with the FRSS structure and the possible impact of missiles. The pools are lined with non-Q stainless steel liners which cover all wetted surfaces to the highest watermark. A system of removable non-Q watertight gates is provided. These stainless steel gates can isolate any pool so that it can be emptied without affecting the water level in any other pool.

The design of the FTP includes provisions for future expansion without affecting water level in the pool system or its integrity. The connection between the FTP and the Separations Facility includes a structural separation between the two structures. The design of this connection ensures no loss of function of the FTP due to differential settlement or seismic motion.

Collection systems are provided. They collect leakage between the stainless steel liner and the concrete confinement structure by means of trenches located on the wall of floor slab. Sumps complete with pumps are provided to collect and recirculate any leakage to the pool filtration system.

The liner of the FSP is designed to sustain the impact of a canister falling from the fuel racks, without loss of function. A Hexel pad is placed at the bottom of the CUP to absorb the impact of a dropped cask if it should ever occur.

Fuel storage racks (constructed of 6061-T6 aluminum) are provided in the FSP, CUP, and FTP. Exposed portions of the base or wall embedments are constructed of stainless steel and are seal-welded to the pool liner. Rack embedments are Q; however, the racks are non-Q. The racks are designed assuming:

- The racks are fully loaded with Q canisters with DBE acting
- The damping effect of the pool water is negligible since damping by pool water would have the tendency to reduce displacement with resultant lower stress values.

The fuel storage racks are designed as cantilevered columns supporting the fuel storage canisters, with their masses lumped at the top of the column.

APPENDIX D

to

Report No. AGNS-1040-1.4-20

SEISMIC ANALYSIS

August 1978

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INTRODUCTION

Design of FRSS structures, vessels, piping, and appendages, to sustain design seismic events required the development of:

- Specified design earthquakes, Operating Basis Earthquake (OBE) and Design Basis Earthquake (DBE), including ground-motion response spectra (Section 1.0 of this Appendix).
- Soil-structure interaction (Section 2.0 of this Appendix).
- Damping properties of the structures and soil-structure interaction (Section 3.0 of this Appendix).
- Mathematical models of the FRSS structures, vessels, piping, and appendages, (Sections 4.0 and 5.0 of this Appendix).

These design parameters and mathematical representatives of the structures were analyzed to determine the seismic forces used in the structural design.

1.0 DESIGN SPECTRA

1.1 Basic Design Spectra

The design spectra were developed in accordance with the data provided by the AEC (now DOE), shown in Table D.1, for 5% damping and 0.12g acceleration for periods between 0.3 and 2.0 seconds.⁽¹⁾ ⁽²⁾ This is called the Reference Spectrum in the subsequent discussion.

The modified spectra (Figures D.1 and D.2) were developed using the following procedure:

The acceleration amplification factor of the Reference Spectrum was calculated by dividing the maximum "g" level by the base "g" level and comparing it to the acceleration amplification factor proposed by Newmark for 5% critical damping.⁽³⁾ This comparison indicated virtually no numerical difference. Therefore, Newmark acceleration amplification factors were adopted for the modified spectra generation.

TABLE D.1

BASIC DESIGN SPECTRA FOR 5% DAMPING AND
0.12g ZERO PERIOD ACCELERATION

For 5% damping and 0.12g zero period acceleration:

<u>Period (sec)</u>	<u>Acceleration (g)</u>
0.3	0.286
0.4	0.310
0.5	0.335
0.6	0.310
0.8	0.286
1.0	0.240
1.25	0.192
1.50	0.158
2.00	0.120

For other damping value percentages, the spectra were modified accordingly.

The Newmark acceleration amplification factors (for values of 0, 1/2, 1, 2, 5, and 9 percentage of critical damping) were then normalized with respect to amplification at 5% critical damping.

The 0.3 second to 3.0 second range of the OBE (0.12g base) Design Spectra was evaluated by first extending the Reference Spectrum from 2.0 to 3.0 seconds (by maintaining a constant spectral velocity). The resultant spectrum was then multiplied by the normalized acceleration amplification factors calculated above. The resulting spectra were then faired into the corresponding original spectra for periods of vibration less than 0.30 second, thus completing the OBE (0.12g base) Design Spectra (Figure D.1).

DBE (0.20g base) Design Spectra (Figure D.2) were evaluated by multiplying the OBE (0.12g base) Design Spectra by the ratio of their respective base accelerations (0.20/0.12).

Such method is a logical means of providing a set of design spectra that remain compatible with the Reference Spectrum as defined above.

The analysis for vertical response was performed in the same manner as for the horizontal motion. Response of a structure or appendage due to vertical seismic motion was computed using two-thirds of the response values provided by the design spectra for lateral motion (Figures D.1 and D.2).(4)(5)

1.2 Time - History Analysis

Records were developed by means of programs used by the Bechtel Power and Industrial Division and in such a manner that their response spectra draw near (but do not fall below) the corresponding design spectra when evaluated for OBE (at 0.12g base) with 5% critical damping and DBE (at 0.20g base) with 9% critical

damping (Figures D.3 and D.4). The resulting acceleration records (Figures D.5 and D.6) may be described as having a buildup and decay time of four seconds, respectively, and a 22-second duration of strong motion during which at least one data point attains the base acceleration (0.12g at OBE and 0.20g at DBE). The time interval used for both records was 0.01 second, so each record is defined by 3000 discrete data points.⁽⁴⁾

These acceleration records have been developed expressly for the 5% and 9% values of damping established for use in the analysis of all Q structures founded on soil, rather than from arbitrary values. (Refer to Section 1 of Appendix C for definitions of Q items.) The 5% and 9% values are in accordance with the values established for the structure as a whole. Hence, it is appropriate to use this time history analysis for Q structures founded on soil for OBE and DBE, respectively. The time history response of critical floor levels of each Q structure was then used to generate the floor response spectra for various values of damping necessary for the design Q and critical non-Q equipment, piping, and appendages.

2.0 SEISMIC SOIL DATA

2.1 Dynamic Moduli

Dynamic soil shear moduli have been developed for the BNFP design seismic environments (OBE and DBE) by the Hydro & Community Facilities Division of Bechtel Corporation in consultation with Dr. H. B. Seed, and are presented in Figures D.7 and D.8. These moduli (variable as a function of depth) reflect the cyclic shear strains experienced by the various soil layers at the BNFP site between the Tuscaloosa formation (Figure D.9), the assumed base, and the top of the berm during OBE and DBE. The dynamic moduli were obtained by modifying the moduli derived from the geophysical survey of the plant site as conducted by Weston Geophysical Engineers, Inc. Modification of these moduli was such that the maximum stipulated ground acceleration was attained at the top of the berm (0.12g at OBE and 0.20g at DBE) when the appropriate base motion was applied. A time history analysis of the soil layers between the assumed base and the top of the berm was conducted, using data similar to that used in the earliest liquefaction studies.

The time-history analysis was performed using the general procedure and the computer program described in a paper by Idriss, Dezfulian, and Seed.⁽⁶⁾

The modification of the shear moduli for the OBE and DBE seismic environments was made without modification of the values of Poisson's ratio, as evaluated by Weston Geophysical Engineers, Inc. A numerical value of 0.380 (the value obtained by Weston for depths below the surface from 6.0 to 45.0 feet) was adopted for well compacted soil.⁽⁷⁾⁽⁸⁾

2.2 Soil Spring Data

The soil springs representing the soil-structure interaction were calculated using the following methods:

- Spring constant representing the soil foundation interaction of structures resting on the surface of the soil were calculated using the formula shown below. (9)(10)

Horizontal Spring Constant

$$K_x = 2(1 + \mu) G B_x \sqrt{BL}$$

Rotational Spring Constant

$$K_\phi = \frac{G}{1-\mu} B_\phi BL^2$$

Vertical Spring Constant

$$K_z = \frac{G}{1-\mu} B_z \sqrt{BL}$$

Where:

- K_x = Horizontal spring constant at base.
- K_z = Vertical spring constant at base.
- K_ϕ = Rotational spring constant at base.
- μ = Poisson's ratio - 0.38 (as determined in the seismic study by Weston Geophysical Engineers, Inc., for $\gamma = 120 \text{ lb/ft}^3$).
- G = Dynamic shear modulus (as determined at the appropriate depth from Figures D-7 and D-8).
- L = Length of rectangular foundation in plane of rotation for rocking, or in direction of horizontal force.
- B_ϕ, B_x, B_z = Dimensionless geometric factors.
- B = Width of foundation along axis of rotation for rocking, or normal to direction of the horizontal force.

All variables are in a consistent set of units, i.e., kips, feet, seconds, radians.

- For partially or fully-buried structures that have their functions located substantially below the top of the berm, additional lateral springs were required in order to better approximate their response to seismic activity. (11) These springs represented the additional resistance to lateral motion encountered when dynamically-induced lateral soil pressures developed against the buried portions of the structures.

Table D.2 provides a summary of dimensions and embedment depth of the FRSS structure.

TABLE D.2
SUMMARY OF FOUNDATION DIMENSIONS AND EMBEDMENT DEPTHS
OF FRSS STRUCTURES

<u>Structural Identification</u>	<u>Plan Dimensions</u>	<u>Total Height</u>	<u>Foundation Type</u>	<u>Bottom Elev. of FDN</u>	<u>Embedment Depth</u>
FRSS	149' x 150'	91'	Footing	249'-6"	22'

2.3 Seismic Soil Displacement

Seismic soil pressures upon fully or principally buried structures, such as the fuel pool structures, were determined by computing relative soil-structure deformations created by the seismic ground displacements.

These relative soil-structure deformations were derived by superimposing a "rigid" structure on the free field soil displacement curve and computing the soil deformations required to accommodate the structure.⁽⁸⁾ This procedure is discussed in Section 4.0.

The free field seismic soil displacements were computed from the derivation of the soil shear moduli curves. These displacements for OBE and DBE are presented in Figures D.10 and D.11, respectively.

3.0 VIBRATIONAL DAMPING FOR STRUCTURES

Development of damping values for the BNFP structures was based upon the rationale developed for the Palisades Nuclear Facility, with adjustments made for local (BNFP) soil conditions.⁽²⁾

The following damping factors are applicable for structures, appendages, and equipment support systems subjected to motion comparable to that produced by the OBE or DBE:

<u>Structure</u>	<u>Percent of Critical Damping</u>	
	<u>OBE</u>	<u>DBE</u>
Concrete shear wall buildings considered as a whole and soil supported	5.0	9.0
Individual concrete shear walls and embedments	2.0	4.0
Welded steel	1.0	2.0
Flexible equipment and support systems on structure floors.	1.0	2.0
Bolted steel frames	2.0	4.0
Rigid equipment and systems on structure floors.	0.5	1.0
Piping vessels and ducts on rigid supports	0.5	1.0
Equipment and support system on soil-supported foundations and slab at grade	3.0	5.0

The damping factors used in the dynamic analyses were based on horizontal ground accelerations of 12% and 20% of gravity, respectively. The response spectra represent the maximum response of a structure, having a characteristic natural period and degree of damping to accelerations experienced during either an OBE or DBE. Maximum response refers to the peak values of acceleration, velocity, and displacement of the oscillating structure.

4.0 MATHEMATICAL MODELS: STRUCTURES

4.1 Fuel Receiving & Storage (FRSS) Building

The FRSS building is a box structure composed of concrete and braced-frame shear walls connected by flexible diaphragms at the roof and floor elevations (see Figure D.12). For the dynamic analysis of the building, the structure was modeled as two coupled roof and shear wall systems, separately resisting N-S and E-W seismic forces parallel to the respective wall faces.

Each wall and horizontal diaphragm was also modeled for analysis of seismic forces normal to their planes. Crane girders were analyzed for lateral and vertical seismic effects.

4.1.1 Models for Walls Parallel to Seismic Motion - The shear wall systems were modeled by making the following assumptions:

- Torsional forces are resisted only by walls parallel to the seismic motion. It is conservative to assume that two walls, instead of all peripheral walls, resist all torsion forces.
- Parallel walls are coupled by the flexible roof diaphragms and, where applicable, by the flexible floor diaphragms.
- The mass of the structure is distributed proportionately to the tributary shear walls parallel to the seismic motion, except for the mass of the crane which will be placed at each involved wall, separately, for maximum effect.
- The building structure is attached to the pool structure. Included in the mathematical model were rigid and flexible reaction points to represent the restraints of the pool. The dynamic properties of the entire pool system were not modeled into the FRSS building, as they would not significantly affect the response of the structure.

The FRSS building was modeled separately for N-S and E-W seismic motion. Idealized physical representations of the shear wall systems acting in the N-S and E-W directions and their mathematical models are shown in Figures D.13 and D.14, respectively. In these models, the roof diaphragms were placed by equivalent springs, and the soil spring constants were evaluated as mentioned in Section 2.0 of this Appendix.

The response mode with the walls in-phase gave the maximum wall deformations and forces, because all strain energy was taken in the walls. Higher modes accounted for maximum out-of-phase action of the walls and maximum deformations in the diaphragms.

Vertical seismic motion was analyzed independently of the lateral motion. The model for this mode of response was similar to those shown in Figures D.13 and D.14, except that the horizontal diaphragms were included as flexure members normal to their plane with distributed mass.

Additive effects of vertical and lateral modes of response were combined for the most severe loading cases.

4.1.2 Models of Walls and Diaphragms Normal to Seismic Motion - The walls, subject to seismic accelerations normal to their faces, were modeled separately as a system of columns restrained at their bases by soil springs and at elevation 274 feet by horizontal slabs. The slabs were restrained horizontally by the shear walls.

4.2 Fuel Pool Structure

The pool structure is composed of a system of thick interconnecting shear walls and foundation slabs (see Figure D.15). The entire system is essentially buried; is of less weight than the soil it displaces; is small, relative to the soil mass in which it is buried; and may be assumed rigid relative to the soil.

The pool structure is attached to the FRSS building via the floor slabs. These slabs are attached to the pool only at intersecting pool walls (walls perpendicular to slabs) and act as flexible beams between the two. The FRSS building, with a much lesser mass, was assumed not to significantly affect the dynamic interaction between the pools and surrounding soil and was, therefore, modeled separately (see FRSS building model, Figure D.12). However, in the pool design, the pool reaction loads to the FRSS structure were applied to the pool structure.

Considering the conditions listed above, it was reasonable to assume that the pool structure, relative to its surrounding, would not react to seismic motion as if it were surface-oriented. The rigid body motion of the pool structure would appear to be wholly dependent on the motion of the soil.

The pool structure is buried in a soil medium that is semi-infinite in dimension, so it was assumed that it would not affect the response and resulting deformation of the medium as a whole. Therefore, the pool structure was analyzed, in part, for the loads imposed upon it resulting from a local alteration of the free soil deformation about the pool structure (see Figure D.16). The loads on the structure were assumed as follows:

- Lateral forces generated where the soils immediately surround the pool were forced to undergo a zero relative lateral deformation between the deepest foundation slab and the top of the berm.
- The "reaction" forces were developed on the foundation slabs in order to maintain equilibrium of the pool structure as a "free body" with such loads applied.

In addition, spectrum response analysis was performed on the shear walls, considering them as flexible plates with appropriate edge support. The influence of "sloshing" of contained water was included in this analysis by providing an equivalent spring-mass system as presented in References (2) and (12). The design spectra presented in Section 1.0 of this Appendix were employed in such analysis.

The pool structure was also assumed rigid in the vertical direction. The vertical analysis consisted of the application of a vertical acceleration equal to two-thirds of the appropriate lateral ground accelerations.

Pool structure equipment and piping were analyzed by employing the OBE and DBE design spectra for lateral seismic analysis and the scaled design spectra (as noted above) for vertical seismic analysis.

The free deformations of the soil medium resulting from the OBE and the DBE seismic events were evaluated previously in order to develop the dynamic soil moduli in Section 2.1. A description of that analysis is presented in Section 2.0 of this Appendix.

5.0 MATHEMATICAL MODELS: VESSELS, PIPING, AND APPENDAGES

5.1 Vessels and Their Support Systems

Vessels and their supports were analyzed to determine their seismic response. Two basic types of vessel support systems are used in the FRSS. They may be classified as the simple cantilever system and the simple beam system. Both systems were represented as planar structural systems and were modeled as lump masses linked by elastic members.

5.1.1 Simple Cantilever System

The simplest type of vessel support system is a vessel supported directly off the floor by legs or by means of lugs from structural beams. This type of system was represented for the seismic analysis by a simple cantilevered lump-mass mathematical model (see Figure D.17).

5.1.2 Simple Beam System

The other type of vessel support system is supported from a structural frame or from the floor and is laterally restrained at one or more locations from structural beams or cell walls. This system was modeled simply as a supported beam representing the vessel attached to the support structure. Again, the model used lumped masses at appropriate locations (see Figure D.18).

5.1.3 Attachments to Vessels and Their Support Systems

Attachments to vessels and their support systems were ignored in the mathematical model, unless the mass, stiffness, or restraint of the attachment contributed significantly to the dynamic behavior of the vessel-support system. Where such attachments made a significant contribution, they were included in the mathematical models by means of lumped masses, elastic members, and specific restraints.

External piping is an example of an attachment which may have significant mass, stiffness or restraint, and which may significantly affect the dynamic behavior of the system. Figure D.18 illustrates how such an attachment was included in the mathematical model if deemed necessary. The additional mass of the pipe (and contents) was added to a lumped mass for the vessel-support system or included in the model as an additional lumped-mass point, as appropriate.

5.2 Piping and Ventilation Systems

Typically, the piping and ventilation systems were analyzed by the simplified seismic analysis method. However, a few critical piping systems were checked by a modal analysis of a mathematical model, as described below.

5.2.1 Mathematical Model

A three-dimensional piping or ventilation system was idealized mathematically as a model consisting of lumped masses linked by elastic members. The lumped

masses were carefully located so as to represent the dynamic and elastic properties of the piping or ventilation system. A lumped mass was located at the beginning and end of every elbow and at the intersection of every tee. On straight runs, lumped masses were located at spacing no greater than the simple span length corresponding to 30 cps. The span was calculated by the equation

$$f = \frac{\pi}{2} \sqrt{\frac{EIq}{WL^4}}$$

which gave the frequency "f" for a simple span of length "L". Figure D.19 shows the mathematical model for the seismic analysis of a typical three-dimensional piping system.

5.2.2 Seismic Analysis of Models

The seismic response of each vessel-support system, piping system, and ventilation system was evaluated by applying the spectrum response technique as a modal analysis for each of the three principal directions (N-S and E-W lateral directions, and the vertical direction). The total seismic design values of inertia force, torque, moment, shear axial loads, deflections, and rotations were obtained by combining the results of each lateral direction with the results for the vertical direction.

Appropriate response spectra were selected for seismic analysis of process building equipment, piping, and appendages as follows:

- For vessel-support systems, a weighted average floor response spectrum was selected based on the location of the supports and the distribution of mass of the system.
- Floor response spectra for supports closer to the center of mass of the system were given a proportionately higher value for averaging purposes. If the system had only one support, the floor response spectrum for that location was used.

The response spectra used for the seismic analysis of a piping or ventilation system corresponded approximately to the input of most of the mass of the system. For a piping or ventilation system running through a large elevation difference within a building, the design spectra corresponded to that of the closest support above most of the mass of the system. For piping or ventilation systems between different structures, the response spectra at the end points were radically different. For such pipes or vents (if intermediate restraints existed on the pipe or vent between the two structures), the response spectra associated with the intermediate restraining structure was used. If no intermediate restraints existed, the average of the response spectra associated with the end points was used.

The effect of differential displacements on systems supported at more than one location was also considered. If the differential displacements were significant, the resulting torque, moment, shear, axial load, deflection and rotation values were combined with the corresponding values from the spectrum response analysis.

5.3 Fuel Storage Racks

The fuel canister storage racks in the pools are of two types, wall-supported beams and floor-mounted beam column frame racks.

5.3.1 Wall Racks

Wall racks are supported by beam studs which cantilever from the walls. This type of support rack is relatively rigid and will experience the same motion as that of the wall itself. They are located on the walls of the CUP, FTP, and FSP. The racks are designed to resist lateral seismic forces equal to the ground acceleration (0.12 g for OBE and 0.20 g for DBE) times the canister mass. The FSP wall racks are designed to resist the forces of two adjacent rows of canisters.

5.3.2 FSP Beam - Column Frames

Parallel rows of frame racks support the canisters in the FSP. These racks are pinned to the wall to resist motion parallel to their axis. They must resist forces perpendicular to their axis by cantilever bending of the columns and their support study projecting from the floor.

The cantilever motion was analyzed using a single mass on a cantilevered column model (see Figure D.20). The analysis of this model provided conservative responses and design forces by:

- Assuming all racks are moving in phase.
- Neglecting end restraints of wall racks, transmitted by friction from rack to canister.
- Neglecting large damping of the water.
- Sloshing effects and the presence or absence of water determined to be negligible.

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DESIGN SPECTRUM*

*Basis is AEC data for BNFP 5% curve at 0.12g.

OPERATING BASIS EARTHQUAKE - 0.12g

FIGURE D.1

DESIGN SPECTRUM*

*Basis is AEC data for BNFP 5% curve at 0.20g.

DESIGN BASIS EARTHQUAKE - 0.20g

FIGURE D.2

SPECTRAL ACCELERATION VS. CIRCULAR FREQUENCY
(OBE - 5% DAMPING)

FIGURE D.3

SPECTRAL ACCELERATION VS. CIRCULAR FREQUENCY
(DBE - 9.0% DAMPING)

FIGURE D.4

OBE (0.12g) GROUND TIME HISTORY
(5% DAMPING)

FIGURE D.5

DBE (0.20g) GROUND TIME HISTORY
(9% DAMPING)

FIGURE D.6

SHEAR MODULUS G FOR $0.12g$ GROUND ACCELERATION

FIGURE D.7

SHEAR MODULUS G FOR 0.2g GROUND ACCELERATION

FIGURE D.8

AGE	FORMATION & DISTRIBUTION WITHIN PLANT SITE AREA		Depth to Top	Thickness in Ft. in DH-2	Thickness * Range (Ft.)	Soil Class.	LOG	Description
QUATERNARY	RECENT	SAND COVER (covers major portion of surface in plant site area)	0	4	3-6	SM		Light gray-buff, silty fine to medium sand; loose; wind blown sand dunes
	MIOCENE	HAWTHORN (exposed in portions of plant area)	3-6	30	14-30	SC-CL		Mottled gray, brown, white, pinkish white, yellowish, white, and brick red sandy clay and clayey fine sand; grades to pinkish white silty sand; gravel lenses and numerous clastic clay dikes
TERTIARY	EOCENE	BARNWELL (exposed in banks of major streams)	30-35	CLAY LAYER NEAR TOP OF BARNWELL FORMATION		CH		Mottled white, brown, gray and red silty fine to medium sand; contains nodules of clay and one prominent clay (Kaolin) bed (CH)-(CL) white to light gray grayish purple gray; discontinuous beds and lenses of sand and sandy clay
				2 31	2-8 29-43	CL SC		
					9-16	SM		
	EOCENE	McBEAN (exposed in banks of major streams)	75-80	81 (not pene- trated)	48-114	SP		Reddish brown, yellowish brown to green, orangish brown, and whitish fine to coarse sand; trace of silt and occasional clay nodules; some soft sandy limestone and limy sand; dense
		CONGAREE ?	160-170	Not present in DH-2	?	SM		Light to dark brown silty fine sand; grading clayier with occasional clay nodules
CRETACEOUS	UPPER CRETA- CEOUS (?)	ELLENTON	375		115 (ASSUMED)	SP-CL		Dark gray to black sandy lignitic micaceous clay containing disseminated crystals of gypsum. Medium to- dark gray coarse sand and gravel
	UPPER CRETA- CEOUS	TUSCALOOSA	490		530 (ASSUMED)	SP-CL		Tan, buff, red and white cross-bedded micaceous quartzitic and arkosic sand and gravel, interbedded with red, brown and purple clay and white kaolin
*Average over site area.								STRATIGRAPHIC COLUMN

VARIOUS SOIL LAYERS AT BNFP SITE

FIGURE D.9

*Report, Preliminary Foundation Investigation, Barnwell Nuclear Fuel Plant, Allied Chemical Corporation, by Dames and Moor. Appendix D, PSAR, Page B4.

SOIL DISPLACEMENT DURING THE OBE
SEISMIC EVENT AT BNFP SITE

FIGURE D.10

*Report, Preliminary Foundation Investigation, Barnwell Nuclear Fuel Plant, Allied Chemical Corporation, by Dames and Moore. Appendix D, PSAR, Page B4.

SOIL DISPLACEMENT DURING THE DBE SEISMIC EVENT AT BNFP SITE

FIGURE D.11

FRSS BUILDING

FIGURE D.12

MATHEMATICAL MODEL OF NORTH-SOUTH SYSTEM

FRSS BUILDING

FIGURE D.13

PHYSICAL PRESENTATION OF WALL SYSTEM RESISTING EAST-WEST EARTHQUAKE

MATHEMATICAL MODEL OF EAST-WEST WALL SYSTEM

FRSS BUILDING

FIGURE D.14

ISOMETRIC OF POOL STRUCTURE

FIGURE D.15

LATERAL MODE

RESPONSES OF SOIL MEDIUM AND POOL STRUCTURE

FIGURE D.16

TYPICALLY, FOR $f (= \sqrt{K/M})$ GREATER THAN 10 CPS, DESIGN SYSTEM FOR $F = M \cdot S_a$, WHERE S_a IS THE APPROPRIATE TIME HISTORY STRUCTURAL ACCELERATION

SIMPLE CANTILEVERED SYSTEM

FIGURE D.17

Frame Supported Vessel

Mathematical Model

Floor Supported Vessel

Mathematical Model

SIMPLE BEAM SYSTEM

FIGURE D.18

MATHEMATICAL MODEL OF A PIPING SYSTEM

FIGURE D.19

FSP FUEL STORAGE RACKS

FIGURE D.20

APPENDIX E

to

Report No. AGNS-1040-1.4-20

CRITICALITY ANALYSIS

August 1978

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1.0 INTRODUCTION

Criticality analysis of the Fuel Receiving and Storage Station was submitted to NRC by AGNS as "Proprietary Information" and is included in the PROPRIETARY SUPPLEMENT to the Final Safety Analysis Report (FSAR). That analysis -- to include special design features, definition of fuel, assumptions used in the analysis, and conclusions derived therefrom -- is summarized herein.

Nuclear criticality safety criteria have been established to ensure that conditions and combinations of circumstances in the FRSS that could cause a nuclear accident will be eliminated or minimized. Criticality prevention in the FRSS will be achieved by requirements that limit the fuel assembly design characteristics (e.g., enrichment) and by geometry controls. Accomplishment of these nuclear safety objectives relies on FRSS design, the design of certain components, and enforcement of certain administrative procedures.

Specific characteristics of BWR and PWR fuel assembly combinations were used in the analysis of FRSS nuclear criticality safety and design features. The analysis considered the most reactive of the fuel types in configurations that are possible both in practice and during plausible accidents.

Final design criteria for the FRSS and storage components were selected (i) in order not to exceed the neutron multiplication factor of 0.95 and (ii) in accordance with American National Standard Nuclear Criticality Safety for Operations with Fissionable Materials Outside Reactors.

2.0 SPECIAL DESIGN FEATURES

The fuel storage canisters are portable, aluminum structures containing compartments for holding individual fuel assemblies. The spacing of these compartments within a canister provides the fuel assembly separation required to ensure subcriticality. The compartments are sized to accommodate fuel assemblies contained within leakers cans. Different canister designs are used for BWR and PWR fuel assemblies.

While in storage, the canisters rest on canister storage support structures. The supports on the canisters are located well above the canister center of gravity so that it is not possible for a stored canister to tip over and spill the contained fuel. These support structures are located at an elevation such that the stored canisters are relatively close to the floor of the related pool. Should the canisters drop from the storage support structure, it is probable the canisters will retain their upright orientation. Even if a canister should subsequently fall on its side, it is not conceivable that the fuel would spill out.

During canister movement, particularly in the deeper pools, it is conceivable for the canisters to accidentally drop in a manner to

potentially spill the contained fuel assemblies. To prevent such a spillage, a cap is placed on the fuel canisters during their movement. The grapple normally used for canister movement is attached to the cap.

The only lifting gear provided on the canister crane is the canister cap and the only crane which handles canisters during operation is the canister crane. Therefore, if a full fuel canister is to be handled by any method other than being capped, a nonstandard lifting rig must be purposely installed on the canister crane.

While it is possible through use of a nonstandard lifting gear to move a canister without a cap, administrative controls require adherence to FRSS operating procedures which require the cap to be attached to the fuel-laden canister during its movement. Administrative controls also prohibit the use of nonstandard lifting gear without written procedures that have been reviewed and approved by AGNS' Operational Safety Committee. The independent Operational Safety Committee will base such procedure review and approval on maximizing personnel and criticality safety on a case-by-case basis.

3.0 FUEL

Specific BWR and PWR fuel assemblies representing the most reactive parameters of currently designed LWR fuels were used in the criticality analysis of the FRSS. The parameters for fuel selection meeting the "most reactive" criteria are given in Table No. 2, page 7 of the PROPRIETARY SUPPLEMENT. The most reactive conditions for these fuel types were used as follows:

- A large array of loaded canisters, both with and without leaker cans
- A fuel assembly moved vertically adjacent to a fully loaded canister
- A fuel assembly positioned across the top of a fully loaded canister.

4.0 ASSUMPTIONS

The following conservative assumptions were used in the analysis:

- Unirradiated fuel was assumed, and no credit was taken for burnable poisons or for fission products.
- The loaded canisters were assumed to be infinite in the axial direction.
- No credit was taken for spatial neutron self-shielding within the fuel pin.

- A conservative estimate of the Dancoff factor was used. (The Dancoff factor was calculated for the largest pin diameter and smallest pin pitch of present generation fuel; and infinite lattice was used in the Dancoff calculation.)
- The largest assembly width was used.
- Zirconium clad was used instead of zircaloy. (Zircaloy contains additives which are neutron poisons.)
- Water density of 0.958 gram/cc, corresponding to 212°F water, was assumed to allow for a failure in the pool coolant system. (The increased coupling between assemblies caused by this reduction in water density more than compensates for the reactivity loss due to the reduction in moderation.)
- The largest volume fraction of water in the assemblies was assumed, since PWR and BWR assemblies are under-moderated.
- The highest linear density of U-235 was used.
- The highest enrichment was used.
- A maximum allowable multiplication factor of 0.95 was used.

5.0 CONCLUSIONS

The following conclusions resulted from the criticality analysis:

- For the most reactive case (with fuel assemblies clustered together at adjacent corners of neighboring compartments) the multiplication factor is 0.927 for PWR fuel and <0.925 for BWR fuel. Hence the storage design is subcritical with either PWR or BWR fuel.
- Assemblies contained in leaker cans filled with water or helium were calculated to be at least 0.046 Δk less reactive than the non-leaker cases. The leaker can design may thus be safely used in the fuel storage pool.
- The case in which a fuel assembly is positioned across the top of the canisters is not a problem, since the conservative assumption was made that the system is infinite in the axial direction. In addition, in such an event the fuel in the assembly across the top of the canister would be separated from the fuel in the canister by the unfueled end pieces of the fuel assemblies.
- The accidental insertion of a BWR assembly (or assemblies) between adjacent PWR canisters is not possible, because of the presence of structural members on the sides of the canister.

- A PWR element moved vertically next to (but not between) PWR canisters containing fuel will increase the multiplication factor less than 0.01 Δk to a value under 0.95.
- Administrative controls required by Technical Specifications ensure that fuel assembly designs not considered in this analysis are properly analyzed prior to receipt and storage of the fuel so designed.
- Administrative controls required by Technical Specifications ensure that fuel assemblies are placed in appropriate canisters, that fuel-laden canisters are normally stored only on canister racks, and that only one PWR fuel assembly or two BWR fuel assemblies are handled outside of the cask or outside of the canister at any given time in a given pool.
- Spillage of fuel assemblies from a canister while in transit is prevented by a canister cap which is secured in position.
- Fuel spillage from canisters in storage is not credible because the canisters are restrained by high integrity storage support structures. Only one loaded canister may be in an unrestrained condition at any time in the fuel storage pool.

APPENDIX F

to

Report No. AGNS-1040-1.4-20

REFERENCE DRAWINGS

August 1978

APPENDIX F

REFERENCE DRAWINGS

- (1) 519D-A-5001 -- Spent Fuel Storage Facility - Plan
- (2) 519D-A-5002 -- Spent Fuel Storage Facility - Elevations
- (3) 519D-A-5003 -- Spent Fuel Storage Facility - Site Plan
- (4) 519D-A-5004 -- Hi-Density Fuel Storage Rack Layouts
- (5) 519D-A-5005 -- Liquid Waste Flow Diagram
- (6) 519R-A-5006 -- P&ID - Spent Fuel Storage Facility - Pool Water Treatment
- (7) 519R-A-5007 -- Piping and Instrument Diagram - Spent Fuel Storage Facility - Liquid Waste Concentrator
- (8) 519B-A-5008 -- HVAC Flow Diagram - Spent Fuel Storage Facility
- (9) 519D-A-5009 -- Spent Fuel Storage Facility - Demineralizer Area
- (10) 519D-A-5010 -- Spent Fuel Storage Facility - Pump, Filter and Exchanger Area
- (11) 519D-A-5011 -- Spent Fuel Storage Facility - Liquid Waste Concentration Area
- (12) 519E-A-5012 -- Fuel Receiving and Storage Station (FRSS) - Plan
- (13) 519E-A-5013 -- Fuel Receiving and Storage Station (FRSS) - Section A-A
- (14) 519E-A-5014 -- Spent Fuel Storage Station - Protected Area

PLAN @ EL. 254'-0"
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BARNWELL NUCLEAR FUEL PLANT									
BARNWELL SOUTH CAROLINA									
AGNS DESIGN ENGINEERING DEPARTMENT									
P. O. BOX 847 BARNWELL, S. C. 29812									
SPENT FUEL STORAGE FACILITY - PLAN									
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			HI-DENSITY FUEL STORAGE RACK LAYOUTS						
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HVAC FLOW DIAGRAM - SPENT FUEL STORAGE FACILITY									
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		DEMINERALIZER AREA							
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519D-A-5001		SCALE 5/8" = 1'-0"		FACILITY		DRAWING NO.		ISSUE		
		DWG. TYPE				519D-A-5010		A		
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Diagram illustrating the layout of a laboratory facility, showing various equipment and dimensions.

Equipment and Components:

- LIQUID WASTE STORAGE TANK (9'-0" x 7'-0")
- LIQUID WASTE DELANTER (3'-9" diameter)
- CHECK TANK 4'Ø
- CONCENTRATOR 4'Ø
- CONC. BOTTOMS PUMP (6'-6")
- SLURRY PUMP
- CONC. FEED PUMP
- FILTER BLOWDOWN TANK (6'-0" x 4'-0")
- FILTER WASTE PUMP
- DRAIN SUMP - 6' DEEP
- EJECTOR (2'-0" x 2'-0")
- INSTRUMENT & CONTROL RACK
- VAPOR SUPERHEATER
- STACK DILUTION AIR HEATER, BLOWER, FILTER
- EXHAUST STACK
- HEPA FILTER
- AIR LOCK
- PIT - 6' DEEP
- CURB

Dimensions:

- Overall Width: 27'-0"
- Overall Depth: 28'-0"
- Storage Tank Width: 9'-0"
- Storage Tank Height: 7'-0"
- Delanter Diameter: 3'-9"
- Check Tank Diameter: 4'-0"
- Concentrator Diameter: 4'-0"
- Conc. Bottoms Pump Width: 6'-6"
- Slurry Pump Diameter: 1'-6"
- Conc. Feed Pump Diameter: 1'-6"
- Filter Blowdown Tank Width: 6'-0"
- Filter Blowdown Tank Height: 4'-0"
- Filter Waste Pump Diameter: 1'-0"
- Drain Sump Depth: 6'-0"
- Ejector Dimensions: 2'-0" x 2'-0"
- Instrument & Control Rack Height: 8'-0"
- Vapor Superheater Dimensions: 14'-6" x 2'-0"
- Stack Dilution Unit Dimensions: 14'-6" x 2'-0"
- Exhaust Stack Diameter: 2'-0"
- HePA Filter Dimensions: 5'-0" x 2'-0"
- Air Lock Dimensions: 5'-0" x 2'-0"
- Pit Depth: 6'-0"

PHYSICAL PROTECTION NOTES:

- 1. ALL EXITS TO BE EQUIPPED WITH BALANCED MAGNET FIELD DOOR ALARMS WHICH ANNUNCIATE AT THE CENTRAL & SECONDARY ALARM SYSTEM ALSO LOCALLY.
- 2. INTERIOR OF FRSS TO BE EQUIPPED WITH CCTV/ MOTION DETECTION UNITS.
- 3. VEHICLE ACCESS PORTALS TO BE EQUIPPED WITH DUAL LOCKING SYSTEM WITH OUTSIDE DOOR AREA UNDER CCTV SURVEILLANCE.

6 3 0 6 12 24 FT
GRAPHIC SCALE

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SECTION A-A

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