VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

November 19, 2015

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Director, Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety and Safeguards
Washington, DC 20555-0001

Serial No. 15-369F
NLOS/TJS R0
Docket No. 72-16
License No. SNM-2507

VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA POWER STATION INDEPENDENT SPENT FUEL STORAGE INSTALLATION
PROPOSED TECHNICAL SPECIFICATION CHANGE REQUEST REGARDING STORAGE OF INCREASED MAXIMUM ENRICHMENT AND BURN-UP FUEL IN A MODIFIED TN-32B STORAGE CASK
SUBMITTAL OF SUPPLEMENTAL INFORMATION

On August 24, 2015, Virginia Electric and Power Company (Dominion) requested an amendment (NRC Accession No. ML15239B251) in the form of revisions to the Technical Specifications to License Number SNM-2507 for the North Anna Power Station (NAPS) Independent Spent Fuel Storage Installation (ISFSI). The proposed amendment would allow storage of spent fuel in a modified TN-32B bolted lid cask as part of the High Burn-up Dry Storage Cask Research and Development Project sponsored by the Department of Energy (DOE) and the Electric Power Research Institute (EPRI).

On November 13, 2015, NRC Senior Project Manager John Nguyen requested the items provided in the attachment to this letter referenced in the submittal discussed above. One of the items requested was the TN-32 Updated Final Safety Analysis Report, Revision 6, dated April 2014. This document was previously submitted to the NRC by AREVA/TN as an attachment to AREVA/TN letter E-37975 dated April 16, 2014. The AREVA/TN letter can be found on ADAMS (Accession Number ML14108AD25).

NMSS26

If you have any questions or require additional information, please contact Mr. Thomas Szymanski at (804) 273-3065.

Sincerely,

Mark D. Sartain
Vice President – Nuclear Engineering

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Mark D. Sartain, who is Vice President – Nuclear Engineering, of Virginia Electric and Power Company. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 19th day of November, 2015.

My Commission Expires: 12/31/16.

CRAIG D SLY
Notary Public
Commonwealth of Virginia
Reg. # 7518653
My Commission Expires December 31, 2016

Notary Public

Commitments made in this letter: None

Attachment 1: Requested Information Related to HBU Cask

cc: U.S. Nuclear Regulatory Commission (w/o attachment)
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ATTACHMENT 1

Requested Information Related to HBU Cask:

- **North Anna Power Station, Units 1 & 2, Independent Spent Fuel Storage Installation (ISFSI) Safety Analysis Report, Revision 8.02, 11/16/15**
- **Letter from AREVA / TN documenting submittal of TN-32 Updated Final Safety Analysis Report (UFSAR), Revision 6, 04/16/14 (ML14108AD25)**
- **Letter from AREVA / TN documenting material density of the B_4C rod material, 11/17/15**
- **SCALE Criticality Safety Analysis Model Input File**

North Anna Power Station ISFSI

Virginia Electric and Power Company

North Anna Power Station
Units 1 & 2

Independent Spent Fuel Storage Installation (ISFSI)

Safety Analysis Report

REVISION SUMMARY

Revision 8.02—11/16/15

Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
2.5.2.2, 2.5.2.4 (new), 2.5.2.4.1 (new), 2.5.6 Refs, 4.1, 4.2.1 [NAPS-ICR-2015-002]	Revised the TN-32 dry storage cask spacing requirement.

Revision 8.01—10/15/14

Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
4.4.3, 5.1.3.3, A.1.4, A1.10 [NAPS-ICR-2014-001]	Update reflects the thermal analysis during recoating of the exterior of TN-32 Casks at the ISFSI.

Revision 8—06/2014

Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
Figure 1-1, Figure 1-2, 2.5.1, 2.5.1.5, 2.5.1.5.1, 2.5.1.6, 2.5.1.7, 2.5.1.9, 2.5.4, 2.5.5, 2.5.6 Refs, Figure 2-3, Figure 2-8, Figure 2-9, Figure 2-18 (new), Figure 2-19 (new), Appendix 2A, 4.1, 4.3.2, Figure 4-1, Figure 4-4, 5.1.1.1, 5.4 [NAPS-ICR-2010-001]	Update adds description of an alternate transport route to the Independent Spent Fuel storage Installation.
4.4.5.4 (new), 4.4.6 Refs [NAPS-ICR-2012-001]	Update added section to reflect the installation of new seismic instrumentation.

Revision 7—06/2010

Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
9.5 [IN 2008-002]	Revises description of Notification of Unusual Event to reflect new Emergency Action Level classification for damage to a loaded SSSC confinement boundary.

Revision 6—06/2008

Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
1.1, Figure 1-2 [IN 2006-001]	Describes the addition and location of the second storage pad.
2.1.3, 2.1.4, 4.4.1.3 [IN 2008-001]	Editorial package.

Revision 5—06/2006

Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
1.5, 9.1.1, 11.1 [IN 2004-001]	Incorporated references to the recently implemented Topical Report DOM-QA-1. The Dominion Nuclear Facility Quality Assurance Program Description is based on ANSI/ASME NQA-1-1994 and will be maintained as a separate, single document for Dominion facilities. [10 CFR 50.54(a)]
7.6, 7.7 [IN 2004-002]	Updated the description of the health physics program to include dosimetry placed on the ISFSI perimeter fence and clarified the description of the environmental monitoring program.
A.1.1 [IN 2003-007]	Deleted the description of the original TN-32 cask protective cover design.

Revision 4—06/2004

Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
Figures 2-9 & 4-4 [IN 2000-002]	Removed the fence and gate symbols incorrectly shown around the service water pump house.

Revision 4—06/2004 (continued)

Section	**Changes** **Made under the provisions of 10 CFR 72.48 except where indicated in brackets.**
3.1.1, 3.1.1.1, 3.1.1.1.1, 3.1.1.1.2, 3.3.4, 3.3.4.1, 3.3.4.2, 3.3.4.3, 3.3.5, 3.3.7, Tables 3-1 & 3-2, 4.2.3.3, 5.1.2, 5.1.3.1, 5.1.3.4, Tables 5-3 & 5-4, Chapter 6, 7.2.1, 7.2.2, 7.2.3, 7.3.2, 7.3.2.1, 7.3.2.2, 7.3.4, 7.4, 7.4.1, 7.5, Tables 7-1, 7-2, 7-3, 7-4, 7-5, 7-6, 7-7, 7-8, 7-9, 7-10, 7-11, 7-12, 7-13, 7-14, 7-15, & 7-16, Figures 7-2, 7-3, 7-4, & 7-5, 8.2.10.2, 8.2.10.3, 8.2.11, Table 8-1, 9.1.1.4, 9.1.4, Table 10-2, A.1.1, A.1.2, A.1.3, A.1.3.1, A.1.4, A.1.8, A.1.8.1, A.1.9, A.1.10, Tables A.1-1, A.1-2, & A.1-3, Figures A.1-1, A.1-2, A.1-3, & A.1-4 [IN 2002-002 & IN 2003-002]	Updated the shielding, criticality, thermal, and accident evaluations associated with the increased initial enrichment of 4.30 weight percent U^{235} and the increased assembly average burnup of 45,000 MWD/MTU. [10 CFR 72.56 License Amendment]
4.1, 7.1.1, 7.1.2, 7.3.1, 7.4, Figure 7-1 [IN 2003-001]	Added locked security personnel access gates to the ISFSI perimeter fence.
4.4.1.2, Figure 4-14 [IN 2003-005]	Placed a cask pedestal in the cask loading area of the spent fuel storage pool.
4.4.5.3, 5.2 [IN 2003-006]	Revised organizational title of the Shift Manager.
11.1 [IN 2003-004]	Made editorial correction to correctly refer to QA Program Topical Report Table 17.2-0.
A.1.1 [IN 2002-004]	Identified the analyses in Chapters 4 & 6 of the TN-32 FSAR, Rev. 0, that were added to the North Anna ISFSI SAR.
A.1.1 [IN 2002-005]	Provided bolt torque ranges for the TN-32 casks.
A.1.1, Appendix A.1 Attachment 1 [IN 2002-003]	Added explanation of the use of TN-32 casks designed and fabricated to TN-32 Final Safety Analysis Report, Revision 0.
A.1.1, Appendix A.1 Attachment 4 [IN 2002-006]	Incorporated additional analyses regarding TN-32 cask gap between center basket rails.
A.1.2 [IN 2003-003]	Added allowance for the storage of a fuel assembly with rod clips.

Revision 3—06/2002

Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
4.4.5.1, 8.2.5.1 [IN 2001-001]	Clarified the description of the placement of fire extinguishers at the ISFSI site as well as the availability of fire fighting equipment and personnel.
5.1.1.1 [IN 2001-005]	Changed cask receipt procedure consistent with the North Anna Power Station Updated Final Safety Analysis Report.
9.2.2.1 [IN 2002-001]	Deleted incorrect testing requirements for electrical and communications systems.
A.1.1, Appendix A.1 Attachment 1 [IN 2001-003]	Incorporated the modified TN-32 cask lid bolt analysis.
A.1.1, Appendix A.1 Attachment 3 [IN 2001-002]	Modified the TN-32 cask protective cover and overpressure system.
A.1.7, Appendix A.1 Attachment 2 [IN 2000-001]	Incorporated structural analyses for missile impacts on TN-32 casks.

Revision 2

Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
3.1.1, A.1.2 [IN 99-01]	Added information on the storage of burnable poison rod assemblies and thimble plug devices in TN-32 casks. [10 CFR 72.56 License Amendment]
A.1.1 [IN 99-02]	Revised the description of the weld in the neutron shield outer shell of TN-32 casks.
A.1.1 [IN 99-03]	Clarified the location of borated aluminum plates in the fuel basket of TN-32 casks.

Revision 1

Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
3.1.1, 3.3.6, 4.2.1, 4.4.4.1, 4.5, Table 4-1, Chapter 6, 7.2.2, A.1.1, A.1.2, A.1.5, A.1.6, Appendix A.1 Attachment 1 [IN 98-03]	Delete references to fuel insert components, clarify the maximum capacity of the backup diesel generator fuel tank, update as-built parameters of the concrete pad, add 120V circuit description, clarify the status of cask handling equipment, delete statement that emergency actions are neither credible nor postulated to occur, discuss operational practices to prevent weather-driven spread of contamination, add I^{129} and Co^{60} inventories per assembly, incorporate TN-32 lid bolt analysis, add TN-32 Cask Sliding and Tip-over Analysis, and add Evaluation of Tornado Missiles.
A.1.1 [IN 98-01]	Include fillet weld as an alternative to the groove weld for the fuel basket.
A.1.3 [IN 98-02]	Add discussion of dose rate and exposure estimates.

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NORTH ANNA ISFSI SAR

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Chapter 1 INTRODUCTION AND GENERAL DESCRIPTION OF STORAGE SYSTEM

1.1 INTRODUCTION

Discharged spent fuel assemblies from the North Anna Power Station, Units 1 and 2 are currently stored in a spent fuel pool common to both Units. The spent fuel pool provides for interim storage of 1737 fuel assemblies in high density storage racks. Typically, 64 spent fuel assemblies are discharged from each Unit about every 18 months. Section 3.1.1 provides a description of the spent fuel. Additional information on the fuel design is available in Section 4.2 of the North Anna Power Station Updated Final Safety Analysis Report (UFSAR).

Based on the current fuel management strategy and refueling outage schedule, the spent fuel pool will lose the capacity for single unit full core discharge in late 1998. Storage capacity in the pool will be completely exhausted in 2000, therefore, additional spent fuel storage capacity is needed. To support this need, sealed surface storage casks (SSSCs) have been chosen for use at an Independent Spent Fuel Storage Installation (ISFSI) at the North Anna site.

The North Anna ISFSI is designed to store all the anticipated spent fuel resulting from the operation of the North Anna Power Station Units 1 and 2 in excess of that which can be stored in the spent fuel pool, or approximately 1824 fuel assemblies. Construction of the North Anna ISFSI is scheduled to begin in June 1997 and the first SSSC should be placed at the ISFSI in August 1998.

The North Anna ISFSI is located within the site boundary of the North Anna Power Station, which is owned 88.4% by Virginia Electric and Power Company (Virginia Power) and 11.6% by the Old Dominion Electric Cooperative. Virginia Power is responsible for operations at the Station.

This SAR is primarily directed towards analyzing the safety aspects of SSSC handling and storage once the SSSCs have been lifted by the cask transporter, and how the safety requirements in 10 CFR 72 are satisfied. Handling of the SSSCs inside the Fuel and Decontamination Buildings and cask crane bay is performed in accordance with the operating license for the North Anna Power Station under 10 CFR 50, however, these operations are also described in this SAR.

This SAR indicates that up to three concrete storage pads could be used at the North Anna ISFSI and were intended to store vertical, metal SSSCs. An additional pad, to be used under a 10 CFR 72, Subpart L general license, was installed in place of the original Pad 2. The ISFSI site plans described in this SAR have been updated to reflect the new configuration of the ISFSI site with this additional pad.

1.2 GENERAL

The North Anna site comprises approximately 1043 acres in Louisa County, Virginia. The ISFSI is located near the center of the site, approximately 2000 feet southwest of the protected area for North Anna Units 1 and 2. Figure 1-1 shows a general layout of the North Anna site.

North Anna Power Station Units 1 and 2 consist of two closed-cycle pressurized water reactors (PWR) provided by Westinghouse. Operating licenses were issued by the NRC in April 1978 and August 1980 for Units 1 and 2, respectively. Unit 1 started commercial operation in June 1978 and Unit 2 in December 1980. A complete description of the power station is provided in the North Anna Power Station UFSAR, NRC dockets 50-338/339.

The North Anna ISFSI consists of three concrete storage pads on which the loaded SSSCs are placed. The storage pads will be built in sequence, as needed, and in an order which minimizes radiation exposures. The storage pads will be surrounded by a security fence and a nuisance fence. Another fence will enclose the perimeter of the ISFSI site (hereinafter referred to as the ISFSI perimeter fence).

1.3 GENERAL STORAGE SYSTEM DESCRIPTION

The North Anna ISFSI uses SSSCs to store fuel irradiated at the North Anna Power Station. Typically, the SSSCs are large cylindrical vessels capable of storing up to 32 unconsolidated PWR fuel assemblies. The SSSCs are made of carbon steel, stainless steel, or cast iron. They are about 16 feet long and 8 feet in diameter, have walls several inches thick and weigh 100 to 125 tons fully loaded. The fuel is stored in a helium atmosphere and held in place by a basket or rack.

Figure 1-2 shows the general arrangement of the North Anna ISFSI.

The loading and preparation of an SSSC takes place within the Fuel and Decontamination Buildings of the North Anna Power Station. The SSSC is loaded under water in the spent fuel pool where a lid is positioned on the SSSC prior to lifting it out of the water. Water in the SSSC is removed, the interior is further dried under vacuum and then filled with helium. Following decontamination of the outer surface, the SSSC is placed in a transporter outside the Decontamination Building. The SSSC is then transferred to the ISFSI, where it is emplaced on one of the three storage pads.

The SSSCs are totally passive systems, with natural convection cooling sufficient to maintain safe fuel clad temperatures. The SSSC walls provide adequate shielding, and no radioactive products are released under any credible conditions.

1.4 IDENTIFICATION OF AGENTS AND CONTRACTORS

SSSCs to be used in the North Anna ISFSI are designed and fabricated by other organizations and will be purchased by Virginia Power. The SSSC suppliers are responsible for SSSC fabrication, testing, and delineation of specific SSSC requirements, if any. Information related to the qualifications of the SSSC suppliers is contained in the Topical Safety Analysis Reports referenced in Section 1.5.

Site preparation and necessary construction will be performed by Virginia Power's Site Services Department, using specialty subcontractors, as required.

1.5 MATERIAL INCORPORATED BY REFERENCE

Detailed information describing the SSSCs is provided in the SSSC Topical Safety Analysis Reports referenced in Appendix A, Table A-1 of this Safety Analysis Report (SAR). General references to the SSSC Topical Safety Analysis Reports are made in sections of this SAR, as needed, to supplement information contained in the SAR. Each SSSC type is described in a sub-appendix of Appendix A. Also, the sub-appendices provide SSSC-specific information not contained in the SSSC Topical Safety Analysis Reports. The combination of this SAR, including appendices, and any one of the reports describing the SSSCs (one per type of SSSC) provides all the information described in Regulatory Guide 3.62 (February 1989), *Standard Format and Content for the Safety Analysis Report for Onsite Storage of Spent Fuel Storage Casks.*

The following documents, which are already on file with the NRC, are referenced throughout this SAR:

1. *North Anna Power Station Units 1 and 2, Updated Final Safety Analysis Report,* NRC dockets 50-338 and 50-339.
2. *North Anna Power Station Units 1, 2, 3 and 4, Environmental Report,* submitted March 15, 1972.
3. *North Anna Power Station, Emergency Plan.*
4. Dominion Nuclear Facility Quality Assurance Program Description, Topical Report DOM-QA-1.
5. *Surry Power Station, Independent Spent Fuel Storage Installation, Safety Analysis Report.*

Security-Related Information
Figure Withheld Under 10 CFR 2.390

Figure 1-1
ISFSI LOCATION ON NORTH ANNA SITE

Figure 1-2
ISFSI GENERAL ARRANGEMENT

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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Chapter 2 SITE CHARACTERISTICS

2.1 GEOGRAPHY AND DEMOGRAPHY OF SITE SELECTED

2.1.1 Site Location

The location of the Independent Spent Fuel Storage Installation (ISFSI) is approximately 2000 feet southwest of the North Anna Power Station Units 1 and 2 protected area and within the boundaries of the North Anna site (see Figure 1-1). The ISFSI occupies approximately 11 acres.

The North Anna site is located in the north-central portion of Virginia in Louisa County. The site is on a peninsula on the southern shore of Lake Anna at the end of State Route 700. The earth dam that creates the lake is approximately 5 miles southeast of the site. The North Anna River flows southeasterly, joining the South Anna River to form the Pamunkey River approximately 27 miles southeast of the site.

The largest community within 10 miles of the site is the Town of Mineral (Louisa County), which had a 1990 population of 452 persons, and is approximately 6 miles west-southwest of the site. The community of Louisa, which had a 1990 population of 1088 persons, is approximately 12 miles to the west of the site. Figure 2-1 shows the general location of the site and the surrounding localities within 10 miles.

Regionally, as indicated in Figure 2-2, the site is approximately 40 miles north-northwest of Richmond; 36 miles east of Charlottesville; 22 miles southwest of Fredericksburg; and 70 miles southwest of Washington, D.C. Interstate highways 95 and 64, the two principal highways serving Richmond, pass within 16 miles east and 16 miles southwest of the site, respectively.

The approximate coordinates of the ISFSI are:

Latitude-Longitude	Universal Transverse Mercator
38° 3.8' N - 77° 47.5' W	4,215,900 mN - 255,100 mE; Zone 18S

2.1.2 Site Description

The North Anna site property comprises 1803 acres, of which approximately 760 acres are covered by water. The site boundary is shown in Figure 2-3. Virginia Power owns, in fee simple, all of the land within the site boundary, both above and beneath the surfaces, including those portions of the reservoir and waste heat treatment facilities (cooling lagoons) that lie within the site boundary. The controlled area is all of the area within the site boundary. Virginia Power also owns, in fee simple, all land outside the site boundary that forms the reservoir and the cooling lagoons up to their expected high-water marks. The Station and all supporting facilities including the reservoir, cooling lagoons, earthen dam, dikes, railroad spur, and roads constitute approximately 13,775 acres.

The site plan for the North Anna ISFSI and its relative location to the North Anna Power Station are presented on Figure 2-3. Consistent with Section 2.1.2.1 of the North Anna Power

Station UFSAR, the restricted area for the ISFSI is the North Anna site boundary. The controlled area boundary is also the site boundary. As shown on Figure 2-3, the minimum distance to the controlled area boundary from the ISFSI is approximately 2500 feet and occurs in the southwest sector relative to the ISFSI.

Since the controlled area for the North Anna ISFSI is wholly within the property lines for the North Anna site, Virginia Power has full authority to determine all activities including the exclusion and the removal of personnel and property. No activities unrelated to operation of the North Anna Power Station or the ISFSI are permitted within the controlled area.

The topography in the site region is characteristic of the central Piedmont Plateau with a gently undulating surface varying from 200 to 500 feet above sea level (see Figure 2-7). The surrounding region is covered with forest and brushwood interspersed with an occasional farm. The land adjacent to the reservoir is becoming increasingly residential as the land is developed.

Figure 2-8 shows the topography in the vicinity of the ISFSI. Drainage of surface water at the ISFSI will be provided by channels to a small creek to the south and west. The area inside the ISFSI perimeter fence will be graded level. Areas not needed for ISFSI operations will be seeded with grass, while areas needed for ISFSI operations will be covered with course gravel. The areas surrounding the west, south and east sides of the ISFSI perimeter fence will remain forested. Based on this description, the potential for erosion at the ISFSI is small, and the potential for forest fires exists only outside the ISFSI perimeter fence.

2.1.3 Population Distribution and Trends

Cities within 50 miles of the site are shown on Figure 2-2. Section 2.1.2 of the North Anna ISFSI Environmental Report, contained in the ISFSI Reference Document Manual, provides detailed information on population projections.

2.1.4 Use Of Nearby Land and Waters

The North Anna site is located in a predominantly rural area of Louisa County, Virginia. In Louisa County and the four adjacent counties of Spotsylvania, Orange, Hanover and Caroline, an average 42.5% of the total county acreage is used for agriculture. Approximately 38% of the 508,443 agricultural acres in these five counties is cropland, 15% is pastureland, and the balance is woodland. Principal crops are barley, tobacco, corn, wheat, hay and soybeans. Poultry, livestock and dairy products are also major agricultural products of the area and represent the greatest share of the area's cash farm income.

Section 2.1.2.3 of the North Anna ISFSI Environmental Report, contained in the ISFSI Reference Document Manual, provides information on recreational activities on Lake Anna. Section 2.2.1 that follows provides information on industrial activities in the area.

2.2 NEARBY INDUSTRIAL, TRANSPORTATION, AND MILITARY FACILITIES

2.2.1 Description

Currently, there are none of the following facilities within 5 miles of the North Anna site: military bases, manufacturing plants, chemical plants and storage facilities, airports, major railroad lines, major water transportation routes or oil and gas pipelines. Also, there are no mining activities within 5 miles of the site.

There are no significant industrial activities within 5 miles of the site. Based on trends of industrial growth and projected population figures, it is not expected that any major industrial expansion will occur in this area.

Roads within 10 miles of the site are shown on Figure 2-1. Virginia Route 208 and US Route 522 are the major transportation routes serving the site area that pass within 5 miles of the site, however, there are no specific data on the types and quantities of products and materials transported on these roads.

State Route 700, east from State Route 652, is the only land access to the North Anna site. It ends at the site west boundary. No chemicals or cargo are expected to be transported on this portion of Route 700 unless the chemicals or cargo are used by the North Anna Power Station.

The railroad line closest to the site is the line owned by CSXT. It passes through the towns of Louisa, Mineral, Fredericks Hall and Bumpass; its closest approach to the site is approximately 5.5 miles southwest. A spur line connects the site with this line.

There are only two airports within 10 miles of the site: Lake Anna (Rest-A-While) Airport and Cub Field. The Louisa County Airport is located 11 miles west-southwest of the site. Operations at these airports involve light aircraft. None of these airports are expected to grow significantly in the foreseeable future. Section 2.2.1.6.2 of the North Anna Power Station UFSAR includes a discussion of airways over the site.

2.2.2 Effects of Potential Accidents

The only sources of explosion and formation of flammable vapor clouds are explosive materials/chemicals carried by truck traffic.

The largest possible explosive load routinely transported contains 8500 gallons of gasoline (set by highway weight limits). Based on an analysis in Section 2.2.2.1.1 of the North Anna Power Station UFSAR, if this amount of gasoline were to explode at the closest point to the site, 1.5 miles on State Route 652, a peak overpressure of 1 psi would be experienced approximately 1900 feet away from the point of explosion. The overpressure experienced by the SSSCs 1.5 miles away from the explosion would be significantly less than 1 psi.

2.3 METEOROLOGY

Meteorology at the North Anna Power Station is described in Section 2.3 of the North Anna Power Station UFSAR. Information from the UFSAR concerning meteorology is summarized and supplemented below.

2.3.1 Regional Climatology

The climate of the site is basically modified continental. The summers are warm and humid while winters are generally mild. The Blue Ridge Mountains to the west act as partial barriers to winter storms, modifying their intensity as they move across the rolling Piedmont to the Tidewater region adjacent to the Atlantic Ocean.

Climatic characteristics are illustrated in Figure 2-4 through Figure 2-6 which show daily average temperatures, daily extreme temperatures, and the probability of an extreme l-mile wind passage for Richmond, Virginia. Temperatures in the site region rarely exceed 95°F or fall below 10°F.

Rainfall averages approximately 44 inches per year around the site region and is fairly well distributed throughout the year, with the exception of the months of July and August, when thunderstorm activity raises the monthly totals to approximately 5 inches. Tropical storms may also contribute significantly to precipitation during the late summer and fall. Records indicate that the maximum rainfall during a 24-hour period was 8.79 inches, which occurred in August 1955.

Snowfalls of 4 inches or more occur an average of once per year. Snow usually only remains on the ground from 1 to 4 days at a time. Richmond averages 14.6 inches of snow per year.

Tornadoes are infrequent in Virginia. In the period from 1916 through 1987, only 65 tornadoes were reported within a 50-mile radius of the North Anna site (Reference 1). This averages to less than one tornado per year within this radius. Based on statistical methods proposed by Thom (Reference 2) and as described in detail in Section 2.3.1.3.2 of the North Anna Power Station UFSAR, the probability of a tornado striking a point within the 50-mile radius is 3.25×10^{-5} per year, or a recurrence interval of 30,800 years.

Richmond averages 37 thunderstorm days per year with a quarter of these typically occurring in July. Cloud-to-ground lightning strike data within an approximate 10-kilometer radius of the site region was analyzed for the ten year period of 1984 to 1993. Results indicate a minimum yearly strike frequency of 1.1 strikes per square kilometer in 1992 and a maximum yearly strike frequency of 3.9 strikes per square kilometer in 1988.

2.3.2 Local Meteorology

2.3.2.1 Data Sources

Meteorology in the North Anna Power Station site area was evaluated as part of its Operating License application review. Data acquired by the National Weather Service and summarized by the Environmental Data Service (Reference 3) were used to determine the normals, means, and extremes of temperature and precipitation applicable to the North Anna site region.

Temperature extremes for Richmond, Virginia are shown in Figure 2-5. In August 1918 a record high of 107°F was recorded and in January 1940 a record low of -12°F was recorded. The extreme temperatures used as the design criteria for the SSSCs, -20°F and 115°F, were selected because they exceed the recorded temperature extremes.

The design solar insolation values for casks stored at the ISFSI are adapted from 10 CFR 71.71(c). The insolation values are 800 gm-cal/cm2 for flat surfaces and 400 m-cal/cm2 for curved surfaces applied over a 12-hour daylight period. These insolation values may be averaged over a 24-hour period for long-term thermal analyses.

Joint frequency distributions of wind speed and horizontal atmospheric stability for both the lower and upper tower levels are presented in Tables 2.3-9 and 2.3-10 of the North Anna Power Station UFSAR. In addition, the joint frequency distribution of lower level wind speed and vertical atmospheric stability are presented in Table 2.3-11 of the North Anna Power Station UFSAR. The distributions are for Stability Classes A through G as defined in Regulatory Guide 1.23.

2.3.2.2 **Topography**

The North Anna Power Station site and exclusion area consist of approximately 1043 acres located in the north-central portion of Virginia in Louisa County beside Lake Anna. The site region is characterized by gently rolling terrain that rises to an average height of 50 to 150 feet above Lake Anna and is cut by the North Anna River. The topography in the site region is characteristic of the Central Piedmont Plateau, which has a gently undulating surface that varies from 200 to 500 feet above sea level.

Figure 2.3-24 of the North Anna Power Station UFSAR is a map showing detailed topographic features within an 8-kilometer (5 mile) radius centered on the site area.

2.3.3 Onsite Meteorological Measurement Program

The North Anna Power Station will also provide meteorological monitoring for the ISFSI. A detailed description of the meteorological monitoring program is provided in Section 2.3.3 of the North Anna Power Station UFSAR. Data from this program, however, will not be used to estimate offsite concentrations of airborne effluents from the ISFSI, as no credible mechanism for the release of airborne effluents has been postulated.

As illustrated in Figure 2.3-25 of the North Anna Power Station UFSAR, the ISFSI is located approximately 3500 feet from the primary meteorological tower, with the service water reservoir and the Units 1 and 2 discharge canal between the ISFSI and the tower. Based on the analysis in Section 2.3.3.6 of the Surry Power Station ISFSI SAR, the separation between the

North Anna ISFSI and the meteorological tower, and the intervening topography and other heat sources, no effect is expected on the tower from the heat source represented by a fully loaded ISFSI.

2.3.4 Diffusion Estimates

2.3.4.1 Basis

No routine or accidental releases are planned or postulated as a result of ISFSI operation. Nevertheless, χ/Q values have been calculated which can be used to estimate radiological doses from the accidental release analyzed in Section 8.2.10.

2.3.4.2 Calculations

Five years of meteorological data from 1989 through 1993 were used to calculate dispersion factors (χ/Q) for use in the dose assessment of accident airborne releases. Wind speed, direction, distance from the ISFSI to the North Anna Power Station site boundary, and atmospheric stability class (based on the temperature gradient determined from instrumentation at the 10 meter and the 158.9 foot elevations) serve as inputs to the dispersion model described in Regulatory Guide 1.145 (Reference 4).

Table 2-1 provides the χ/Q values at the site boundary for an instantaneous accidental release from the ISFSI. Time-dependent χ/Q values are not provided since routine releases are neither planned nor anticipated. The χ/Q values provided in Table 2-1 represent the most limiting χ/Q values to members of the public with the SE sector having the greatest χ/Q at 1100 meters from the ISFSI to the site boundary. According to the dispersion model, the topographical features surrounding the North Anna site are such that the χ/Q values monotonically decrease with distance from the site boundary. Therefore, the limiting dose to members of the public will occur at the site boundary in the SE sector and dose to members of the public will decrease as the distance from the site boundary increases.

2.3.5 References

1. Storm Data, National Oceanic and Atmospheric Administration, National Weather Records Center, Environmental Data Service, Asheville, North Carolina.
2. H. C. S. Thom, "Tornado Probabilities," *Monthly Weather Review,* Vol. 91, Nos. 10-12, pp. 730-736.
3. Richmond, Virginia 1987 Local Climatological Data, Annual Summary With Comparative Data, National Oceanic and Atmospheric Administration, National Weather Records Center, Environmental Data Service, Asheville, North Carolina.
4. U. S. NRC Regulatory Guide 1.145, *Atmospheric Dispersion Models for Post Accident Consequence Assessments at Nuclear Power Plants,* Revision 1, November 1982, Reissued February 1983.

2.4 HYDROLOGY

The data and analyses in this section were obtained from the material presented in Section 2.4 of the North Anna Power Station UFSAR (References 1 & 2). In addition, hydrologic data for the period from 1971 to 1993 were also reviewed. No severe event occurred from 1973 to the present which exceeded the maximum flood on record that has occurred on the North Anna River. The subsurface hydrology section includes site specific data produced as a result of the ISFSI site soils investigation, and follow-up monitoring.

2.4.1 Hydrologic Description

2.4.1.1 Site and Structures

The general site grade for the ISFSI is at Elevation 311 feet msl. This grade varies somewhat to permit proper drainage. The top elevation of the storage pads will be at 311.5 feet msl. Areas outside of the ISFSI generally slope to the south, towards Lake Anna. There is an ISFSI access road to the west of the ISFSI which is graded from Elevation 332 feet msl to Elevation 311 feet msl into the site. Site grade is above the probable maximum flood level, as discussed in Section 2.4.2.2. There are no above-ground enclosed structures associated with this facility.

2.4.1.2 Hydrosphere

Regional topography and characteristics are shown on Figure 2-7. The region surrounding the North Anna Power Station site is characterized by gently rolling terrain that rises to an average height of 50 to 150 feet above Lake Anna and is bisected by the North Anna River. The topography in the site region is characteristic of the Central Piedmont Plateau, which has a gently undulating surface that varies from 200 to 500 feet above sea level.

An earth dam approximately five miles southeast of the site forms Lake Anna, which extends approximately 17 miles along the old North Anna river bed. The lake and waste heat treatment facility cover a surface area of 13,000 acres and contain approximately 100 billion gallons of water.

The ISFSI site is located more than 60 feet above normal lake level elevation, and 45 feet above the flood elevation assumed to occur due to the Probable Maximum Flood postulated to occur on Lake Anna. The terrain near the ISFSI site varies from Elevation 336 feet msl northwest of the ISFSI to Elevation 250 feet msl near the lake.

The North Anna River rises in the eastern slopes of the southwestern mountains in the Appalachian Range near Gordonsville, Virginia, flows into the Lake, and then continues along a southeasterly course to its confluence with the South Anna River 5 miles northeast of Ashland, Virginia, where the Pamunkey River is formed. The Pamunkey River continues on a general southeasterly course to West Point, Virginia, where it is joined by the Mattaponi to form the York River. The York River flows into the Chesapeake Bay approximately 15 miles north of Hampton, Virginia.

The North Anna River drains a watershed of 343 square miles above the dam. The dam is located approximately 4 miles north of Bumpass, Virginia and approximately 0.5 mile upstream of Virginia Route 601. The nearest United States Geological Survey (USGS) stream gauging station on the North Anna River was at the bridge at Virginia Route 601. This stream gauge had been operating from October 1978 to January 1997. There have also been gauges located at Doswell and Hart Corner, Virginia, approximately 15 miles downstream from the dam. These gauges have provided coverage since 1929. The current USGS gauge at Hart Corner monitors flow over a watershed of approximately 463 square miles. Table 2-2 summarizes the records at these gauging stations and tabulates basic stream flow data for the dam site, which have been estimated using the gauge records as a guide for years prior to 1971, and the Partlow gauge data for years after 1977.

No river control structures exist on the North Anna River other than the dam described above.

There is one industrial user of water on the North Anna River downstream of the dam, Bear Island Paper Company, and this facility is located approximately 26 miles from the North Anna Power Station. There are no known industrial users of water on the Pamunkey River until it reaches the York River some 60 miles downstream at West Point, where a large pulp and paper manufacturing plant is located. There is one known potable water withdrawal on the North Anna River, the Hanover County Treatment Plant near Doswell. This plant is located approximately 24 miles downstream from the power station.

2.4.2 Floods

The North Anna ISFSI is a flood-dry site due to the elevation of the site with respect to Lake Anna and the conservative design of storm drainage facilities within the local site area. Local intense precipitation is the controlling case for storm drainage design.

2.4.2.1 Flood History

Floods due to precipitation on the watershed of the North Anna River are the only flooding conditions applicable to historical consideration. Surges due to tropical systems, or tsunamis are not applicable to this site. The site is also not influenced by tidal effects. Gauge records have been available since the late 1920s at the USGS gauge near Doswell and in later years at Hart Corner (Reference 3). In this time the most serious flooding on the North Anna River that occurred took place in 1969 due to the remnants of Hurricane Camille (Reference 4). The second largest event on gauged record was in 1972 with the passing of the remnants of Hurricane Agnes through the watershed. Two smaller events occurred in 1928 and 1937 (Reference 5). The largest twelve floods on gauged record are listed in Table 2-3.

The average annual flood on the North Anna River near Doswell is approximately 7000 cfs.

2.4.2.2 Flood Design Considerations

A discussion of flood elevation levels compared to the ISFSI site is provided in Section 2.4.1.2. A discussion of the analysis of the Probable Maximum Flood and its basis is contained in Section 2.4.3 and Appendix 2A of the North Anna Power Station UFSAR. The effects of local intense precipitation have been taken into account in the design of the storm drainage system for the ISFSI site. Detailed discussion of this item is contained in Section 2.4.2.3.

2.4.2.3 Effects of Local Intense Precipitation

The ISFSI site is at a higher elevation than the surrounding area as shown on Figure 2-8. The site is drained by gradual fine grading away from the storage pads, and a combination of earthen, and concrete channels to the exterior of the site. The southern eight acres of the site are drained by a system of earthen and concrete trapezoidal channels, and the remainder of the site is drained via concrete culverts. This is shown on Figure 2-8. The drainage system was designed using a 10-year storm rainfall intensity. Storm drainage channels were checked and provided with additional depth to accommodate the 100-year storm (References 6, 7 & 8). These channels were checked to confirm that adequate hydraulic capacity existed in the storm drain system, and that the hydraulic grade line elevations were less than the top elevations of the storage pads. Since the storage pads are located at the highest part of the ISFSI, severe flooding or hydrodynamic loading due to floodwater is not credible based on the 100-year storm.

2.4.3 Probable Maximum Floods On Streams and Rivers

Based on information presented in Section 2.4.3 and Appendix 2A of the North Anna Power Station UFSAR, the probable maximum flood on Lake Anna would result in a lake level of 264.2 feet msl at the Main Dam. The water level at the Power Station site was calculated to be 267.3 feet msl, including possible wave effects. The effects in the Sedges creek area of the Waste Heat Treatment facility would be similar to that in the main lake, however, the wave effects would be less due to decreased fetch. The ISFSI is sited at an elevation approximately 45 feet above the postulated PMF lake elevation.

2.4.4 Potential Dam Failures (Seismically Induced)

As stated in Section 2.4.4 of the North Anna Power Station UFSAR, there are no dams in existence on the North Anna River, other than the Lake Anna dam, either upstream or downstream. The only impoundments in the area would be small farm ponds whose failure would not produce any measurable effect on Lake Anna, the Lake Anna dam, or any safety-related systems. Thus, because the ISFSI is at a higher elevation than the station, the ISFSI is unaffected by flood levels due to seismically induced dam failures.

2.4.5 Probable Maximum Surge and Seiche Flooding

Surge and seiche flooding effects are considered in coastal or tidal areas where cyclonic activity results in increased water levels. These increased levels are due to the momentum of the storm event and the reduction in volumetric flow area near the coast (References 9 & 10). The

North Anna Power Station is approximately forty miles upstream from the confluence of the North Anna river with the South Anna near Doswell. The Pamunkey River becomes tidal in the region of the US 360 bridge approximately thirty-six miles downstream of this confluence. Surge effects would dissipate with distance from the coast, available storage of floodwater, elevation above sea level, etc. Therefore, surge flooding is not considered credible. Since the Power Station and the ISFSI site are not within an enclosed or semi-enclosed bay or harbor, seiche due to free oscillations is not applicable. Seiche due to forced oscillations is applicable primarily to coastal situations and as stated previously, the ISFSI site is inland.

2.4.6 Probable Maximum Tsunami Flooding

Tsunami flooding is not a consideration for the North Anna site because of its inland location (Reference 9).

2.4.7 Ice Flooding

As discussed in Section 2.4.1.2, the North Anna ISFSI is approximately 60 feet above the normal level of Lake Anna. The formation of ice on Lake Anna would not have an effect on the ability of the North Anna ISFSI site to drain properly.

2.4.8 Flooding Protection Requirements

The ISFSI is situated well above the maximum water level occurring on Lake Anna. As stated in Section 2.4.1.2, the ISFSI site grade is 60 feet above the normal stillwater level of Lake Anna. There are no special precautions that need to be taken to protect SSSCs on the storage pads.

2.4.9 Environmental

There are no liquid or gaseous releases that could result from operation of the North Anna ISFSI.

2.4.10 Subsurface Hydrology

2.4.10.1 **Regional Characteristics and Site Characteristics**

The hydrologic boundaries of the North Anna Power Station site proper are Lake Anna on the north and east, Freshwater Creek approximately three miles to the west, and Elk Creek approximately four miles to the south. A description of groundwater conditions and onsite use are discussed in Section 2.4.13 of the North Anna Power Station UFSAR.

The hydrologic boundaries of the North Anna ISFSI site consist of a tributary to Sedges Creek to the west and south of the site, Canal A to the east, and Lake Anna to the north. The closest distance to Lake Anna to the north is located near the Unit 2 intake structure which is approximately 3000 feet away. The distance to Canal A is approximately 2500 feet to the east. The closest distance to Lake Anna in the Waste Heat Treatment Facility is 1500 feet to the southeast. A tributary to Sedges Creek, however, varies from less than 100 feet to the west of the

ISFSI to 1000 feet directly to the south of the ISFSI. Figure 2-9 depicts the ISFSI and its location with respect to the lake.

The elevation of rock surface varies at the ISFSI site from Elevation 272 feet msl to Elevation 245 feet msl. The groundwater generally moves along this rock surface until it exits the ground surface as springs, or into the lake. There are three permanent groundwater monitoring wells that have been installed onsite, one upgradient and two downgradient. The average groundwater elevation of the upgradient well is 296.3 feet msl. The average groundwater elevation of the southwesterly downgradient well is 289.0 feet msl. The average groundwater elevation of the southeasterly downgradient well is 280.3 feet msl. The average elevations cited are based on a three month period in which the readings were taken. The southwesterly gradient is approximately 0.01 ft/ft, and the southeasterly gradient is approximately 0.02 ft/ft. Using a horizontal coefficient of permeability of 10^{-6} cm/sec, an estimate of the seepage rate is between 1.5 and 3.0 gal/day/ft near the ISFSI. Groundwater from below the ISFSI site will tend to migrate towards the lake via springs, which will accumulate in the tributary stream to Sedges Creek. This groundwater will eventually move into the lake at the Sedges Creek "arm" of the Waste Heat Treatment Facility.

2.4.10.2 **Onsite and Offsite Water Use**

Water for domestic use at the plant site is taken from groundwater wells. There are currently seven wells in use at the Power Station. The closest of these to the ISFSI site is approximately 1500 feet away to the east near the North Anna Nuclear Information Center (NANIC).

The closest offsite well to the ISFSI site is in a residential area approximately 3500 feet away to the south. As discussed in Section 2.4.10.1, the groundwater regime below the ISFSI site will tend to move water to the tributary of Sedges Creek directly to the south of the site, and eventually into the Lake. The wells in this residential area are drilled very close to the lake and the effects of the presence of the lake (hydrostatic pressure), and distance from the site would preclude any groundwater movement from the ISFSI to this location.

2.4.11 References

1. *Site Environmental Studies, Proposed North Anna Power Station, Louisa County, Virginia,* Dames & Moore.
2. *Site Environmental Studies, North Anna Power Station Proposed Units 3 & 4, Louisa County, Virginia,* Dames & Moore.
3. Water Resources Data for Virginia, U.S. Geological Survey Water-Data Reports, 1961 through 1993.
4. Flood of August 1969 in Virginia, U.S. Department of the Interior, Geological Survey, Water Resources Division, 1970.

5. Floods in Virginia, Magnitude and Frequency, U.S. Department of the Interior, Geologic Survey, Water Resources Division, E. M. Miller, 1969.
6. Drainage Manual, Virginia Department of Transportation, 1989.
7. *Applied Hydrology,* Chow, Maidment and Mays, 1988.
8. *Open Channel Hydraulics,* Chow, 1959.
9. *Handbook of Coastal and Ocean Engineering,* Vol. 1, Wave Phenomenon and Coastal Structures, John B. Herbich, Editor.
10. *Shore Protection Manual,* Vol. 1, Coastal Engineering Research Center, Department of the Army, 1984.

2.5 GEOLOGY AND SEISMOLOGY

2.5.1 Basic Geologic and Seismic Information

This section presents information developed from analysis of borings, laboratory tests and additional bedrock exposures at the ISFSI site. The geology and seismology for the North Anna Power Station as previously presented from the original plant licensing and other documents is discussed in Section 2.5 and Appendices 2B, 2C and 3E of the North Anna Power Station UFSAR. Also presented is a general update to Section 2.5 of the North Anna Power Station UFSAR based on geologic information developed over the last 15 to 20 years, including a reclassification of the basic Piedmont geologic nomenclature as a result of geologic mapping in the Northern Virginia Piedmont.

The results of additional subsurface investigation, laboratory testing, and geotechnical evaluation for areas south and east of Units 1 and 2 are summarized in a geotechnical report (Reference 39). This report provides geotechnical information from additional borings completed at locations along the alternate transport route.

2.5.1.1 **Storage Site Geomorphology**

The ISFSI site is contiguous with that of the North Anna Power Station, and is collectively called the site hereinafter. The site is located within the Piedmont Plateau Province, which is characterized by an undulating, rolling topography with as much as 100 feet of relief in the general site area. The Piedmont Province is bounded on the east by the Atlantic Coastal Plain Province, some 15 miles east-southeast of the site, and the Blue Ridge Province to the northwest, some 40 miles distant from the site. Bedrock within the Piedmont is typically metasedimentary and metavolcanic, with some plutonic granitic rocks. The bedrock typically is deeply weathered into a saprolitic cover of up to 100 feet in thickness.

2.5.1.2 **Geologic History of Storage Site and Surrounding Region**

The ISFSI site is located within an area of the eastern North American craton that has undergone extensive tectonism since Precambrian time. This has resulted in a complex pattern of regional folding and faulting. Three of the periods of tectonism in the Paleozoic era were the result of a collisional or accretionary tectonic style, while the last period of tectonism was generally a continental rifting, or extensional style of deformation. This last period of tectonism in the late Jurassic and early Triassic resulted in the formation of the numerous downfaulted Triassic basins that exist along the eastern margin of North America, from Connecticut to Georgia.

2.5.1.3 **Specific Structural Features of Significance**

The ISFSI site lies adjacent to the North Anna Power Station upon a bedrock lithology mapped previously (Reference 1), and shown in Figure 2-10, as hornblende gneiss. The hornblende gneiss, which is the dominant lithology, is generally an interbedded sequence of hornblende gneiss, biotite granite gneiss and granite gneiss. As shown in Figure 2-10, the dominant lithology onsite is the interbedded hornblende gneiss/biotite granite gneiss/granite gneiss sequence, with the massive granite gneiss unit being subordinate. Both units as mapped onsite are part of the Ta River Metamorphic Suite, mapped and classified by Bobyarchick, et al. (1981) (Reference 2). The Ta River occurs west of the Spotsylvania Lineament (a northeast-southwest trending aeromagnetic lineament described below), and is generally composed of amphibolites, amphibole gneiss and minor biotite granite gneiss and schist units.

The dominant structural features noted during detailed geologic mapping at the site in 1973 (Reference 1) are shown in Figure 2-10. The site is located on the northwest flank of a northeasterly trending, gently plunging (15 degrees) to the north, antiform. During the Paleozoic era, these rocks were deformed repeatedly and resulted in the polydeformational expression seen in the rocks today. Boundaries between the different units at the site were primarily affected by flexural slip folding during that era as the antiform was forming. The resulting deformation along one of these boundaries formed the Zone A Chlorite Seam that was the object of the very detailed geologic investigation in 1973 because of its location relative to Units 1 through 4 of the North Anna Power Station. Details describing this geologic investigation can be found in Section 2.5.2.4 of the North Anna Power Station UFSAR.

The closest fault to the site other than that described above is located near Mineral, Virginia, some six to seven miles west of the site. The fault has no surface expression and is known only from exposures in underground mine workings near Mineral. The known length of the fault is approximately 1000 feet, with a projected maximum length of several miles. If projected along its strike of N20°E, it would pass approximately 4-1/2 miles northwest of the site (Section 2.5.2.4 of the North Anna Power Station UFSAR).

The locations of recent borings drilled at the ISFSI site for purposes of developing subsurface information for foundation design and for confirming bedrock geology characteristics are shown on Figure 2-11. Figure 2-12 presents a subsurface cross-section of the bedrock and overlying soils beneath the storage pads. The bedrock encountered in the core retrieved from the borings confirms the previous bedrock mapping and interpretation made in 1973. Additionally, fractures identified in the core were consistent in both frequency and general orientation relative to the core as those observed and mapped in the excavations for Units 3 and 4 and elsewhere onsite in 1973. No structural zones similar to what was observed in Units 3 and 4 during the 1973 geologic investigation were observed in the core retrieved from the recent ISFSI borings. Foliation observed in the core ranged from 35 to 50 degrees (interpreted to be dipping to the northwest based on previous mapping onsite).

Details regarding the recovery and rock quality designation (RQD) values are contained in Table 2-4. The boring logs and logs of the rock coring for the bedrock investigation, are provided in Appendix 2A.

A brief description of structural features of significance is provided below. Additional details regarding the site can be found in Section 2.5.3.1 of the North Anna Power Station UFSAR.

1. Hylas Zone

   In a section of the Piedmont and Triassic subprovince approximately 25 km west of Richmond, and to the south-southeast of the site, lies the Hylas zone which trends roughly northeast (Figure 2-13). This is a group of mylonitic rocks produced by late Paleozoic ductile shearing of pre-existing biotite gneiss, granite gneiss, and amphibolite. The rocks west of the Hylas zone (between Columbia and the Hylas zone), referred to as the Goochland complex, are metamorphosed sedimentary and igneous rocks consisting of biotite gneiss and schist, granite gneiss, amphibolite, and granite.

   The Petersburg granite, a coarse-grained unit, bounds the eastern margin of the Hylas zone at Hylas and northeastward to the Taylorsville Basin. It is a two-feldspar muscovite-biotite granite with at least one poorly to moderately developed tectonic foliation. Emplacement of the Petersburg granite occurred prior to the formation of the Hylas zone since field mapping indicates mylonitic rocks are gradational into relatively unaltered granite (Reference 3).

   Rocks in the Goochland complex west of the Hylas zone underwent at least two deformations (D_1, D_2) prior to ductile shearing in the Hylas zone (D_3). D_3 was responsible for a mylonitic foliation (S_c) and a later widely-spaced shear cleavage (S_s) to be formed in rocks in the Hylas zone. At about 220 Ma, brittle deformation was superimposed on the Hylas zone in the form of high-angle faulting and locally intense fracturing (D_4) which is probably equivalent to the Palisades disturbance of New England. D_4 was associated throughout the Piedmont with synchronous downwarping and dominantly continental sedimentation to form a series of parallel Triassic basins represented locally by the Richmond Basin. Northwest-oriented high-angle faults that apparently displace Triassic sedimentary rocks are interpreted to have occurred prior to the Late Cretaceous (Reference 3).

   The Goochland complex underwent regional prograde metamorphism to amphibolite facies (M_1) and included D_1 and D_2; structural elements that compose these deformational events consist mainly of oriented metamorphic minerals. Well-equilibrated microstructures seen in the gneiss suggest that the M_1 peak persisted past D_2. M_1 is interpreted to have occurred approximately 340 Ma. During the late Paleozoic time, D_3 was accompanied by retrograde metamorphism (M_2) to greenschist facies in the Hylas zone. The Hylas zone may continue to the north in the Brandywine area of the Coastal Plain as indicated by Cenozoic reverse faulting 90 km along the strike of the Hylas zone (Reference 4). Current stress release beneath the Coastal Plain may be influenced by the Hylas zone and analogous fault systems throughout the Piedmont (Reference 2).

2. Stafford Fault System

Various field investigations of the upper Mesozoic and Cenozoic deposits of the Inner Coastal Plain of Virginia between Washington, D.C. and Richmond, Virginia have revealed evidence of faulting of Coastal Plain beds. In 1976 Newell and others (Reference 5) recognized and described the Stafford fault system which is a series of end echelon, northeast striking, northwest dipping, high-angle reverse faults that displace both the Apostolic rocks of the Piedmont and the overlying Coastal Plain sediments. The Stafford fault extends for more than 33 miles along the Virginia Fall Line and the northeast-trending reach of the Potomac River. Mixon and Newell (1977) (Reference 6) believe that the position of the Stafford fault system supports the hypothesis that the Fall Line and major river deflections along it have been tectonically influenced (Reference 7).

Fault movement along the Stafford system began as compressional deformation at least as early as the Early Cretaceous. A detailed trench study of the Dumfries fault zone west of Stafford, Virginia is of special significance: Ordovician slate, phyllite, and schist have been thrust at a high angle over the lower Cretaceous Potomac Formation. Likewise, major deformation occurred in the middle Tertiary and pre-Choptank time. There is as much as 1-1/2 feet of reverse fault offset at the base of the upland gravel in an artificial cut near the US 1 highway bypass in south Fredericksburg, Virginia which indicates that at least some Pliocene deformation occurred along the Stafford system. "Approximately 1.0 foot of fault offset of the base of high-level Rappahannock River terrace deposits by the Fall Hill fault, which is a major strand of the Stafford system, indicates middle to late Pliocene or, possible, younger faulting." (Reference 7)

Mixon and Newell (1977) (Reference 6) noted the alignment of zones of compressional faulting in the Maryland and Virginia Coastal Plain in linear zones of early Mesozoic extensional faulting in the Piedmont and in the crystalline basement beneath the Coastal Plain. The early Mesozoic extensional faults and the Coastal Plain compressional fault zones are, in turn, aligned with Paleozoic thrusts and shear zones in the underlying basement rock. In Virginia, for example, the Stafford fault system is aligned with the border faults of the early Mesozoic Farmville basin trend and with the Spotsylvania magnetic lineament (Reference 5).

During 1976, Dames & Moore (Reference 4) investigated the age and geologic origin of the Stafford fault system, which approaches the site at its closed point, approximately 22 km northeast in the vicinity of Fredericksburg. The detailed drilling, trenching and mapping program demonstrated that the youngest identifiable fault movement on any one of the four structures making up the Stafford fault system was pre-mid-Miocene in age, or more than 10 million years ago. Accordingly, the Stafford fault system is not capable in the meaning or intent of Appendix A to 10 CFR 100.

3. Spotsylvania Lineament

The Spotsylvania lineament is a northeast-trending aeromagnetic anomaly that separates the Ta River and Po River Metamorphic Suites. To the west of the lineament, and where the North Anna Power Station is located, the Ta River rocks are characterized by linear, northeast trending medium to high intensity anomalies; however, to the east of the lineament, the Po River terrane is characterized by relatively lower intensity, north-trending anomalies. Researchers believe that the Spotsylvania lineament represents a fault or system of faults to explain its regional linearity. Microstructures and field data indicate that the Spotsylvania lineament, if it represents a fault, formed during or before regional metamorphism (Reference 2).

Inasmuch as the Spotsylvania lineament is directly on strike with a projected extension of the Stafford fault system to the southwest, Dames & Moore (1977) (Reference 8) investigated the minimum age of the Spotsylvania lineament (then known as Neuschel's lineament) by categorizing and mapping the extent and continuity of a Pre- or Early Cretaceous erosion surface across the extent of the lineament. Dames & Moore's findings were that the lines of evidence discerned indicated a minimum age of movement of 100 million years (Early Cretaceous) if the lineament were indeed a fault zone, and that it is not structurally related to the Stafford fault system.

4. Mountain Run Fault Zone

The Mountain Run fault zone (MRFZ) is a regional feature approximately 75 km in length. It is best defined as a physiographic feature, in the form of a northeast-trending linear fault-scarp, in the Unionville, Virginia quadrangle. The northern end of the MRFZ forms part of the southeast boundary of the early Mesozoic Culpeper basin. The scarp is "held up" by phyllonite which extends over a width of at least 2-1/2 km to the southeast of the scarp. On the northwest side of the scarp lies an alluvium-filled valley. The northwest side of this valley is a narrow zone of faulted and sheared rocks that form the northwest boundary of the MRFZ. Mapping indicates that the MRFZ extends from about the Mesozoic basin near the Rappahannock River southwestward to near Charlottesville, Virginia (Reference 9).

On its southeast side, the MRFZ separates a thrust-faulted early Paleozoic (pre-440 Ma) melange terrane from a phyllite, slate, and limestone unit that uncomformably overlies the Precambrian Catoctin Greenstone; together these are considered as part of ancestral (pre-400 Ma) North America. Therefore, the MRFZ is thought to be a suture which "juxtaposed a Cambrian island arc (Central Virginia volcanic-plutonic belt) and its associated fault-imbricated back-arc basin (melange terrane) onto or against ancestral North America in pre-440 Ma." In early Mesozoic time, part of the MRFZ was reactivated to partly delineate the southeast boundary of the Triassic-Jurassic Culpeper basin. According to Pavlides (1986) (Reference 9), there may have been additional local reactivation within the MRFZ during the late Cenozoic time indicated by the recent (ca. 1986) discovery of a thrust fault within the MRFZ that offsets gravels of probably post-Pliocene age (Reference 9).

5. Giles County Zone

   A series of five extensional faults were recently uncovered in new excavation for landfill material adjacent to the New River in Giles County, Virginia, some 220 miles west-southwest of the site (Figure 2-13). The faults strike about N50°E and dip either northwesterly or southeasterly. The structures displace alluvial terrace deposits of suspected Tertiary or Quaternary age. Seismic monitoring in this part of the Valley and Ridge Province over the past 20 years indicate that earthquake foci are located at depths greater than 5 km (Reference 10).

2.5.1.3.1 Regional Geology

The predominant lithologies in the region surrounding the site include rocks of the Central Virginia Volcanic-Plutonic Belt, the Ta River and Po River Metamorphic Suites and interlayered mafic and felsic metavolcanic rocks. The Falmouth Intrusive Suite and the Quantico Formation are rocks of the Central Virginia Volcanic-Plutonic Belt. The Falmouth Intrusive Suite is composed of fine-grained to pegmatitic granite, quartz monzonite, granodiorite, and tonalite and also consists of dike, sills and small plutons. This unit has been dated at about 300 to 325 Ma and locally intrudes the Ta River Metamorphic Suite and the Quantico Formation. The Quantico Formation is predominantly a slate and porphyroblastic schist. This unit contains gray to black, graphitic, pyritic phyllite and slate (in the northern Piedmont) whose metamorphic grade increases to the southwest to produce porphyroblastic staurolite-, kyanite-, and garnet-biotite-muscovite schists. This unit reaches a thickness of up to 3000 feet. The Quantico Formation is Ordovician in age and unconformably overlies older units in the northeastern Piedmont. It is correlated with the Arvonia Formation to the southwest (Reference 11).

The Ta River Metamorphic Suite is a layered sequence which consists mainly of greenish-gray to black, medium to coarse-grained, poorly to well lineated, massive to well-layered amphibolite and amphibole-bearing gneiss and schist. Likewise, this suite contains interlayered ferruginous quartzite, and minor biotite gneiss and schist, felsic volcanic rocks, gabbro and granite. The amphibolitic rocks commonly contain quartz-epidote lenses and veins. The grade of regional metamorphism increases from northeast to southwest along strike as does the proportion of biotite gneiss and schist. Pavlides (Reference 12) correlated the Ta River with the James Run and Chopawamsic Formations, and considered the Ta River to be a more oceanward facies of a Chopawamsic island arc sequence, based on geologic and geochemical factors. The Ta River is Cambrian in age. The Quantico Formation generally overlies the boundary between the Ta River and the Chopawamsic, obscuring the contact relationships (Reference 11).

The Po River Metamorphic Suite, which lies to the east of the Ta River Metamorphic Suite, is characterized primarily by biotite gneiss with lesser amounts of hornblende gneiss and schist. Furthermore, pegmatoid and granitoid dikes are abundant. "The age of the Po River is uncertain, but may be considered Proterozoic Z and (or) early Paleozoic based on its stratigraphic position underlying the Ta River Metamorphic Suite and the Holly Corner Gneiss, both correlated with the Lower Cambrian Chopawamsic Formation." (Reference 12)

Ferruginous quartzites, which are distinctive local marker units, locally delineate map-scale structures in some places. "This lithology is recognizable in rocks of variable degree of deformation and metamorphic grade; it has been mapped within the Ta River Metamorphic Suite and within correlative unnamed interlayered mafic and felsic metavolcanic rocks to the southwest." (Reference 11)

2.5.1.3.2 Regional Tectonics

Since the time of the initial geologic investigation at the North Anna Power Station, two major tectonic models have emerged to explain the evolution of the central and southern Appalachians. The initial model was presented in 1972 by Hatcher, which proposed that the eastern Piedmont volcanics (Charlotte, Caroline Slate, Raleigh, and eastern slate belts) represented a late Precambrian to Early Ordovician island arc on the eastern edge of Laurentia. An Andean-type orogeny during the Middle Ordovician-Silurian was presumed to have formed by westward subduction of oceanic crust. Collision with Africa, during Mid-Late Devonian to Permian, resulted from continued westward subduction and produced the Acadian and Alleghanian orogenies. Following Hatcher's model in 1972, Odem and Fullagar and Rankin suggested models in which the Brevard zone along the Eastern Blue Ridge was a suture (Reference 13).

In 1978, Hatcher revised his earlier model increasing the number of sutures from one to three. Between 800 and 700 Ma, the basements of the Inner Piedmont and Charlotte/slate belts were thought to be continental fragments rifted from Laurentia. From about 700 to 450 Ma, subduction towards the west draped the outer fragment with Charlotte/slate belt volcanics. Concurrently, the oceanic basins between the Laurentian continent/Inner Piedmont and Charlotte belt/slate belt fragments were closing, culminating in the Taconic Orogengy during the Middle/Late Ordovician. Oceanic crust continued to subduct to the west beneath the Charlotte/slate belt, which eventually closed the Iapetan Ocean. Continental collision with Africa took place in the Acadian/Alleghanian orogenies during the Late Paleozoic (Reference 13).

In 1980, Hatcher and Odom modified the 1978 model to include: Taconic collision between the North American craton and the Piedmont fragment; Acadian collision between the Piedmont-North American block and Avalonia; and the Alleghanian collision between Africa and Avalonia (Reference 13).

Coney and others (1980) established the suspect terrane concept which was formalized in the western North American Cordillera. This concept initiated the beginning of a new tangent in the development of Appalachian tectonic models. In 1982, Williams and Hatcher published a paper on the accretionary history of the Appalachians, essentially discarding the model proposed by Hatcher in 1978 for the southern and central Appalachians, but added several new terranes thought to possibly be bounded by suture zones. Since that time, others have proposed that the southern and central Appalachians are divided into numbers of micro-terranes each bounded by possible sutures (Reference 13).

In 1982, Glover and others presented another model, different than the one proposed by Williams and Hatcher, to explain the tectonic configuration of the Appalachians. They concluded that the only suture in the Piedmont and the Blue Ridge of the central and southern Appalachians is the Taconic suture, based on the ages of ductile deformation and metamorphism in the central and southern Appalachians. The Taconic suture is found along the western boundary of the Kings Mountain belt in North Carolina and extends into Virginia along the western boundary of the Charlotte belt and Chopawamsic volcanics. Likewise, Glover and others believe that other sutures, of Acadian and/or Alleghanian ages, must lie under the Atlantic Coastal Plain or offshore in basement rocks (Reference 13).

In 1987, Hatcher further revised the Hatcher and Odom (1980) model to include the Penobscottian orogeny (early Cambrian to Early Ordovician) as an early stage in the collision of the "Piedmont arc" with the North American craton (Reference 13). Additional details regarding the regional tectonic characteristics of the area around North Anna Power Station can be found in Section 2.5.2.4 of the North Anna Power Station UFSAR.

2.5.1.4 **Large Scale Geologic Map**

The locations of the structural feature discussed in Section 2.5.1.3 are shown in Figure 2-13.

2.5.1.5 **Plot Plan and Site Investigations**

Soil borings and laboratory tests were performed as part of the development of the North Anna Power Station license application. The boring logs and site maps showing the boring locations are contained in Appendix 2C of the North Anna Power Station UFSAR. Additional borings and laboratory tests were performed in the area of the Service Water Reservoir. Results of these borings and tests are contained in Appendix 3E of the North Anna Power Station UFSAR. An investigation consisting of soil test borings, rock coring, and laboratory tests was performed at the ISFSI site to identify and document site geotechnical conditions and to develop soil parameters required for evaluation of design requirements. Two soil test borings were performed in 2008 to support development of the alternate transport route. Results of the borings and rock coring are contained in Appendix 2A and laboratory tests are contained in Appendix 2B of this document.

The geologic portion of the field investigation for the siting of the ISFSI at the North Anna Power Station consisted of:

1. The logging and preparation of bedrock boring logs for eight borings, using standard techniques; and
2. Examination of weathered bedrock exposures in a borrow pit west of the North Anna Power Station switchyard and close to a tributary arm of Lake Anna.

The purpose of the field geologic investigation was to ascertain the physical nature and characteristics of the bedrock from the cores retrieved from the borings, as well as the limited exposure afforded in the borrow pits, in order to compare them to previous onsite geologic investigations in 1973 and 1974. The field geologic investigation was performed by a geologist from Dames & Moore.

2.5.1.5.1 Field Investigation

At the direction of Virginia Power, eight borings (F-4 through F-11) were drilled in June through July of 1994 at the proposed ISFSI storage pad locations as shown on Figure 2-11. The borings were located in plan and elevations by Stone & Webster surveyors. Boring F-2, drilled in April 1994 for a preliminary investigation and located at the North end of the center storage pad is also included herein. In addition, seven shallow borings designated P-l through P-7 were drilled along the original (main) transport route. The soil test borings were drilled by Froehling & Robertson, Inc. (F&R) using a Central Mining Equipment (CME), Model 55 truck mounted drill rig by mechanically advancing continuous flight hollow stem augers into the soil. At regular intervals a standard 1.4-inch i.d., 2.0-inch o.d., 20-inch long split spoon sampler was driven into the soil with a 140 lb hammer falling 30 inches in accordance with American Society for Testing and Materials (ASTM) D1586 Standard Penetration Test (SPT) procedures (Reference 14). SPT results provide an indication of compaction, strength and support capacity of the soil. SPT tests were performed continuously to depths of 4.5 feet, from 6.0 to 7.5 feet, 9.0 to 10.5 feet, and at five-foot intervals thereafter to spoon or auger refusal (rock). Disturbed split-spoon samples were collected with each SPT and visually classified by a geotechnical engineer from Virginia Power. The boring logs showing elevation and depth of samples, penetration resistances (blow count), soil stratum description and Unified Classification, and groundwater information are contained in Appendix 2A.

Where borings could no longer be advanced with standard soil boring equipment, rock was cored. A water-cooled double-tube NX-size core barrel with diamond studded bit was used to secure the rock cores. The core recovery from each five foot long run was examined and classified by a geologist from Dames & Moore. The percent recovery, which is the ratio of the recovered length to the total length of run, was calculated for each run. The RQD was also calculated for each five-foot run. RQD is the ratio of the cumulative length of pieces of core greater than 4 inches long compared to the total length of run. RQD is an index to the soundness and quality of the rock. Core recoveries and RQD values for all core runs are contained on the boring logs and are provided in tabular form in Table 2-4.

Split spoon samples are suitable for visual examination and classification (index) tests but are not sufficiently intact for quantitative laboratory testing. Six relatively undisturbed samples were obtained by forcing sections of 3-inch o.d., 16 gauge, steel tubing into the soil at the desired sampling levels. This sampling procedure is described by ASTM Specification D-1587 (Reference 15). Each tube, together with the encased soil, was carefully removed from the ground, made airtight, and transported to the laboratory. Locations and depths of undisturbed samples are shown on the boring logs. Five additional undisturbed samples were obtained by pushing sampling tubes into the soil using a backhoe bucket.

Five monitoring wells were installed at locations across the site. These wells consist of slotted well screens attached to 2-inch diameter PVC riser pipe. Filter sand was placed around the screen and a bentonite seal was placed above the well screen and sand. The annular space around the pipe and soil above the seal was filled to the surface with cement grout. Logs of the monitoring wells are also contained in Appendix 2A.

The locations o f the two soil test borings conducted by MACTEC Engineering and Consulting, Inc. in April 2008 along the alternate transport route are shown in Figure 2-18. These borings, designated B-713 and B-714, were each drilled to 20 feet depth. The borings were advanced by a CME 550x drill rig using hollow-stem augers with 4.25-inch inside diameter and a nominal 8-inch outside diameter. The soil was sampled using an SPT sampler at 2.5-feet intervals to 15 feet depth, with a final sample being taken between 18.5 to 20 feet depth. The SPT was performed using an automatic hammer, and was conducted in accordance with ASTM D 1586. The recovered soil samples were visually described and classified by the MACTEC geotechnical technician. Pocket penetrometer (PP) tests were performed in the field on the lower end of the samples. No laboratory testing was performed on samples from these two borings, and no intact samples were collected. All of the borings were backfilled with a cement/bentonite grout upon completion.

2.5.1.5.2 Laboratory Testing

The following tests were performed on selected split spoon, bulk, and undisturbed samples. Results of the test are contained in Appendix 2B:

Name of Test	ASTM Standard	Reference No.	Test Performed
Particle (Gradation) Size Analysis	D422 and D1140	16 and 17	19
Atterberg Limits	D4318	18	3
Natural Moisture Content	D2216	19	19
Moisture Density Determination	D1557	20	2
California Bearing Ratio (CBR)	D1883	21	6
Consolidation Test	D2435	22	3
Triaxial Shear Test	D2850	23	2
Unconfined Compression Test	D2166	24	5
Constant Head Permeability	D2434	25	1

Name of Test	ASTM Standard	Reference No.	Test Performed

Note: 1 ASTM D2850 is the standard for the Unconsolidated Undrained Triaxial Shear Tests. One Consolidated Undrained Shear Test with pore pressure was also performed. Currently there is no ASTM standard for the Consolidated Undrained Shear Test.

2.5.1.5.3 Borrow Pit Exposure

A borrow pit, located approximately 1000 feet west of the North Anna Power Station switchyard (Figure 2-10), was used to provide fill for a number of onsite projects over the last five to ten years. Its location in relation to a previously-mapped fold axis would have provided additional confirmation of the presence of the fold axis and the interpreted bedrock geology from saprolite exposures during the 1973 onsite geologic mapping.

During the onsite logging of the core retrieved from the ISFSI site borings, the borrow pit was visited by the geologist from Dames & Moore to map the exposed bedrock. The borrow pit, unfortunately, had been in-filled and graded to reclaim and replant the exposed saprolite slopes. Enough exposed saprolite bedrock could be observed, however, to confirm that the interpreted bedrock at that location was indeed granite gneiss, and that the fold axis was within the exposure limits. It was observed that the fold axis, although not directly measurable because of the lack of complete exposure of the saprolite bedrock, would have been aligned in a northerly direction and plunging gently. This is consistent with the orientation of F2 folds in the Lake Anna East Quadrangle west of the Spotsylvania Lineament (Reference 1).

2.5.1.6 **Geologic Profiles**

Based on the information gathered from the eight borings and associated sampling and testing obtained in June and July 1994, the following stratigraphic sequence is inferred to underlay the site.

Surface elevations, depth of residual soil and quality of rock varied moderately across the site. The materials encountered consist of residual soil derived from the in-place weathering of the parent metamorphic rock. The typical soil profile consists of clay minerals near the ground surface which were converted from the feldspars, micas, and ferro magnesian minerals contained in the parent rock. At depth, these minerals become less weathered and only partially altered, retaining their inter-particle bonding. Below the firm surficial clays and clayey silts (ML and MH), the soil grades from a fine sandy silt to a silty fine sand (SM to SP) with varying amounts of mica. The soils possess highly plastic fines in varying amounts, therefore, the characteristics of the fine grained soils and predominantly granular soils with some fines and mica are similar. The transition between the surficial fine grained soils and the more granular soils encountered with depth is gradual.

The penetration resistances (SPT) are higher in the surficial clays and clayey silts, drop off in the highly micaceous silty soils, and pick back up in the sandy soil and decomposed rock above the less weathered parent rock. The deeper residual soils retain the original fabric or bonding of the parent rock and are termed saprolites. The saprolite retains the foliation of the parent rock along with interparticle bond. There is no well defined boundary between soil and rock, only a transition.

The generalized soil profile as encountered by the borings across the ISFSI site is as follows. The surficial fine grained clayey silts (ML and MH) extend to depths of 7 to 29 feet in all but two borings. In borings F-5 and F-8, the clayey silt extends all the way to rock. These soils are stiff to hard in consistency and possess good to excellent strength and support capacity.

The more granular sandy micaceous silt and micaceous silty fine sand (SM and SP) are encountered below the cohesive material and normally extend to rock. However, in two of the borings, F-9 and F-10, silty fine sand was present from the ground surface to the top of rock. This material was medium dense to very dense in consistency with only a few SPT results falling below 10 blows per foot.

As shown on the boring logs (contained in Appendix 2A), the lithologies penetrated by the borings are entirely consistent with those mapped and shown on Figure 2-10. The ISFSI is located entirely within a unit mapped as interbedded hornblende gneiss, biotite granite gneiss and granite gneiss, with the predominant lithology being hornblende gneiss.

Rock as defined by auger or spoon refusal and the initiation of rock coring was encountered at elevations varying from 245 to 272 feet. All of the cores retrieved, except for portions of Borings F-10 and F-4, were extremely weathered. Primary structures in the rock, however, are still recognizable. Table 2-4 provides a summary of the percent recovery and percent RQD values for all eight borings. Recovery varies from 0 to 95%, and RQD values vary from 0 to 35.8%.

Fractures are clearly observable, even in the most weathered of the cores. Typically, fractures vary from near horizontal to about 70 degrees from the vertical. Almost all fractures observed have iron and manganese staining on the fracture surfaces, indicative of groundwater flow. Slickensides were not observed on any of the fractures. This is not surprising, as the borings penetrate a rock mass away from those boundaries (such as Zone A) that underwent primarily flexural slip deformation during tectonism in the Paleozoic.

Foliation in the hornblende gneiss is well developed, with elongation of individual hornblende crystals. Foliation dip observed was between 35 and 50 degrees, which is consistent with the closest field observation point (Figure 2-10).

Groundwater was encountered at depths of 19 to 27 feet below existing grade (Elevation 289 to 296 feet) across the site several days after completion of individual borings. The groundwater level is at least 20 feet below the proposed final elevation of Elevation 311 feet.

Figure 2-12 presents a geologic profile across the site showing the soil and rock stratigraphy as discussed above.

The soil profile interpreted from Borings B-713 and B-714 drilled for the alternate haul route in 2008 is shown in Figure 2-19. Very stiff sandy clay fill was encountered in the top 5 feet of B-713, reducing to about 3 feet at B-714. Below the fill, the native saprolitic soils extend to the bottom of the borings at 20 feet depth. The saprolite consists of medium dense sandy silt (ML) underlain by medium dense silty sand (SM). About 5 ft of clayey topsoil was encountered beneath the fill in B-713.

2.5.1.7 **Plan and Profile Drawings**

Figure 2-8 shows the site grading plan. Figures 2-14, 2-15 and 2-16 show sections through the centerline of the three storage pads and details of cut and fill. As noted in the previous section, Figure 2-18 shows the subsurface profile along a section of the alternate transport route.

2.5.1.8 **Local Geologic Features Affecting Site Location**

The location of recent borings drilled at the ISFSI site for the purposes of developing subsurface information for foundation design and for confirming bedrock geology characteristics are shown in Figure 2-11. Figure 2-12 presents a subsurface cross-section of the bedrock beneath the ISFSI storage pads. The bedrock encountered in the core retrieved from the borings confirms the previous bedrock mapping and interpretation made in 1973. Additionally, fractures identified in the core were consistent in both frequency and general orientation relative to the cores observed and mapped in the excavations for Units 3 and 4 and elsewhere onsite in 1973. No structural zones similar to those observed during the 1973 geologic investigation were observed in the core retrieved from the recent ISFSI borings. Foliation observed in the core ranged in depth from 35 to 50 degrees (interpreted to be dipping to the northwest based on previous mapping onsite).

Details regarding the recovery and RQD values, and the boring logs for the bedrock investigation, are found in Appendix 2A.

2.5.1.9 **Site Groundwater Conditions**

The depth to the water table was measured in each of the borings taken in June and July 1994. The depth to the ground water was 19 to 27 feet (Elevation 289 to 296 feet). Water levels in groundwater monitoring wells three months after installation varied from Elevation 280 to 296 feet which is consistent with water levels obtained initially. No water was encountered in the two borings drilled in the alternate transport route (maximum depth of drilling was 20 feet).

Site groundwater conditions are discussed in Section 2.4.2. Additional groundwater information is provided in Section 2.4 of the North Anna Power Station UFSAR.

2.5.1.10 **Geophysical Surveys and Studies**

Section 2.5 of the North Anna Power Station UFSAR summarizes geophysical surveys and studies which have been performed to evaluate the stratigraphic structure and bedrock in the region of the North Anna Power Station.

2.5.1.11 **Engineering Properties of Soil and Rock**

The static and dynamic engineering properties of the site are described in this section. The engineering properties of the weathered rock (saprolite) and crystalline rock are described in Section 2.5.4.3 of the North Anna Power Station UFSAR, and further referenced in Appendices 2B and 2C of the North Anna Power Station UFSAR.

Physical property tests conducted on the saprolitic soils and fresh rock included:

- Dry density tests on selected samples
- Moisture Content Tests
- Triaxial Compression on undisturbed samples
- Particle Size Analysis (Gradation)
- Consolidation Tests on undisturbed samples
- Cyclic Triaxial Tests
- Shock Scope Tests

Additional onsite investigations that provide information on seismic wave propagation properties of the subsurface saprolite and rock included:

- Birdwell 3D Seismic Logs
- A Refraction Seismic Survey of the site area C
- A Cross Hole Shear Wave Survey of the rock supporting the reactor containments

Soil and rock properties defined by the borings and laboratory test results at the ISFSI site are contained in Appendices 2A and 2B. The properties developed from the ISFSI site investigation compare closely to the properties previously documented in the North Anna Power Station UFSAR and other references provided below.

Shear strength tests consisting of Unconfined Compression Test and Unconsolidated Undrained Triaxial Shear tests performed on the partially saturated surficial clayey silts (ML and MH) indicated these soils possess a cohesion (c) of 1500 psf and an angle of internal friction (ϕ) of 15 degrees for the total stress condition. This compares closely with an average c of 1800 psf and ϕ of 14.5 degrees obtained on extensive testing at the main dam site (Reference 26).

Consolidated Undrained Triaxial Shear test on the more granular silty sand (SM) encountered at a greater depth and near below the water table yield a cohesion of 700 psf and a ϕ

of 27 degrees for the effective stress condition. This compares closely with a c of 720 psf and a ϕ of 26 degrees previously obtained and used as design parameters (Reference 26).

Consolidation Tests performed on samples of residual soil did not exhibit the sharp curvature or break-in-slope usually present in over-consolidated deposited soils. The test results on the surficial soils tested (4 to 6 feet) show a slight curvature, but no distinctive break. This is probably the result of sample disturbance or rebound due to stress changes during and after sampling or both.

The deeper sample (F-7A, 16 to 18 feet) which classifies as a SM, is predominantly granular. Consolidation tests performed on material shows significant curvature at slightly less than the expected overburden pressure. Disturbance may also be present in this sample.

For these reasons results of these Consolidation Tests were not used in estimating settlement on this project. Results of previous testing on similar material from the same geologic formation was used. An average Recompression Ratio of 0.024 was used to estimate consolidation settlement. An average initial target modulus (E_s) of 500 ksf was used in elastic settlement estimates (Reference 27).

The average unit weight and natural moisture content as determined from the laboratory tests contained in Appendix 2B are 100 pcf and 36% respectively. The vertical permeability, as obtained from a constant head permeability test, was 4×10^{-7} cm/sec, which compares closely with previously developed permeabilities.

Results of CBR tests performed for this project were compared to corresponding values for Modulus of Subgrade Reactor (k_s) provided by a chart giving the interrelationship of soil classifications and bearing values (Reference 28). The average unsoaked CBR of the near surface soils was 39 and soaked 7.5. The corresponding k_s from the chart was 375 pci and 175 pci which is higher than the conservative k_s of 115 pci (100 tcf) for saprolite as described in Section 3.8 of the North Anna Power Station UFSAR.

No new testing was performed on the rock encountered at the ISFSI site. Due to the depth of the rock and the very small increase in loading which the storage pad and SSSC would impose on the rock, the physical properties of the rock are not a factor. Rock was encountered at sufficient depth as not to be an influence in bearing capacity or settlement. The rock is competent and possesses no solution cavities, sink holes, voids or caverns.

No new dynamic testing was performed during the investigation for the ISFSI since the results of recent borings and laboratory tests were similar to those previously obtained and documented at the station and main dam site. Dynamic soil and rock properties for the site are contained in Section 2.5 of the North Anna Power Station UFSAR. A shear modulus (G) of 19,800 psi and Poisson's Ratio (μ) of 0.3 were used in design of the storage pads.

2.5.1.12 **Analysis Techniques and Calculated Results**

The factor of safety against a bearing capacity failure is defined as the ratio of the net ultimate soil bearing capacity to the net applied foundation bearing pressures. The static factor of safety considered the total dead and live loads acting on the structure. A minimum safety factor of 3.0 was established as the design criterion. The ultimate bearing capacity was calculated using conventional bearing capacity equations for shallow strip footings and the appropriate bearing capacity factors for the soil parameters present (Reference 29). Bearing capacity for a wide footing is normally not critical unless the footing is subject to very heavy load and a high water table and/or very soft or loose soil conditions exist. The factor of safety against a bearing capacity failure calculated for the storage pad bearing on the stiff residual soil was significantly in excess of the required factor of 3.

Settlement was estimated by calculating the immediate elastic settlement and long-term consolidation settlement of the underlying residual soil. The elastic and consolidation settlement occur at different times but are additive. However, settlement calculations utilizing the classical consolidation theories which were developed for saturated sedimentary soils are generally not appropriate for the partially saturated residual soils. Consolidation theory considers the soils to be cohesive, homogeneous and isotropic. The residual soils encountered below the storage pads are only partially saturated, are highly variable and possess an interparticle bond related to the weathering of the parent rock, not the clay ion bond. Previous estimates of settlement of residual soils using consolidation theory have not agreed closely with the actual documented settlement which occurred at various structures onsite.

Therefore, settlement calculations were also performed using empirical equations developed by Schmertmann and others and utilizing results of correlations between STP and in-situ pressuremeter tests in residual soils (Reference 30). Based on results obtained from the two different methods, it is estimated that a total settlement of less than 1-1/2 inches will occur under full load. This estimate assumes that only 5 feet of overburden will be removed. Six and a half to ten feet (for pad 1) of overburden will be removed prior to construction of the storage pads, which would reduce the amount of settlement that would occur. This estimate assumes that the total load will be placed on the soil in one increment, which is a very conservative assumption. The time rate of loading will decrease the actual effect of any settlement that does occur, since it will take over nine years after the initial SSSC is placed for the storage pads to be fully loaded. The settlement will occur in small increments as the SSSCs are placed on the storage pads.

2.5.2 Vibratory Ground Motion

This section of the report describes the principal bases of the seismologic studies for Units 1 and 2 of the North Anna Power Station, and provides the framework for which the design-basis earthquake and its associated vibratory ground motion were evaluated. Additional reference is made to studies to evaluate the engineering properties of materials and their effect on seismic wave propagation and soil structure interaction.

2.5.2.1 **Engineering Properties of Materials**

The static and dynamic engineering properties of the site are described in Section 2.5.1.11.

2.5.2.2 **Seismic History**

A complete description of the seismic history of the site areas, as well as a summary of all significant earthquakes to the establishment of the design basis earthquake for North Anna Power Station Units 1 and 2, are presented in Appendix 2B of the North Anna Power Station UFSAR. Table 2-5 and Figure 2-17 in this report provide an updated chronological listing (through January 1994) and a regional epicenter map, respectively, for an area of 200-mile radius around the site.

The eastern United States is generally divided into four basic geologic-tectonic provinces: the Valley and Ridge, the Blue-Ridge, the Piedmont and the Coastal Plain. All four of these provinces are characterized by a general northeast-southwest trend. The Valley and Ridge is dominated by a structural style of large anticline-syncline structures which are further complicated by faulting, igneous intrusions and the development of terrestrial sedimentary basins (Reference 1).

The Piedmont Province is a large northeasterly-trending elongated group of crystalline rocks extending for approximately 800 miles (1288 km) from Alabama to New Jersey. This province is primarily characterized by metamorphosed sedimentary and volcanic rocks deformed into anticlinoria and synclinoria whose major axes parallel the dominant northeasterly trend of the province (Reference 1). The North Anna site is located in the north-central portion of Virginia within the Piedmont Province.

The historical record of earthquakes in the Appalachian region of the United States reveals significant differences in the seismic characteristics between the individual provinces. Generally, the activity occurs parallel to the regional structure and primarily in the Valley and Ridge and Blue Ridge Provinces northwest of the Piedmont Province (References 31, 32 & 33). Earthquakes are found to occur with less frequency in the Piedmont Province than in the adjacent provinces. Furthermore, none of the historical earthquakes in the Piedmont province in particular, or in the Appalachian region in general, have been reported to have caused surface displacement. There are three principal geographic zones in the Piedmont and Coastal Plain Provinces where there is a tendency for epicenter clustering. One recognizable geographic cluster of activity is in the South Carolina-Georgia region (Piedmont-Coastal Plan), and another is in central Virginia (Piedmont Province). The third apparent cluster of activity is along the Fall Zone (Coastal Plain and Piedmont boundary) in the Delaware-New Jersey region.

The clustering of activity in Central Virginia is referred to as the Central Virginia Seismic Zone (Reference 31) and includes the North Anna site on its northern boundary. The principal activity in this zone is some 30 miles (48 km) south of North Anna, following an east-west trend. There have been 22 earthquakes of Modified Mercalli (M.M.) intensity V to VI reported within 100 miles (161 km) of the site since the end of the 18th century (Reference 34). The Central

Virginia Seismic Zone has historically exhibited a low level of activity (2 to 10 shocks per decade), with most shocks having M.M. intensity levels of III to V.(31) Based on historical seismicity, the largest intensity shock that has occurred in the immediate site area (within 30 km) is approximately M.M. V (Figure 2-17).

The most significant earthquake in the region of the station affecting its design occurred near the Richmond Basin in 1774 (Intensity VI-VII), and near the Arvonia Syncline in 1875 (Intensity VII). These shocks and related zones of earthquake activity are both located within 50 miles of the site, and are believed to be associated with faulting in their respective basin-like structures. Additional earthquakes of epicentral intensity V occurred on December 11, 1969, near Richmond, Virginia (37.8°N 77.4°W) and on March 15, 1991, west of Richmond in Goochland County, some 37 km south-southwest of the site (Reference 35).

The 1875 shock was probably felt in the vicinity of the site, with an intensity approaching V. The 1774 shock cannot be accurately projected to the site area because of the lack of information, but it is believed that ground motion at the site did not exceed a few percent of gravity. The 1969 shock was perceptible over a 3500 square-mile area. A study of the recent land forms in the site area does not reveal any adverse features such as faulting, slides, or areas of instability or brecciation that could have been caused by these shocks or from earlier earthquake shocks.

North Anna Power Station experienced a large ground response to the August 23, 2011 Central Virginia earthquake. With the epicenter located approximately 11 miles southwest of the station, the intensity of this seismic event was recorded as M5.8. Sections 2.5.2.4 and 2.5.2.4.1 discuss this event in further detail and provide ground acceleration values experienced at the North Anna Power Station Unit 1 basemat and ISFSI Pad #1.

Additional details on seismic history are found in Appendix A to the North Anna Power Station Units 1 and 2 PSAR.

2.5.2.2.1 Microearthquake Monitoring

Dames & Moore's geologic investigation of the fault zone at the North Anna Power Station indicated that the zone had not experienced movement for the past 500,000 years, and was not in a critical state (Reference 1). None of the historic earthquakes in the Piedmont Province are known to have caused faulting at or near the surface. The fault zone underlying the reactor containment buildings and the fault zone underlying the North Anna dam appear to be of limited extent, and not structurally related to, or a continuation of, any known fault. No seismic activity, either instrumentally recorded or historically determined, can be shown to have any direct tectonic relationship to these fault zones. The closest zone of activity is 30 miles (48 km) south of the lake (Central Virginia Seismic Zone). No topographic expression of recent faulting has been observed in the vicinity of the lake. Due to the absence of definite earthquake-tectonic correlations for the region, it is not surprising that no activity was found associated with the fault zone, nor associated with the impoundment of Lake Anna.

As a means of demonstrating this observation, the NRC required confirmatory microearthquake monitoring of the area around the site and Lake Anna. Phase I and Phase II (permanent) monitoring occurred at the site between January 21, 1974 through August 1, 1977. No microearthquake detected in the three and one-half years of monitoring was associated either with the fault onsite or related to the impoundment of Lake Anna. Four stations of the original 17-station monitoring network were incorporated into Virginia Tech's Central Virginia Monitoring Network for the specific purpose of monitoring any changes in seismicity in the region of the North Anna Power Station. To date, no changes have been observed that would contradict the conclusions reached in 1977 regarding the lack of association of microearthquakes with Lake Anna or with the fault at the North Anna Power Station (Reference 36).

2.5.2.3 **Design Basis Earthquake**

The North Anna Power Station Units 1 and 2 Preliminary Safety Analysis Report and design were completed prior to the promulgation of Appendix A to 10 CFR 100. Consequently, the term "design-basis earthquake," as used in this report, has the meaning it had prior to December 1973 when Appendix A to 10 CFR 100 became effective.

The design basis earthquake (DBE) for the North Anna Power Station Units 1 and 2 was established by assuming that an earthquake equivalent to the largest shock associated with the Arvonia Syncline might occur close to the North Anna site area. With the epicenter of a shock similar to the 1875 MM I-VII moved to the vicinity of the site, it was estimated that the maximum horizontal ground acceleration at rock surface would be less than 0.12g.

Accordingly, the design basis earthquake for Seismic Class I structures founded on rock was established as 0.12g for horizontal ground motion, and two-thirds (0.08g) that value for vertical ground motion.

For Seismic Class I structures founded on rock, analyses for earthquake motion were made using response spectra developed by enveloping the response spectra, for various degrees of damping, of the east-west and north-south components of the Helena (1935) earthquake and the southeast component of the Golden Gate record of the San Francisco (1957) earthquake, all normalized to 0.12g for the DBE. For Seismic Class I structures founded on saprolite more than 15 feet thick, these analyses for earthquake motion were normalized to 0.18g for the DBE to provide for calculated amplification through the overburden. The response spectra are shown on Figures 2.5-12 and 2.5-14 of the North Anna Power Station UFSAR.

The amplification of earthquake motion through the overburden was computed using a lumped-mass spring system with model superposition.

Based on the two-to-three pulses of strong ground motion for the San Francisco, California (1957), and Helena, Montana (1935), earthquakes, a conservative estimate of strong ground motion pulses to be experienced at the North Anna site is four to five pulses of strong ground motion for the operating-basis earthquake and eight to ten pulses of strong ground motion for the design-basis earthquake.

The results of the regional seismicity and structural geologic update for this report have not provided any basis for modifying the original seismic design basis for the site. Additionally, continued seismic monitoring in the region surrounding the site over the last 20 years has not provided any basis to associate the minor seismicity of the region with either Lake Anna or the fault at the North Anna Power Station. The North Anna Power Station seismic design provides adequate conservatism for seismic Class I Structures at the North Anna Power Station.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

2.5.2.4 **Beyond Design Basis Earthquake**

The August 23, 2011 Central Virginia earthquake was determined to have exceeded the design basis earthquake (DBE) for North Anna Power Station Units 1 and 2, and ISFSI Pad #1. Evaluations and results of analyses performed for plant systems, structures, and components (SSCs) are described in Section 3.7.8 of the North Anna Power Station Units 1 and 2 UFSAR. Similarly, evaluations and results of analyses performed for ISFSI systems, structures, and components (SSCs) are described in Section 2.5.2.4.1 of this document.

Documentation of the August 23, 2011 Central Virginia earthquake in this section is solely for historical information. The August 23, 2011 Central Virginia earthquake and its associated ground accelerations does not replace the ISFSI DBE as stated in Sections 2.5.2.3 and 3.2.3.

2.5.2.4.1 Evaluation and Results of Analyses Performed for Seismic Motions Recorded During the 5.8 Magnitude Central Virginia Earthquake on August 23, 2011

North Anna Power Station experienced a 5.8 magnitude seismic event centered approximately 11 miles southwest of the station on August 23, 2011 which transmitted a large ground response to the North Anna site. Although cask movement up to 4.5 inches was observed (Reference 40), inspections and evaluations concluded the ISFSI Pad #1 and the Transnuclear TN-32 dry storage systems remain operational and capable of performing their design and safety functions (Reference 41).

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Peak ground accelerations recorded at the North Anna Power Station Unit 1 basemat for the 8/23/2011 event were 0.26g north-south, 0.11g east-west, and 0.12g vertical (Reference 42). Due to the difference in subterranean structure at the ISFSI Pad, a Soil Structure Interaction (SSI) analysis was performed to translate the 8/23/2011 seismic parameters from the Unit 1 basemat to ISFSI Pad #1. As stated in Sections 2.5.2.3 and 3.2.3, the design basis earthquake (DBE) horizontal acceleration is 0.18g for structures founded on sapprolite more than 15 feet thick, and two-thirds (0.12g) of the horizontal value for vertical acceleration. Results of the SSI analysis (Reference 43) for ISFSI Pad #1 concluded that the enveloped maximum acceleration at the pad and at the Center of Gravity (CG) of the cask were 0.55g for the NS direction (long direction of the pad), 0.502g for the EW direction (short direction of the pad), and 0.38g in the vertical direction. Thus, the ISFSI DBE was exceeded.

Conservatively assuming 14 feet cask center-to-center spacing, a strength evaluation of ISFSI Pad #1 was performed and determined imposed loads on Pad #1 for the 27 TN-32 dry storage casks at the time of the earthquake as well as for a symmetrical loading of two TN-32 dry storage casks in the center of the pad, the most limiting case (Reference 44). This evaluation was performed to determine if the strength of the ISFSI pad was sufficient to support a reduction in cask center-to-center spacing from 16 feet to 14 feet and to resist the loadings applied during the seismic event while remaining within all original design bases and code requirements. The strength evaluation of the pad determined the internal moments, shears and soil bearing pressure induced at the time of the seismic event were within the code allowable for which the ISFSI pad was designed. Additionally, since the internal forces and stresses induced in the pad were within the code allowable for which the ISFSI pad was designed, the operability of the pad is confirmed and no additional specific operability concerns due to the seismic forces seen need to be addressed.

Prior to the August 23, 2011 seismic event, TN-32 dry storage casks on ISFSI Pad #1 were spaced 16 feet nominal center-to-center and 16 feet minimum center-to-center (for heat loads exceeding 27.1 kW) in accordance with ISFSI Technical Specification 4.2.3. Subsequent to the seismic event, it was determined that 25 of the 27 TN-32 dry storage casks had shifted from their original locations and that 13 casks are now less than 16 feet from another cask. Updated cask heat load evaluations confirmed that all casks contained a heat load less than 27.1 kW at the time of the earthquake.

Several evaluations, including thermal, nuclear, and structural, were performed by the cask vendor to ensure the TN-32 dry storage casks are capable of performing their design functions with reduced cask spacing (References 45 and 46). These evaluations assumed 14 feet center-to-center spacing and a cask heat load no greater than 27.1 kW, thus providing the basis for leaving the TN-32 dry storage casks in their post-seismic locations.

2.5.3 Surface Faulting

Surface faulting and capable faults are addressed in Section 2.5.2.2.

2.5.4 Stability of Subsurface Materials

The geologic features, seismicity, groundwater conditions, and soil and rock characteristics are addressed in Section 2.5.1 and Appendices 2A and 2B. The earthquake design basis is addressed in Section 2.5.2.

The storage pads and new portions of the original (main) transport route will be undercut a minimum of 18 inches and be brought up to grade with a compacted dense graded crushed aggregate fill. Random soils across the site will be used to construct leveling fills, slopes and berms. The soil fill will be placed in a controlled compacted manner.

Portions of the alternate transport route were constructed using both cut and fill. Alternate transport route areas were proof-rolled prior to road construction to determine subgrade conditions and stability. Portions of the alternate transport route with soft or unsuitable materials were replaced with soil and/or sand/gravel fill, and additional subgrade stabilization was provided, as required, by a 3 inch layer of crusher-run stone. Rock encountered during cut was removed to a depth of 6 inches below finished subgrade and replaced with suitable fill. Soil and sand/gravel fill was placed in a controlled and compacted manner.

Liquefiable soils consist primarily of loose sands at or below the water table which have low overburden or confining pressures, or highly sensitive clays. The fine grained soils encountered at the ISFSI site possess significant cohesion or inter-particle bond from the relic rock structure of the parent rock. Even the granular soils possess relatively high percentages (25% to 50%) of fine grained silt and clay size particles. The grains are also angular or sub-angular, not rounded or sub-rounded as deposited soils tend to be. Only one STP taken in the predominantly granular soils below the water table had a penetration resistance below 10 blows per foot, which would classify the soil as loose. Liquefaction at the Service Water Reservoir (SWR) was addressed in Section 3.6 of Appendix 3E of the North Anna Power Station UFSAR. It was concluded that liquefaction would not occur under the DBE of 0.18g. As stated, the soils encountered at the ISFSI site are similar to those encountered at the reactors, the Service Water Reservoir and the main dam. The soils encountered at the ISFSI site are a product of weathering of the same parent rock.

Dr. James Martin at Virginia Polytechnic Institute was retained by Virginia Power to evaluate the liquefaction potential for a horizontal earthquake acceleration of 0.30g at North Anna (Reference 38). This acceleration value is 2/3 higher than that generated by the DBE. His report concludes that liquefaction of the residual soils at the North Anna site will not occur under this horizontal earthquake loading.

2.5.5 Slope Stability

The ISFSI site will utilize both cut and fill to obtain final grade. A berm will be constructed across the front of the site. Soil fill will be utilized to construct portions of the original (main) transport route. Cut and fill slopes will not be steeper than two horizontal to one vertical (2H:lV). Proper compaction of onsite soils as required by specifications will ensure that the design parameters are achieved. The soils that comprise the cut or fill slopes are highly erodible, therefore, care will be taken to grade and seed the slopes to minimize the effects of erosion.

Soil and/or sand/gravel were used to construct portions of the alternate transport route. Cut and fill slopes were not steeper than two horizontal to one vertical (2H:1V). Proper compaction of soil and/or sand/gravel fill ensured that design requirements were achieved. Compliance with applicable jurisdictional requirements for soil erosion and sediment control including dust abatement, were implemented to minimize soil erosion.

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Table 2-1
DISPERSION FACTORS (χ/Q) IN ACCORDANCE WITH REGULATORY GUIDE 1.145

Sector	Distance (meters)	χ/Q (sec/m^3)
N	2033	6.61×10^{-5}
NNE	2113	6.85×10^{-5}
NE	2055	7.74×10^{-5}
ENE	1867	6.45×10^{-5}
E	1606	1.16×10^{-4}
ESE	1335	2.01×10^{-4}
SE	1100	3.15×10^{-4}
SSE	948	1.77×10^{-4}
S	847	1.10×10^{-4}
SSW	818	1.03×10^{-4}
SW	836	9.30×10^{-5}
WSW	919	8.43×10^{-5}
W	1067	8.53×10^{-5}
WNW	1281	7.04×10^{-5}
NW	1556	5.24×10^{-5}
NNW	1820	4.42×10^{-5}

Table 2-2

SUMMARY OF USGS GAUGING STATION RECORDS AND ESTIMATED STREAM FLOW DATA FOR THE NORTH ANNA DAM

River Location	Drainage Area (sq.mi.)	Period of Record [a]	Discharge (cfs) Average	Minimum	Maximum
USGS gauge at Doswell	439	1929-1971	382 [b]	1 [c]	24,800 [d]
USGS gauge at Doswell	439	1972-1992	399 [e]	35.5 [f]	23,300 [g]
North Anna Dam	343	1929-1971	300 [h]	1 [h]	19,500 [h]
North Anna Dam	343	1978-1999	288 [i]	25 [j]	11,700 [k]

a. Dam was closed January 1972.
b. Average discharge for 41-year period.
c. Date of discharge: September 30 to October 2, 1932.
d. Date of discharge: August 21, 1969.
e. Average discharge for 21-year-period since 1971.
f. Date of Discharge: October 8, 1991.
g. Date of Discharge: June 22, 1972.
h. Estimated.
i. Average Discharge since Partlow gauge has been in operation.
j. Date of Discharge: August 1, 1988.
k. Date of Discharge: February 26, 1979.

References 3, 4 and 5

Table 2-3
FLOODS ON THE NORTH ANNA RIVER

Flood Period	Peak Flow at Doswell (cfs)	Volume of Direct Runoff at Doswell (acre-feet)
August 12, 1928	18,400	—
April 24-29, 1937	18,300	81,400
October 17, 1943	11,600	—
August 12-25, 1955	12,400	54,700
August 20-23, 1969	24,800	141,000
June 20-22, 1972	23,300	107,200
Sept. 21-30, 1975	11,600	77,870
Feb. 22-March 3, 1979	11,700	73,131
March 27-April 3, 1984	11,700	78,229
Nov. 1-11, 1985	10,700	55,625
March 27-April 2, 1994	12,000	85,600
Sept. 5-13, 1996	11,600	61,380

1. References 3, 4 and 5

Table 2-4
RECOVERY AND RQD VALUES OF BORINGS

Boring No.	Run No.	From (Feet)	To (Feet)	Inches Recovered	Recovery Percent	Percent RQD
F-4	1	49.1	54.1	13	21.6	0
	2	54.1	59.1	47	78.3	40
F-5	1	64.5	69.5	0	0	0
	2	69.5	74.5	8	13.3	0
	3	74.5	79.5	2	3.3	0
	4	79.5	84.5	0	0	0
	5	84.5	89.5	4	6.6	0
	6	89.5	94.5	0	0	0
	7	94.5	99.5	0	0	0
	8	99.5	104.5	0	0	0
	9	104.5	109.5	30	50	0
	10	109.5	114.5	48	80	0
F-6	1	44.0	49.0	0	0	0
	2	49.0	54.0	0	0	0
	3	54.0	59.0	42	70	18.3
F-7	1	75.0	80.0	0	0	0
	2	80.0	85.0	0	0	0
	3	85.0	90.0	0	0	0
	4	90.0	95.0	2	3.3	0
	5	95.0	100.0	0	0	0
	6	100.0	105.0	38	63	0
F-8	1	64.2	69.2	48	80	0
F-9	1	59.1	64.1	0	0	0
	2	64.1	69.1	0	0	0
	3	69.1	74.1	7.5	12.5	0
	4	75.0	80.0	28.5	47	7.5
	5	80.0	85.0	12	20	6.6
	6	85.0	90.0	0	0	0
	7	90.0	95.0	8	13	0
	8	95.0	100.0	19	31	6.6
	9	100.0	105.0	36	60	17.5
F-10	1	69.0	74.0	57	95	35.8

Table 2-4 (CONTINUED)
RECOVERY AND RQD VALUES OF BORINGS

Boring No.	Run No.	From (Feet)	To (Feet)	Inches Recovered	Recovery Percent	Percent RQD
F-11	1	39.0	44.0	6	10	0
	2	44.0	49.0	8	13.3	0
	3	49.0	54.0	14	23	0
	4	54.0	59.0	42	70	0
	5	59.0	64.0	35	58	28
	6	64.0	69.0	42	70	22.5

Table 2-5
EARTHQUAKES WITHIN 200 MILES OF NORTH ANNA SITE
EVENTS LISTED CHRONOLOGICALLY

Date	Latitude		Longitude		MMI	Magnitude
Apr 25, 1758	38.900	N	76.500	W	V	4.20
Feb 21, 1774	37.200	N	77.400	W	VI	4.54
Feb 22, 1774	37.200	N	77.400	W	IV	3.61
Mar 16, 1775	37.700	N	78.800	W	IV	3.61
Aug 30, 1775	37.700	N	78.800	W	III	
Nov 19, 1798	38.300	N	77.500	W	III	
Jan 13, 1791	37.700	N	78.800	W	IV	3.61
Jan 15, 1791	37.500	N	77.500	W	IV	3.61
Feb 11, 1795	37.800	N	77.300	W	III	
Feb 12, 1795	38.300	N	77.500	W	III	
Mar 29, 1800	39.800	N	75.200	W		3.00
Feb 11, 1801	37.400	N	79.200	W	III	
Aug 23, 1802	37.400	N	79.100	W	V	4.20
May 1, 1807	37.400	N	79.100	W	V	4.20
Nov 27, 1811	36.100	N	80.200	W	IV	3.61
Feb 2, 1812	37.600	N	77.400	W	IV	3.61
Apr 22, 1812	37.500	N	77.500	W	IV	3.61
Jan 8, 1817	36.000	N	80.200	W	V	5.04
Jul 15, 1824	39.700	N	80.500	W	IV	3.61
Mar 9, 1828	37.000	N	80.000	W	V	5.04
Aug 27, 1833	37.700	N	78.000	W	VI	5.04
Nov 11, 1840	39.800	N	75.200	W	V	4.20
Oct 19, 1846	39.300	N	77.900	W	III	
Mar 30, 1850	35.400	N	78.000	W	V	4.20
Oct 17, 1850	37.300	N	78.400	W	IV	3.61
Oct 18, 1850	37.400	N	78.400	W	IV	
Nov 2, 1852	37.500	N	78.600	W	VI	4.34
Jan 30, 1853	38.900	N	78.500	W	III	
May 2, 1853	38.500	N	79.500	W	V	4.64
Jan 3, 1855	39.200	N	77.500	W	V	
Feb 2, 1855	37.00	N	78.600	W	V	4.04
Jan 16, 1856	39.200	N	78.20	W	IV	3.61
Mar 21, 1856	37.700	N	78.900	W	III	
Apr 21, 1871	36.400	N	78.600	W	III	
Oct 9, 1871	39.700	N	75.500	W	VII	4.59
Mar 1, 1872	36.800	N	79.400	W	III	
Jun 5, 1872	37.700	N	78.000	W	IV	3.61

Table 2-5 (CONTINUED)
EARTHQUAKES WITHIN 200 MILES OF NORTH ANNA SITE
EVENTS LISTED CHRONOLOGICALLY

Date	Latitude		Longitude		MMI	Magnitude
Oct 3, 1873	37.200	N	78.200	W	IV	3.61
Dec 23, 1875	37.600	N	78.500	W	VII	4.54
Jan 3, 1876	37.600	N	77.900	W	III	
Apr 10, 1876	38.500	N	76.600	W	III	
Dec 23, 1876	37.400	N	77.500	W	IV	3.61
Sep 1, 1877	38.700	N	76.800	W	III	
Jan 3, 1878	37.900	N	77.700	W	III	
Mar 26, 1879	39.200	N	75.500	W	V	4.20
Apr 2, 1882	38.600	N	78.700	W	IV	
Mar 11, 1883	39.500	N	76.400	W	IV	3.61
Mar 12, 1883	39.500	N	76.400	W	IV	3.61
Sep 21, 1883	36.100	N	79.800	W	V	4.20
Jan 3, 1885	39.200	N	77.500	W	V	4.06
Jan 15, 1885	4.300	N	76.300	W	III	3.02
Feb 2, 1885	36.900	N	81.100	W	IV	3.61
Oct 10, 1885	37.700	N	78.800	W	VI	4.24
Mar 8, 1889	40.000	N	76.000	W	V	4.11
Oct 7, 1895	35.900	N	77.500	W	V	4.20
Feb 11, 1896	36.300	N	78.600	W	IV	3.61
May 3, 1897	37.100	N	80.700	W	VII	4.34
May 31, 1897	37.300	N	80.700	W	VII	5.84
Jun 28, 1897	37.300	N	80.700	W	V	4.04
Sep 3, 1897	37.300	N	80.700	W	IV	3.61
Oct 22, 1897	36.900	N	81.100	W	V	4.20
Nov 27, 1897	37.700	N	77.500	W	IV	3.61
Dec 18, 1897	37.700	N	77.500	W	V	4.04
Feb 5, 1898	37.000	N	81.000	W	VI	4.34
Nov 25, 1898	37.000	N	81.000	W	V	4.64
Feb 13, 1899	37.000	N	81.000	W	V	4.74
Mar 3, 1899	36.900	N	76.300	W	IV	3.61
Mar 11, 1902	39.600	N	77.100	W	III	
May 18, 1902	37.300	N	80.600	W	V	4.20
Jan 1, 1903	39.600	N	77.200	W	III	
Apr 29, 1905	37.300	N	79.500	W	III	
May 8, 1906	38.700	N	75.700	W	IV	3.40
Oct 13, 1906	39.200	N	76.700	W	III	
Feb 11, 1907	37.700	N	78.300	W	VI	4.79

Table 2-5 (CONTINUED)
EARTHQUAKES WITHIN 200 MILES OF NORTH ANNA SITE
EVENTS LISTED CHRONOLOGICALLY

Date	Latitude		Longitude		MMI	Magnitude
Aug 23, 1908	37.500	N	77.900	W	V	4.20
Apr 2, 1909	39.400	N	78.000	W	V	4.20
Feb 8, 1910	38.800	N	78.700	W	IV	3.64
Apr 24, 1910	39.200	N	76.700	W	III	
May 8, 1910	37.700	N	78.400	W	IV	3.61
Feb 10, 1911	36.600	N	79.400	W	IV	3.61
Apr 8, 1911	38.300	N	75.500	W	IV	3.61
Aug 7, 1912	37.700	N	78.400	W	IV	3.61
Aug 8, 1912	37.700	N	78.400	W	IV	3.61
Apr 10, 1918	38.700	N	78.400	W	VI	4.93
Apr 16, 1918	38.700	N	78.400	W	IV	3.61
Apr 19, 1918	36.800	N	76.300	W	III	
Sep 6, 1919	38.800	N	78.200	W	VI	4.79
Jul 24, 1920	38.700	N	78.400	W	IV	3.61
Aug 7, 1921	37.800	N	78.400	W	VI	4.79
Dec 31, 1923	39.200	N	78.000	W	V	
Jan 1, 1924	39.100	N	78.100	W	IV	
Jan 5, 1924	39.100	N	78.100	W	IV	3.61
Dec 26, 1924	37.300	N	79.900	W	V	4.20
May 16, 1925	37.300	N	77.500	W	V	4.20
Jul 14, 1925	37.600	N	77.500	W	IV	3.61
Jun 10, 1927	38.000	N	79.000	W	V	4.20
Oct 27, 1927	36.300	N	76.200	W	IV	3.61
Oct 15, 1928	38.300	N	75.100	W	IV	3.61
Oct 30, 1928	37.500	N	77.500	W	IV	3.61
Dec 26, 1929	38.100	N	78.500	W	VI	4.79
Sep 15, 1930	37.500	N	77.500	W	III	
Nov 1, 1930	39.100	N	76.500	W	IV	3.61
Oct 6, 1931	37.700	N	78.300	W	III	
Jan 5, 1932	37.600	N	78.400	W	IV	3.61
Jan 27, 1933	37.200	N	77.400	W	IV	3.61
Jul 23, 1933	37.700	N	78.300	W	III	
Apr 3, 1934	37.200	N	77.400	W	III	
Feb 10, 1935	37.200	N	77.400	W	IV	3.61
Nov 1, 1935	38.900	N	78.900	W	IV	3.61
Feb 3, 1937	37.700	N	78.700	W	IV	3.611
Mar 25, 1937	40.900	N	78.200	W	III	3.02

Table 2-5 (CONTINUED)
EARTHQUAKES WITHIN 200 MILES OF NORTH ANNA SITE
EVENTS LISTED CHRONOLOGICALLY

Date	Latitude		Longitude		MMI	Magnitude
Jul 15, 1938	40.680	N	78.430	W	VI	3.34
Nov 15, 1939	39.580	N	75.050	W	V	4.04
Nov 18, 1939	39.500	N	76.600	W	IV	3.61
Nov 26, 1939	39.500	N	76.600	W	V	4.20
Mar 26, 1940	38.800	N	78.500	W	V	4.20
Jan 3, 1942	37.400	N	79.100	W	III	
Oct 7, 1942	37.600	N	78.400	W	IV	3.61
Jan 8, 1944	39.800	N	75.500	W		4.25
Oct 10, 1945	37.700	N	78.300	W	III	
Oct 12, 1945	37.500	N	78.500	W	IV	3.61
Oct 30, 1945	37.500	N	78.500	W	IV	3.61
May 24, 1946	38.000	N	78.600	W	III	
Jan 4, 1948	37.600	N	78.600	W	IV	3.61
Jan 5, 1948	37.500	N	78.500	W	V	4.20
Mar 26, 1948	38.100	N	78.500	W	III	
May 8, 1949	37.600	N	77.600	W	V	4.20
Nov 26, 1950	37.700	N	78.300	W	V	4.20
Mar 9, 1951	37.600	N	77.600	W	V	4.20
Sep 11, 1952	38.100	N	78.500	W	IV	
Feb 7, 1953	37.700	N	78.100	W	IV	3.61
Jan 7, 1954	40.300	N	76.000	W	VI	4.79
Aug 11, 1954	40.30	N	76.000	W	IV	3.61
Jan 17, 1955	37.300	N	78.400	W	IV	3.61
Jan 20, 1955	40.300	N	76.000	W	IV	3.61
Apr 23, 1959	37.380	N	80.680	W	VI	3.84
Jul 7, 1959	37.300	N	80.700	W	IV	3.61
Aug 21, 1959	37.300	N	80.700	W	IV	3.61
Sep 4, 1960	37.400	N	79.300	W	IV	3.61
Sep 4, 1962	39.500	N	77.700	W	IV	3.61
Sep 7, 1962	39.700	N	78.200	W	IV	3.61
Jan 17, 1963	37.300	N	80.100	W	IV	3.61
Oct 10, 1963	39.800	N	78.200	W		3.60
Feb 13, 1964	40.380	N	77.960	W	VI	3.29
May 12, 1964	40.300	N	76.410	W	VI	3.19
Jul 15, 1965	37.310	N	74.390	W		5.30
Sep 16, 1965	37.250	N	74.360	W		5.00
Oct 8, 1965	40.080	N	79.750	W		3.60

Table 2-5 (CONTINUED)
EARTHQUAKES WITHIN 200 MILES OF NORTH ANNA SITE
EVENTS LISTED CHRONOLOGICALLY

Date	Latitude		Longitude		MMI	Magnitude
May 31, 1966	37.660	N	78.130	W	V	3.69
Sep 28, 1966	39.300	N	80.300	W	IV	3.61
Mar 8, 1968	37.280	N	80.770	W	IV	4.09
May 22, 1969	39.610	N	78.250	W		3.10
Nov 20, 1969	37.450	N	80.930	W	VI	4.69
Dec 11, 1969	37.840	N	77.670	W	V	3.39
May 27, 1970	39.620	N	78.280	W		3.20
Jul 14, 1971	39.700	N	75.600	W	IV	3.61
Sep 12, 1971	38.150	N	77.590	W	V	3.60
Dec 29, 1971	39.70	N	75.600	W	IV	3.61
Jan 2, 1972	39.700	N	75.600	W	IV	3.61
Jan 3, 1972	39.700	N	75.600	W	IV	3.61
Jan 7, 1972	39.700	N	75.600	W	IV	3.61
Jan 22, 1972	39.700	N	75.600	W	IV	3.61
Jan 23, 1972	39.700	N	75.600	W	IV	3.61
Feb 11, 1972	39.700	N	75.600	W	V	4.20
Aug 14, 1972	39.700	N	75.600	W	IV	3.61
Sep 5, 1972	37.600	N	77.700	W	IV	3.39
Sep 12, 1972	39.600	N	79.900	W	III	3.02
Dec 8, 1972	40.140	N	76.240	W	V	3.52
Feb 28, 1973	39.690	N	75.430	W	V	3.79
Apr 9, 1973	37.300	N	77.700	W	IV	3.61
Jul 10, 1973	39.700	N	75.700	W	IV	3.61
Mar 23, 1974	38.700	N	77.800	W		3.80
Apr 28, 1974	39.800	N	75.600	W	IV	3.61
May 30, 1974	37.460	N	80.540	W	V	3.59
May 31, 1974	37.400	N	80.400	W		3.80
Mar 7, 1975	37.320	N	80.480	W	II	3.04
Nov 11, 1975	37.220	N	80.890	W	IV	3.19
May 6, 1976	39.600	N	79.900	W	IV	3.61
Sep 13, 1976	36.620	N	80.770	W	VI	3.29
Apr 26, 1978	39.700	N	78.240	W		3.10
Jul 16, 1978	39.900	N	76.220	W	V	3.09
Oct 6, 1978	40.080	N	76.150	W		3.00
Aug 30, 1980	39.800	N	74.900	W		3.00
Nov 5, 1980	38.180	N	79.900	W		3.00
Feb 11, 1981	37.720	N	78.440	W	IV	3.39

Table 2-5 (CONTINUED)
EARTHQUAKES WITHIN 200 MILES OF NORTH ANNA SITE
EVENTS LISTED CHRONOLOGICALLY

Date	Latitude		Longitude		MMI	Magnitude
May 12, 1982	40.410	N	77.960	W		3.00
Apr 19, 1984	40.131	N	76.037	W		3.00
Apr 23, 1984	39.950	N	76.370	W	V	4.46
Aug 17, 1984	37.868	N	78.324	W		4.20
Jun 10, 1985	37.248	N	80.485	W		3.20
Mar 15, 1991	37.746	N	77.916	W	V	3.80
Apr 22, 1991	37.996	N	80.266	W		3.40
Jun 28, 1991	38.231	N	81.335	W		3.00
Aug 15, 1991	40.786	N	77.657	W	V	3.00
Mar 16, 1993	39.190	N	76.870	W	III	
Nov 17, 1993	39.190	N	76.870	W	III	
Jan 16, 1994	40.330	N	76.037	W	V	4.60

Figure 2-1
AREA MAP (0-10 MILES)

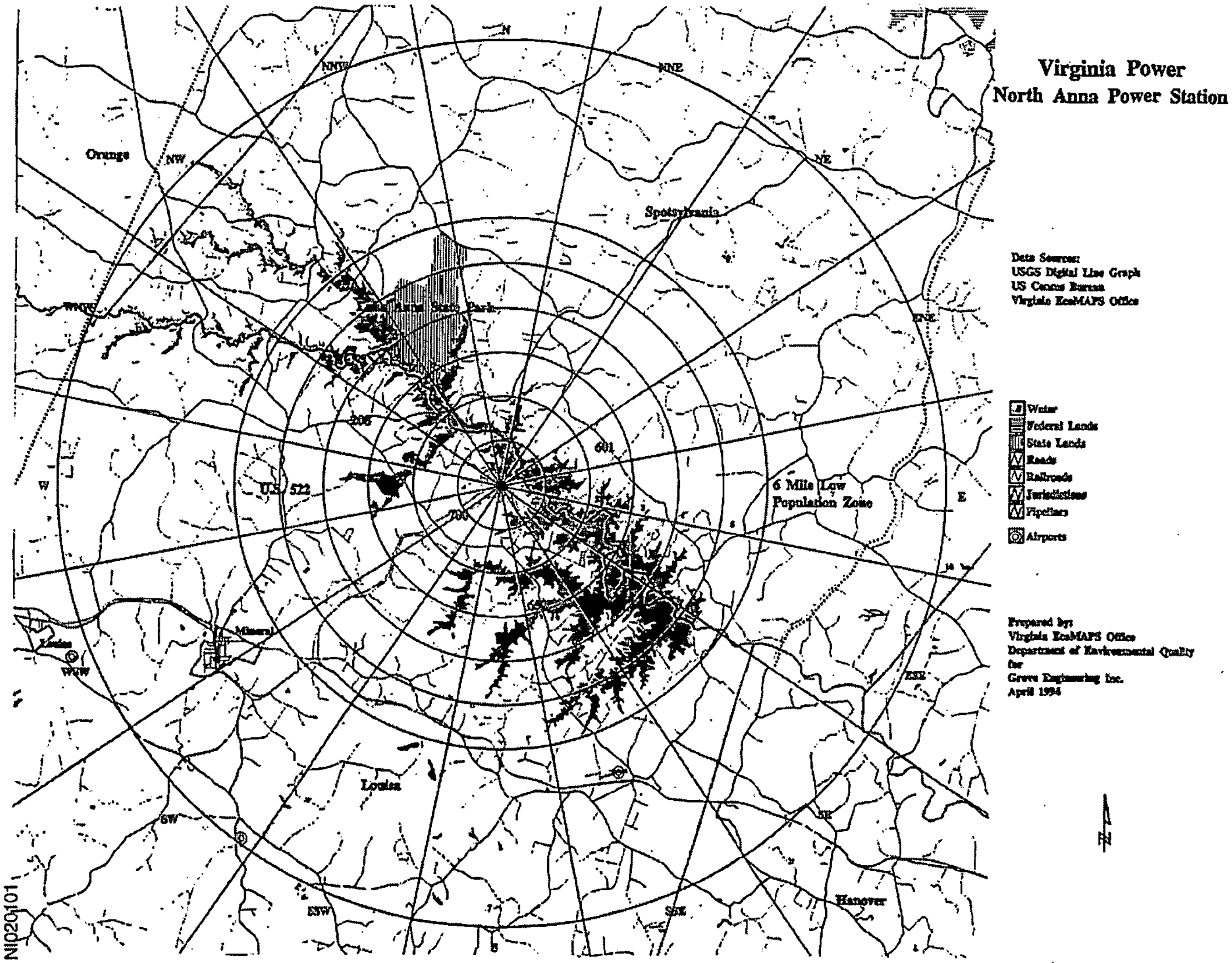
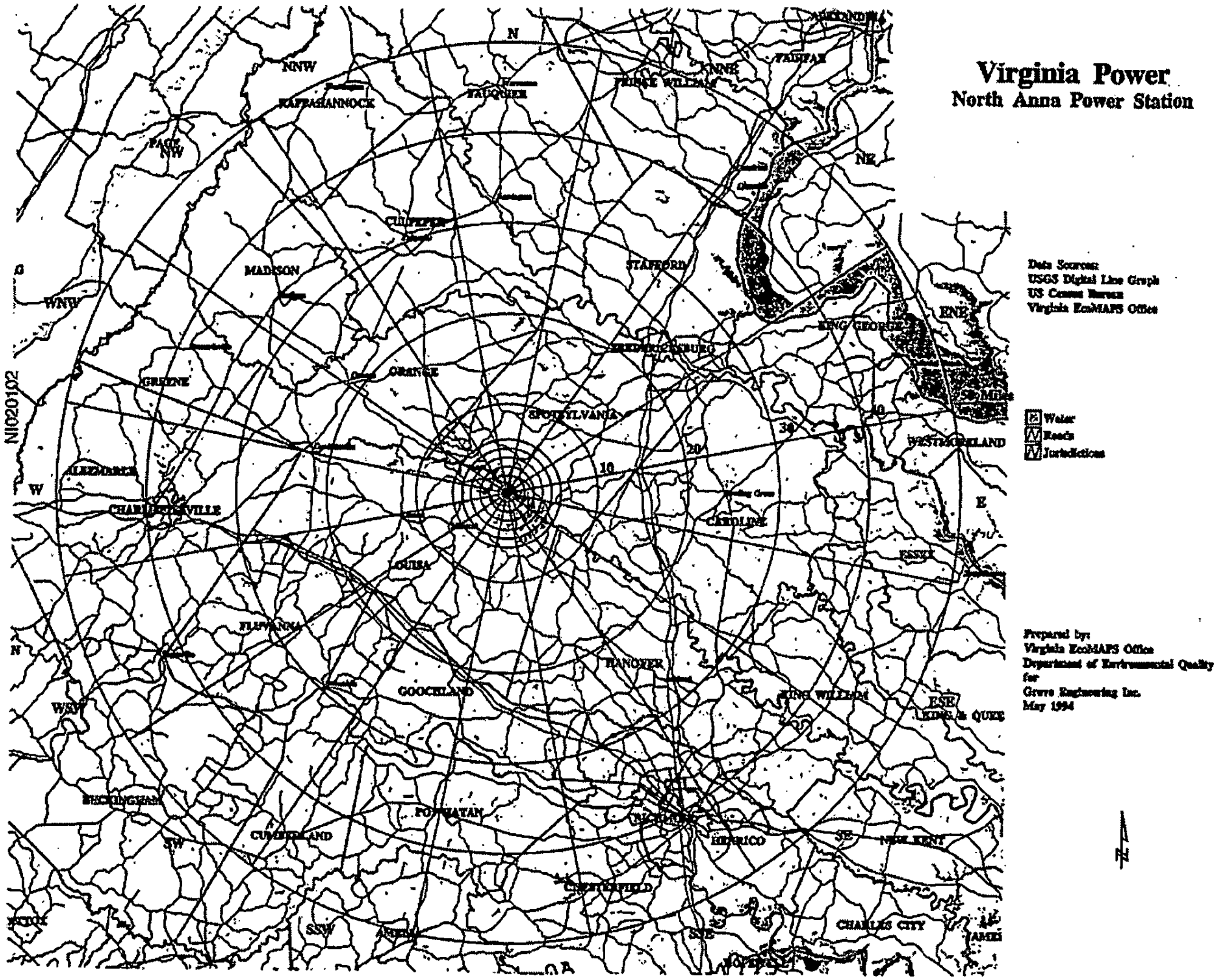


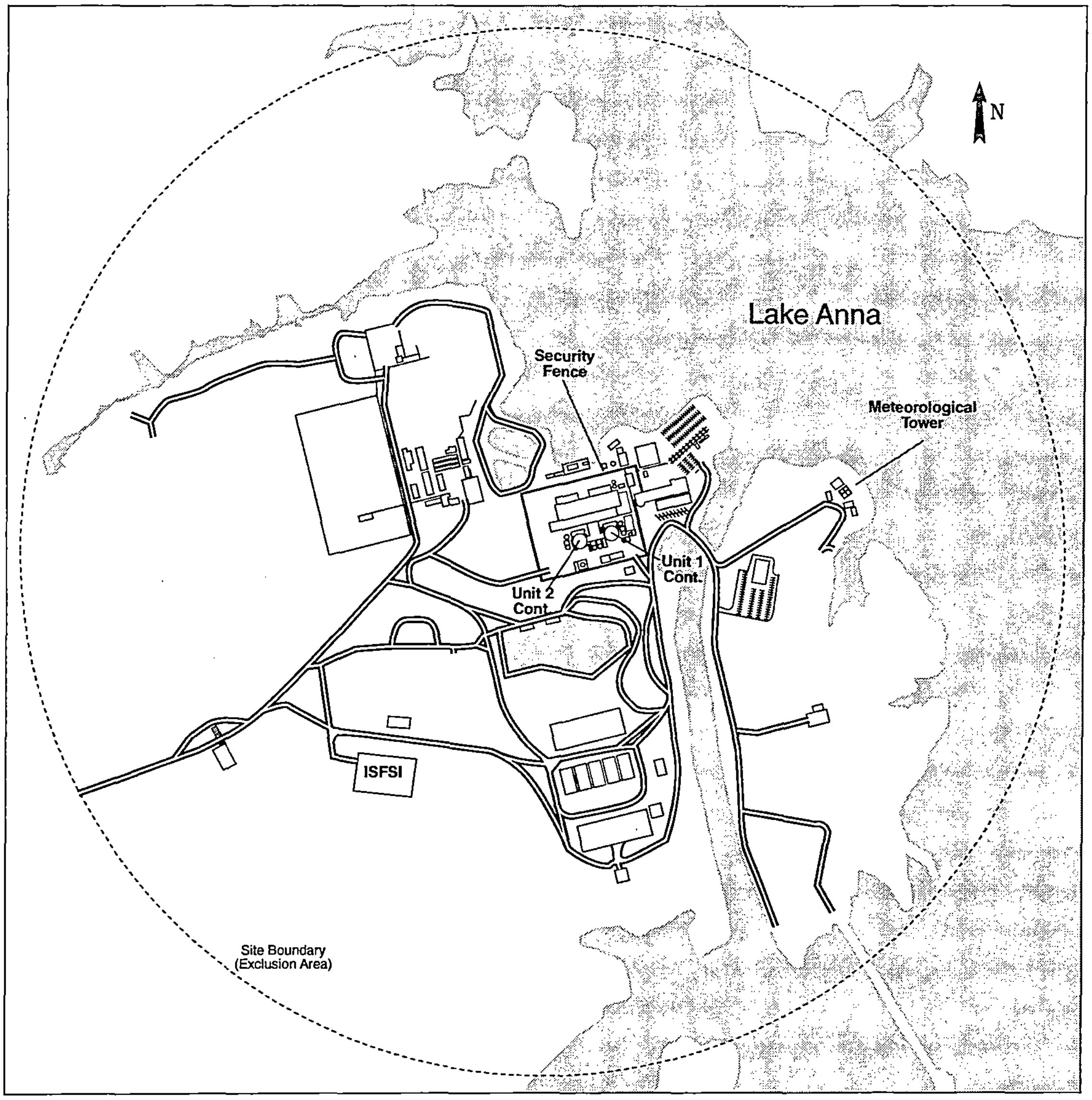
Figure 2-2
REGIONAL MAP (0-50 MILES)



Revision 8.02—Updated Online 11/16/15

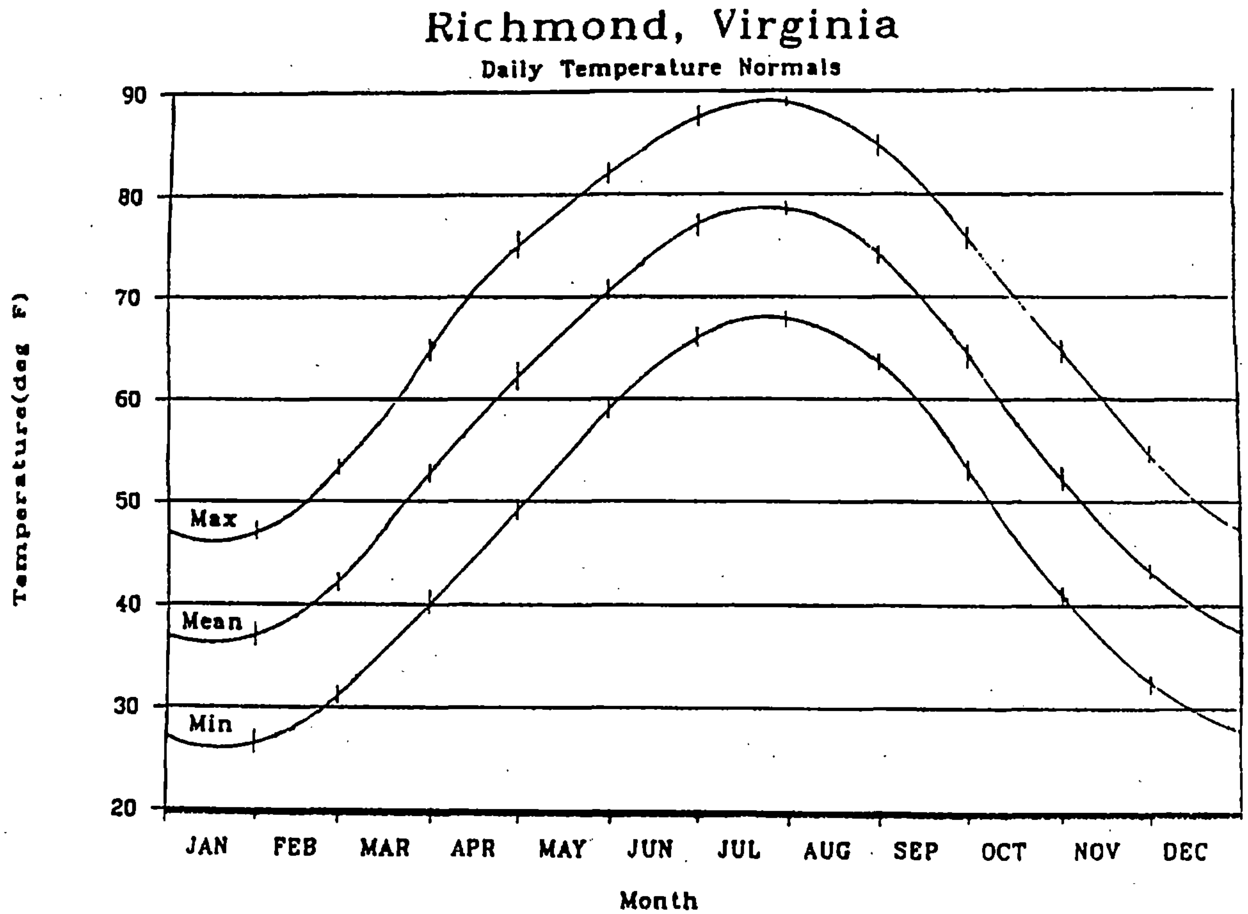
North Anna ISFSI SAR

Figure 2-3
NORTH ANNA SITE BOUNDARY



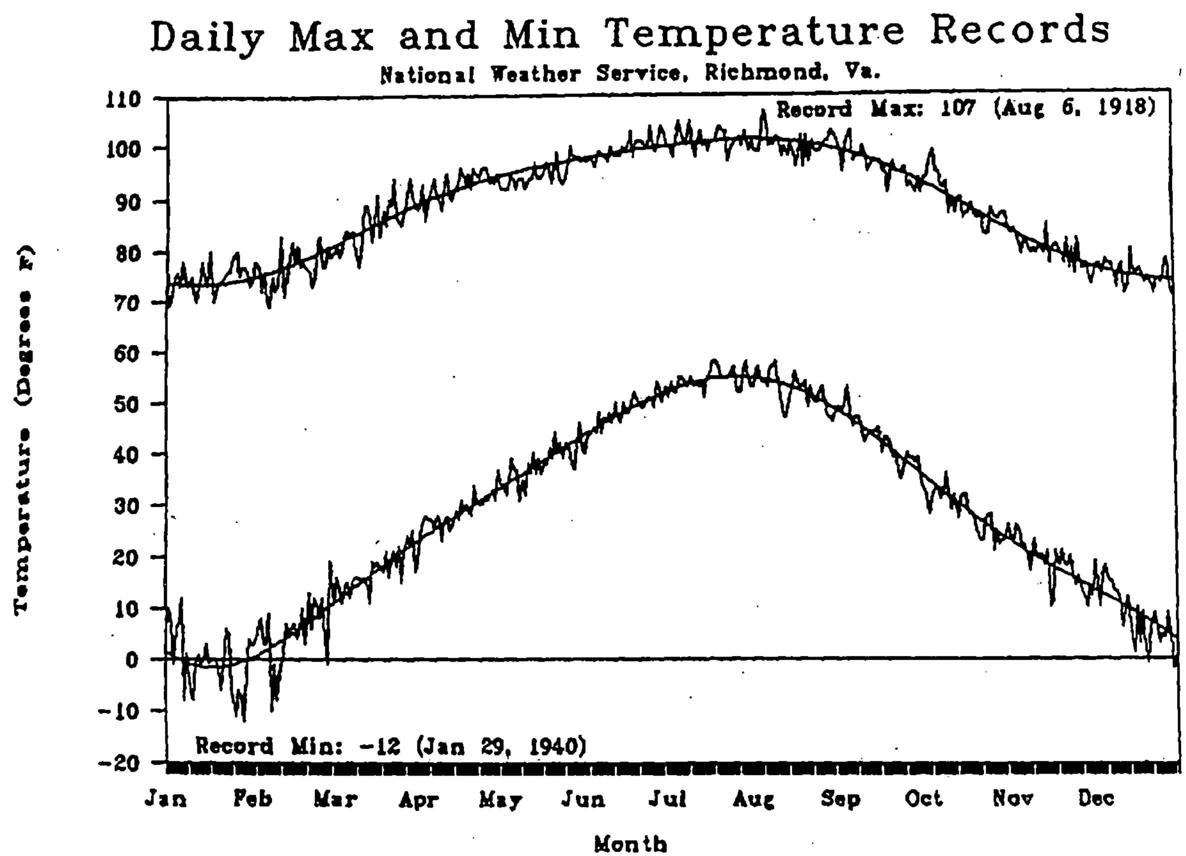
Graphics No: SV644K

Figure 2-4
DAILY AVERAGE TEMPERATURES FOR RICHMOND, VIRGINIA (1951-1980)



NI020301

Figure 2-5
DAILY EXTREME TEMPERATURES FOR RICHMOND, VIRGINIA (1898-1991)



NI020302

Figure 2-6
EXTREME 1-MILE WIND PASSAGE AT RICHMOND, VIRGINIA

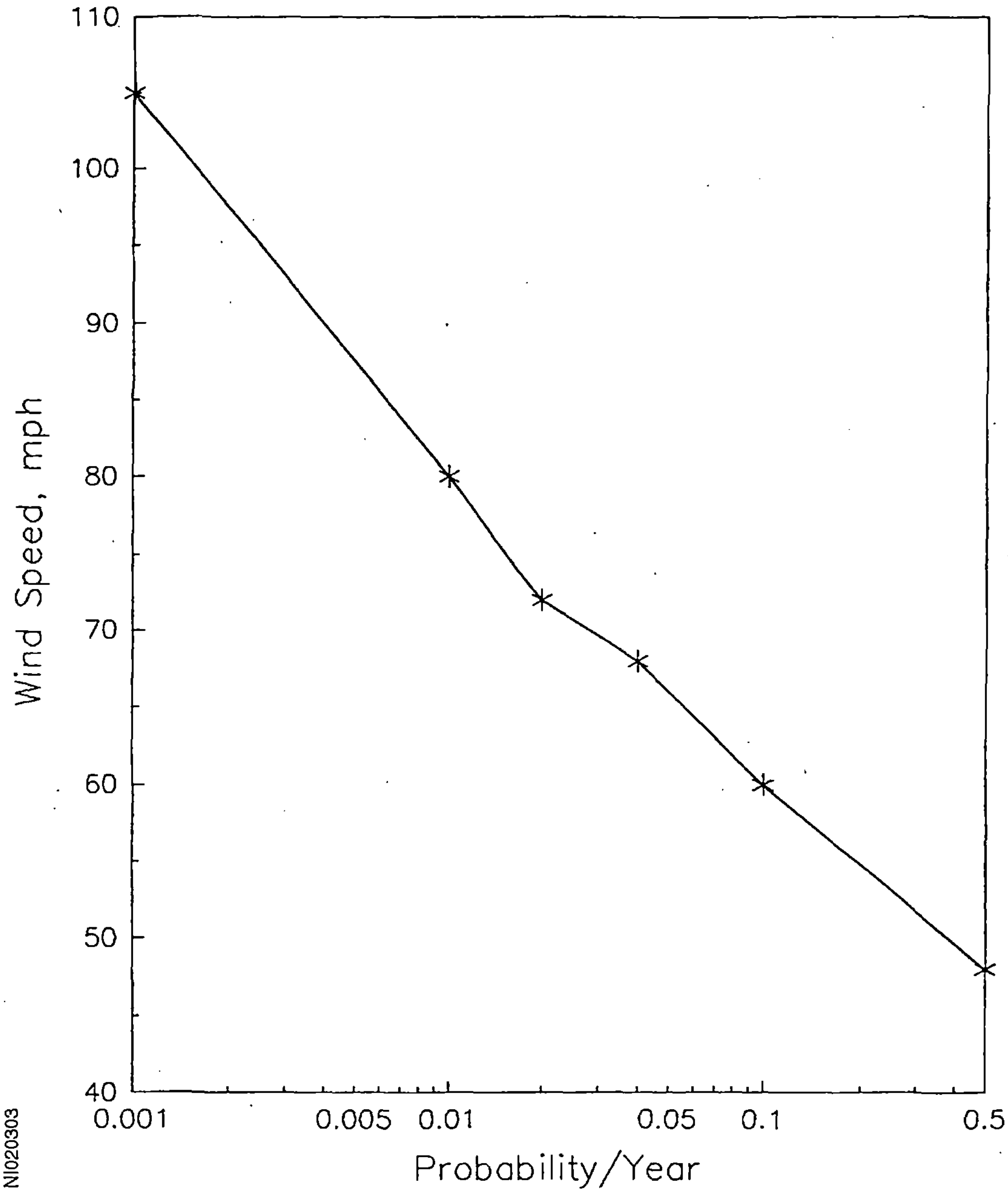
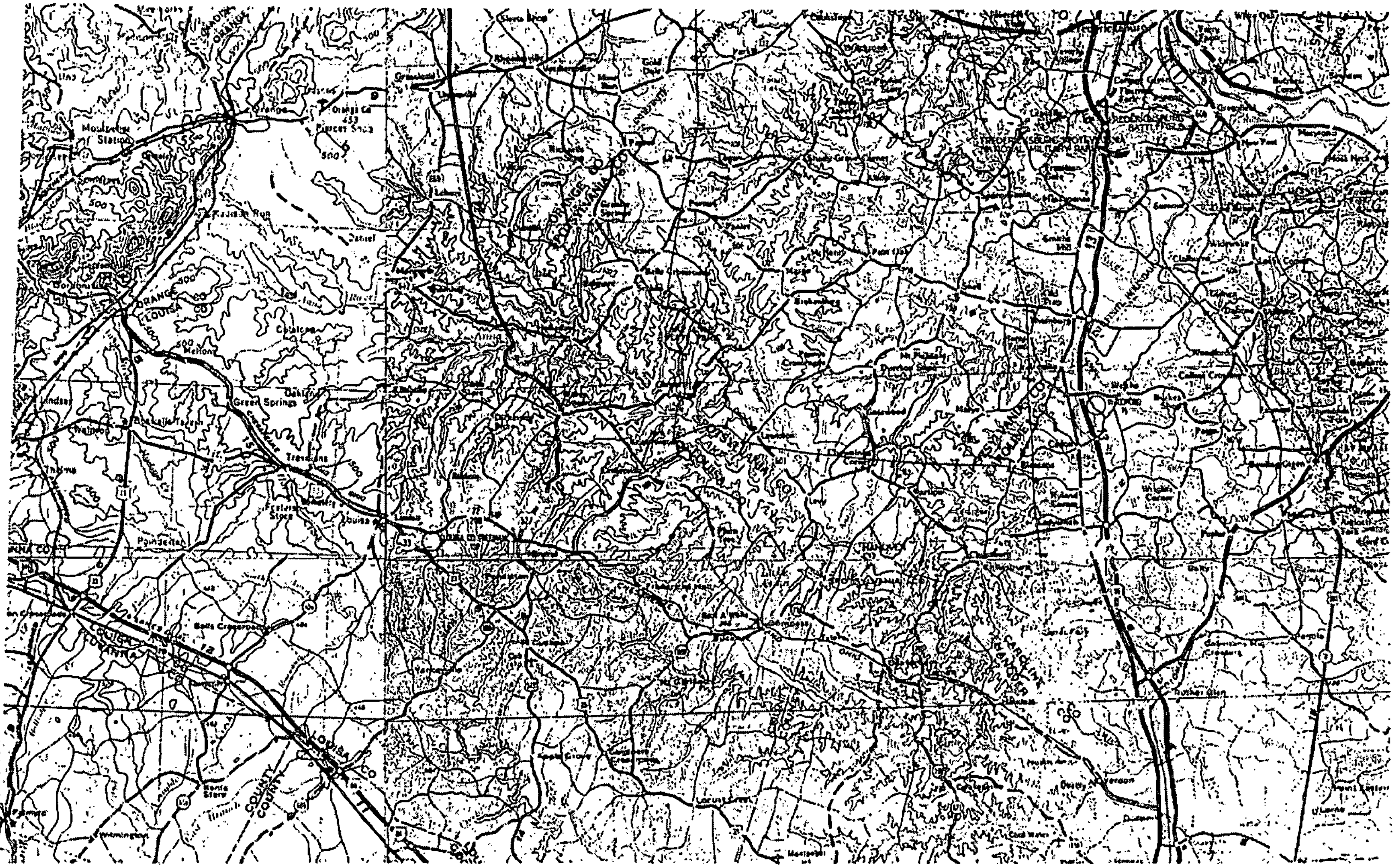


Figure 2-7
REGIONAL TOPOGRAPHY AND CHARACTERISTICS



NI020401

Figure 2-8
ISFSI LOCAL TOPOGRAPHY AND GRADING PLAN

Security-Related Information Figure Withheld Under 10 CFR 2.390.

Security-Related Information
Figure Withheld Under 10 CFR 2.390

Figure 2-9
HYDROLOGIC CHARACTERISTICS OF THE ISFSI SITE

Figure 2-10
SITE GEOLOGICAL MAP

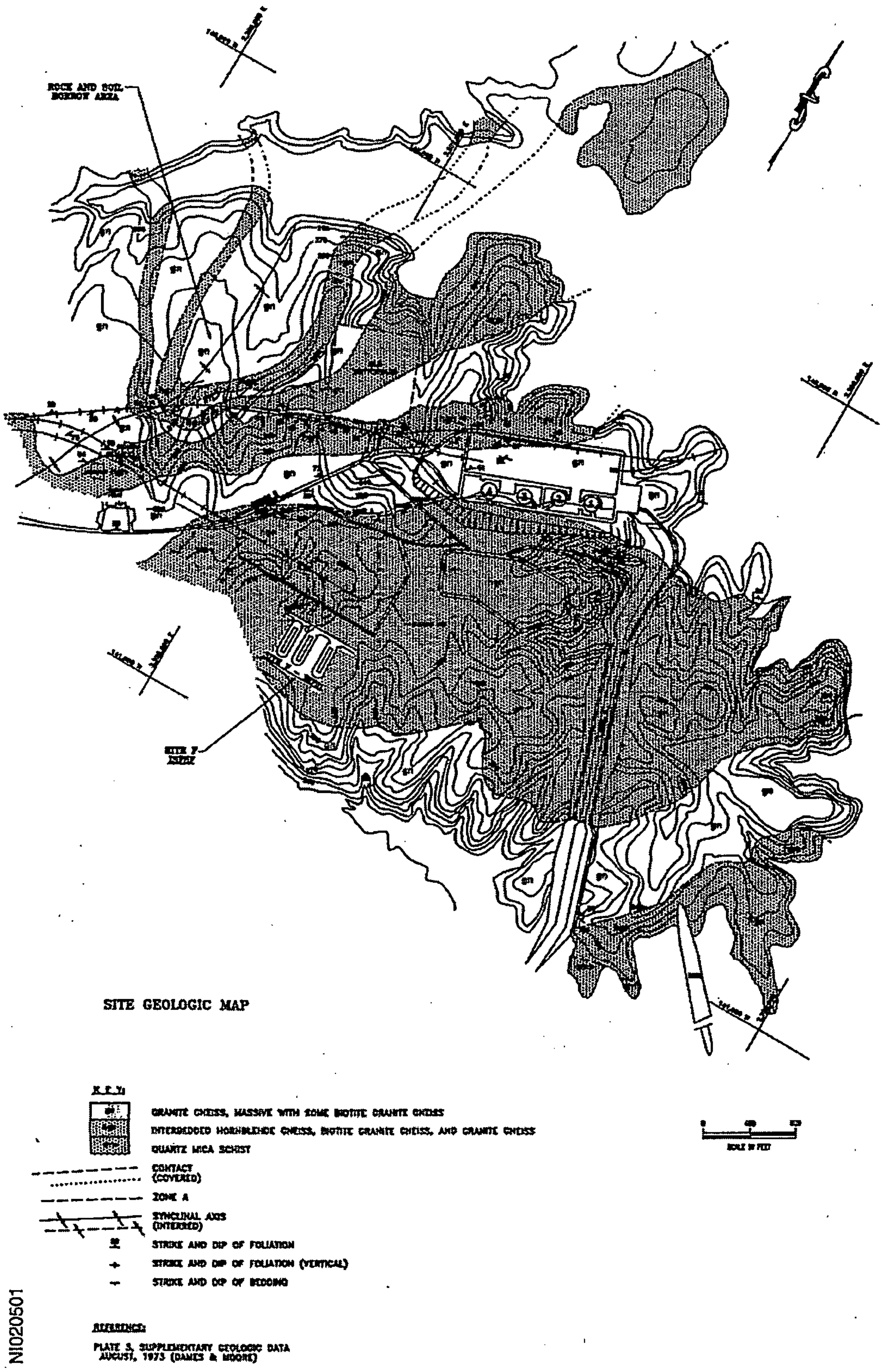


Figure 2-11
ISFSI BORING LOCATIONS

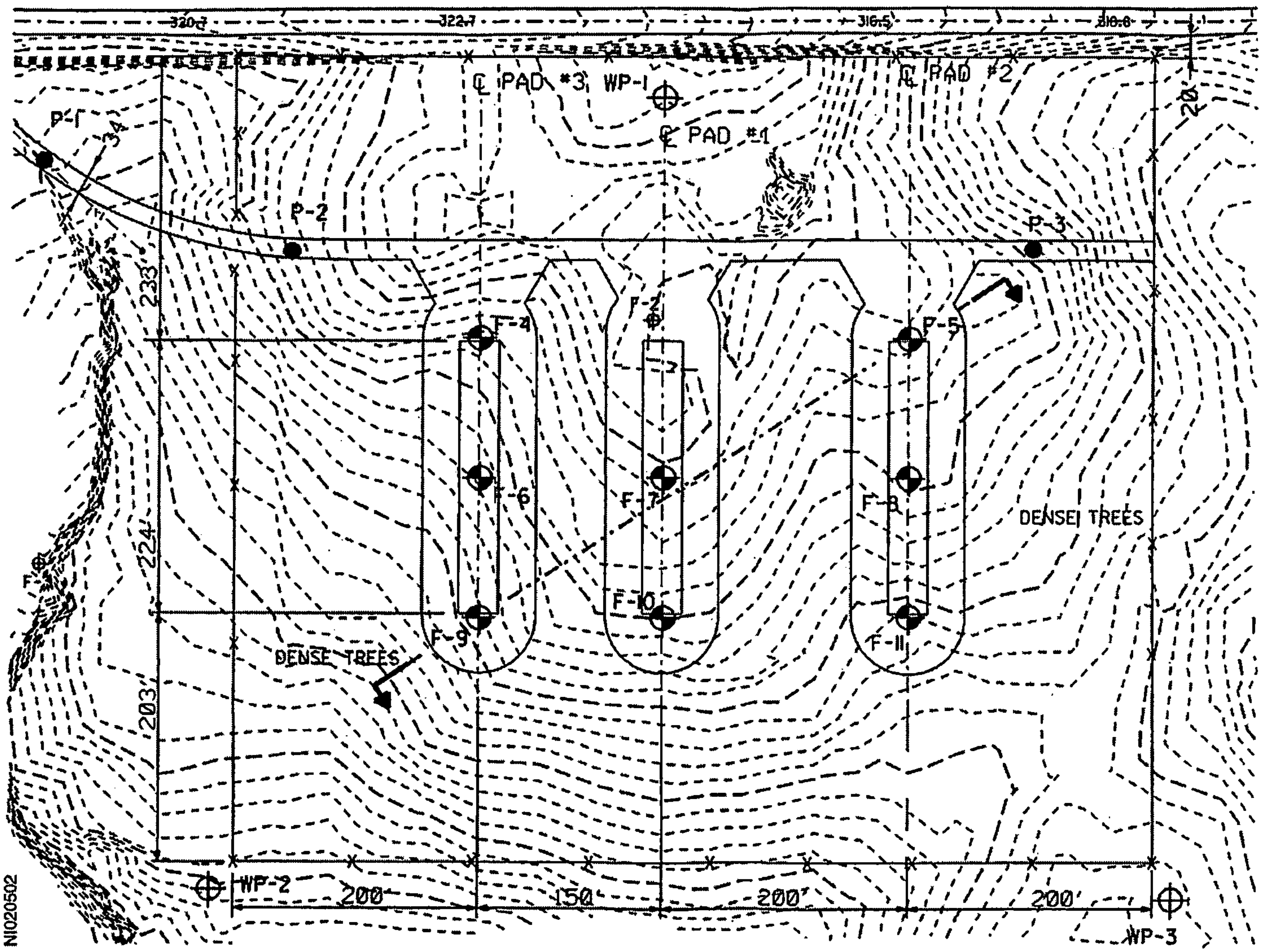
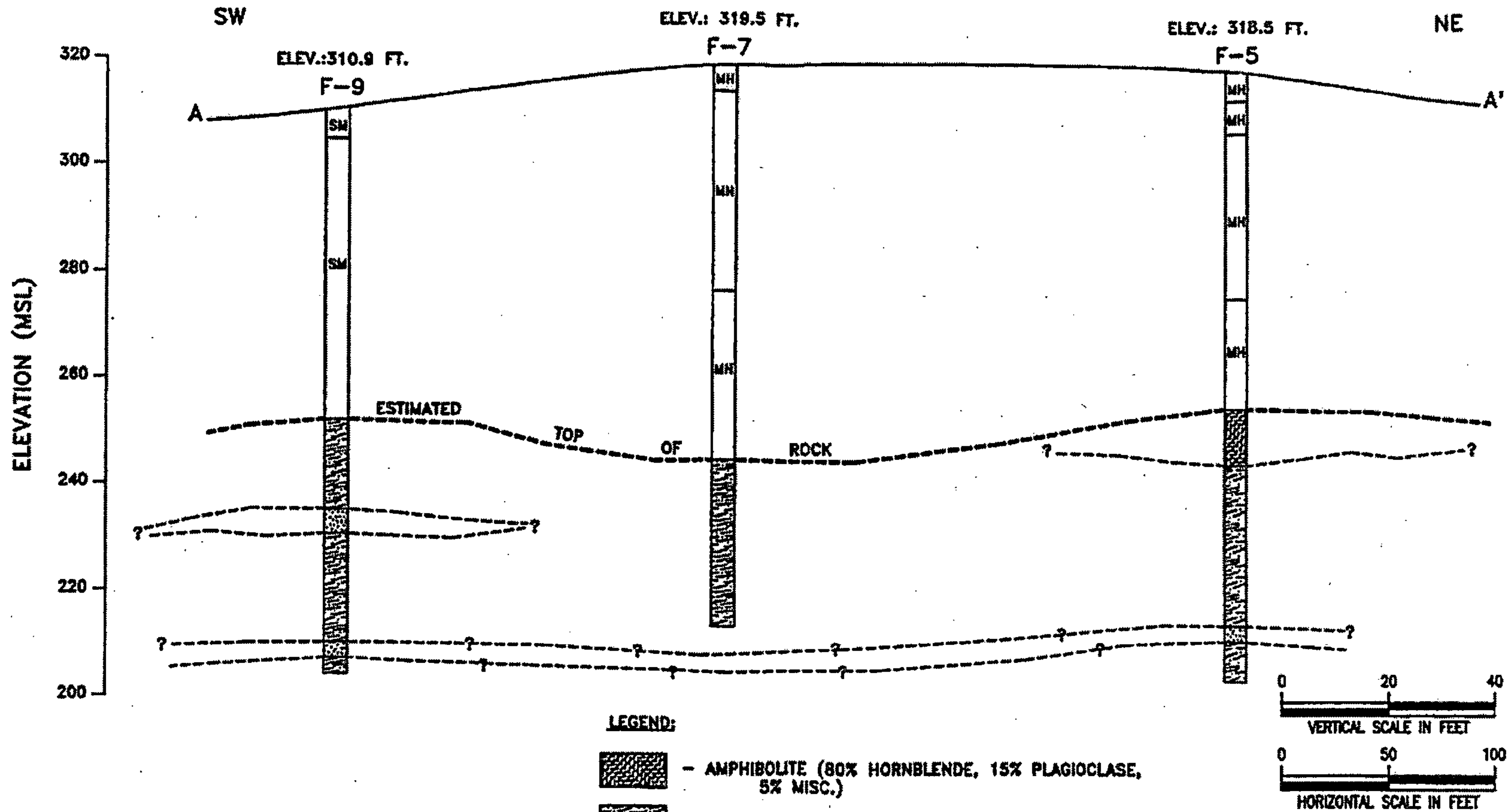


Figure 2-12
ISFSI SUBSURFACE CROSS SECTION



LEGEND:

- AMPHIBOLITE (80% HORNBLENDE, 15% PLAGIOCLASE, 5% MISC.)
- HORNBLENDE BIOTITE GNEISS
- BIOTITE GRANITE GNEISS
- SM – SILTY SAND
- MH – FINE SANDY SILT

NOTES:
1) SEE FOR CROSS SECTION LOCATION.
2) VERTICAL EXAGGERATION = 2.5 TO 1.
3) SEE TEXT FOR DISCUSSION.
4) SEE FOR BORING LOGS (SOILS DESCRIPTION BY VA. POWER)

NI020503

Figure 2-13
REGIONAL GEOLOGIC MAP

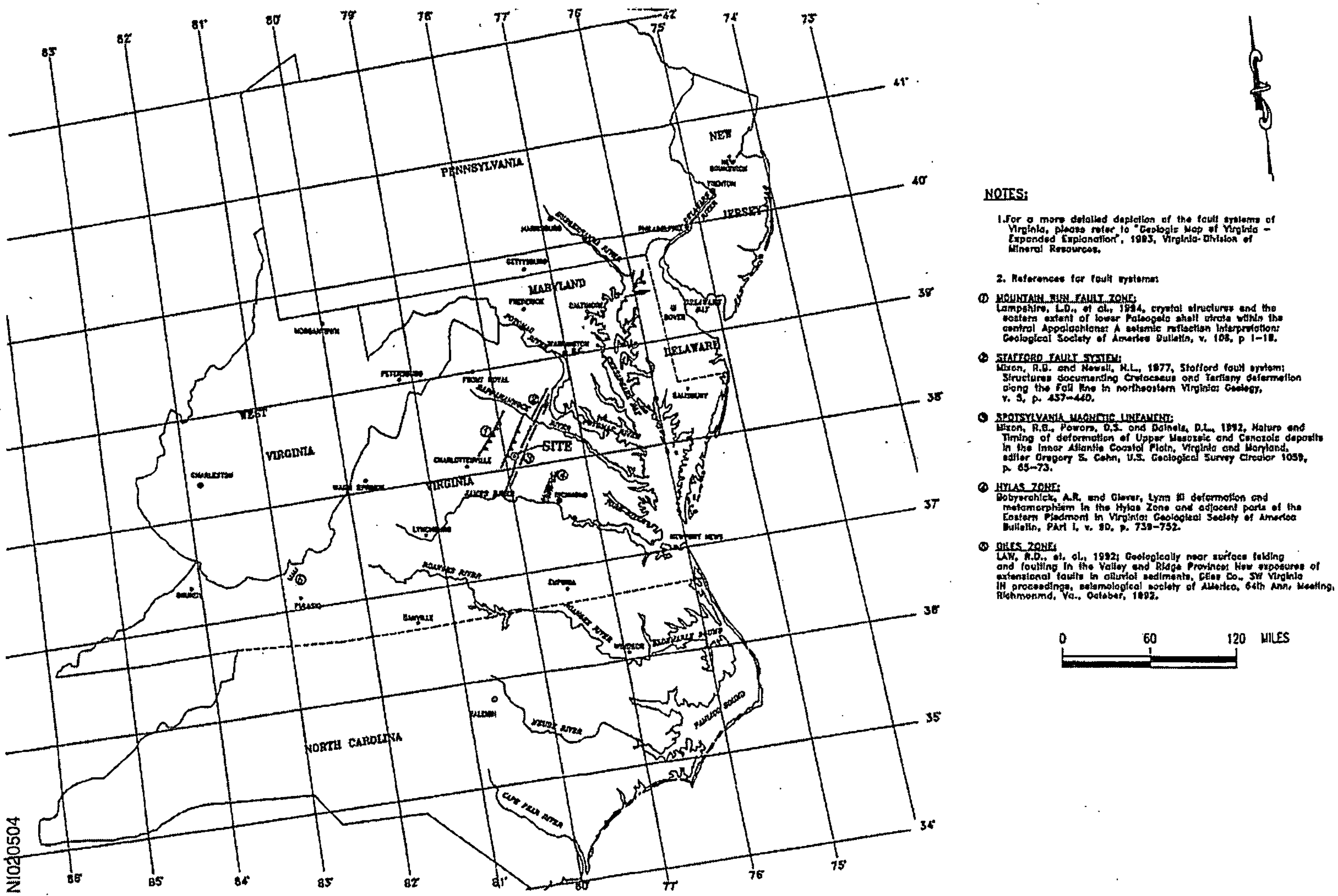
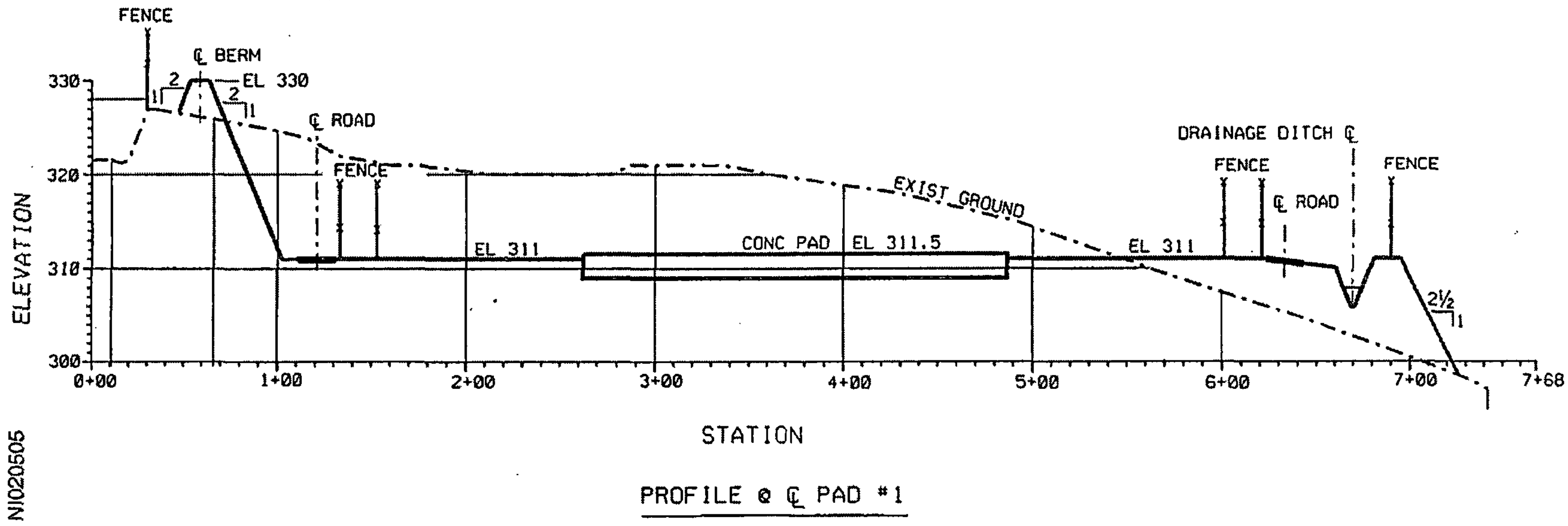
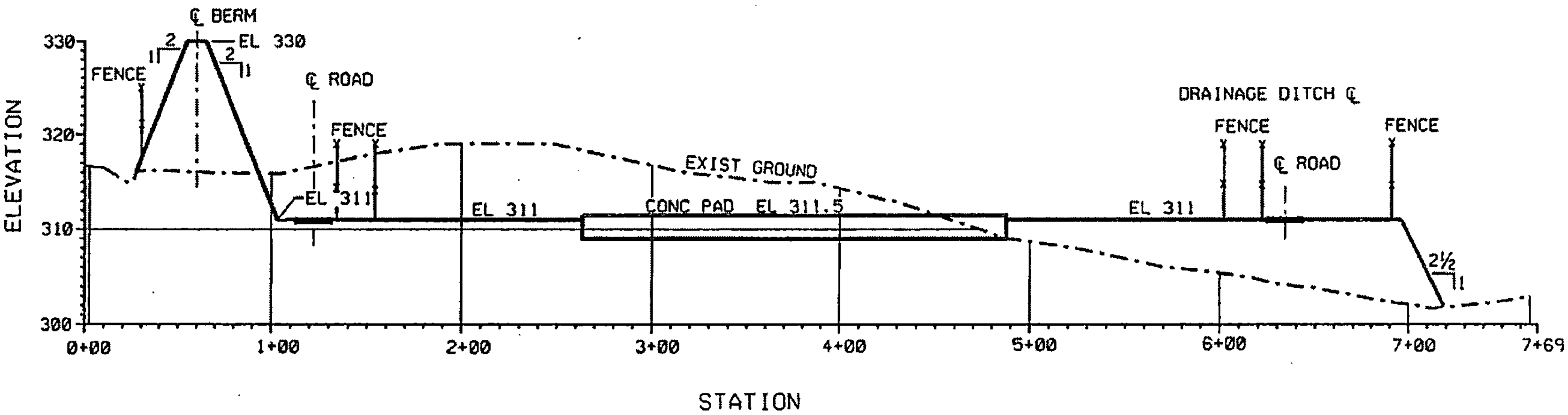


Figure 2-14
PAD #1 SURFACE PROFILE



PROFILE @ ℄ PAD #1

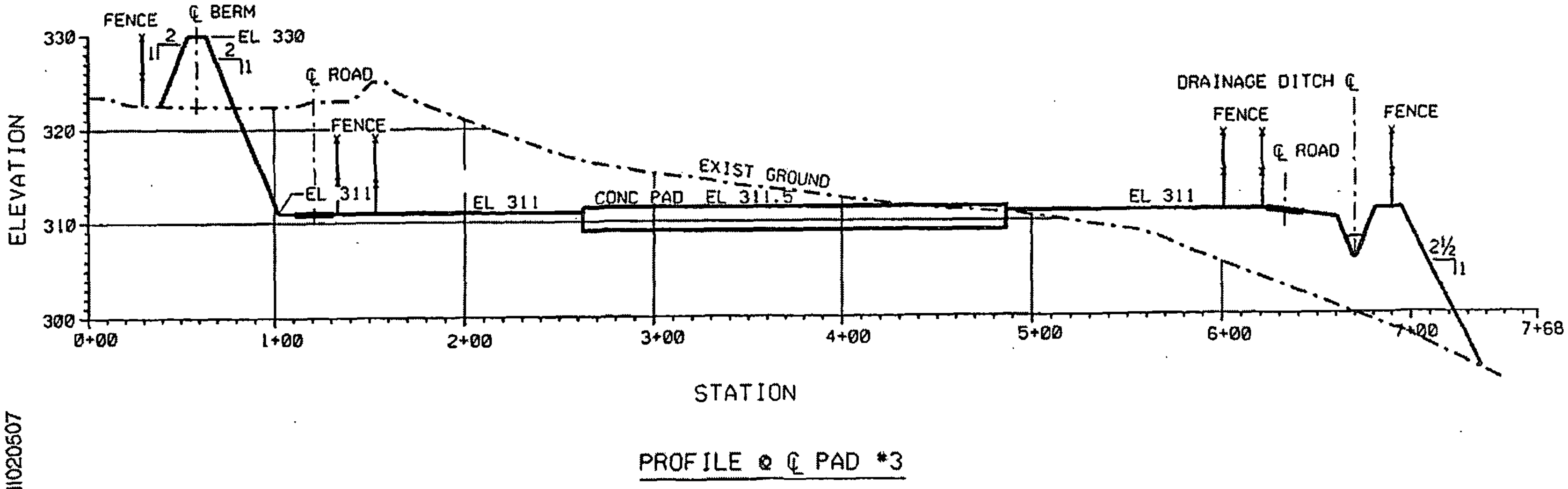
Figure 2-15
PAD #2 SURFACE PROFILE



PROFILE @ ℄ PAD #2

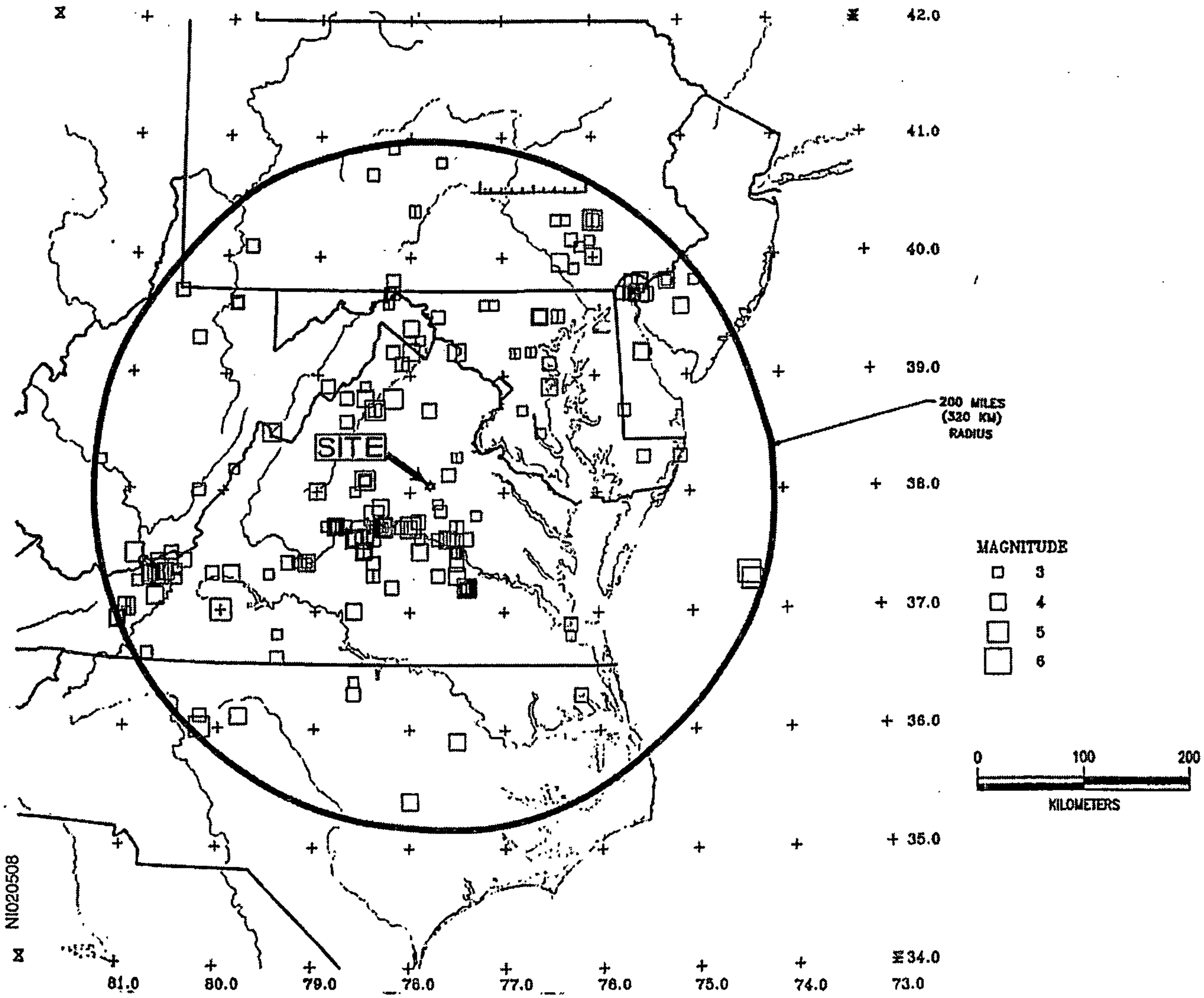
NI020506

Figure 2-16
PAD #3 SURFACE PROFILE



NI020507

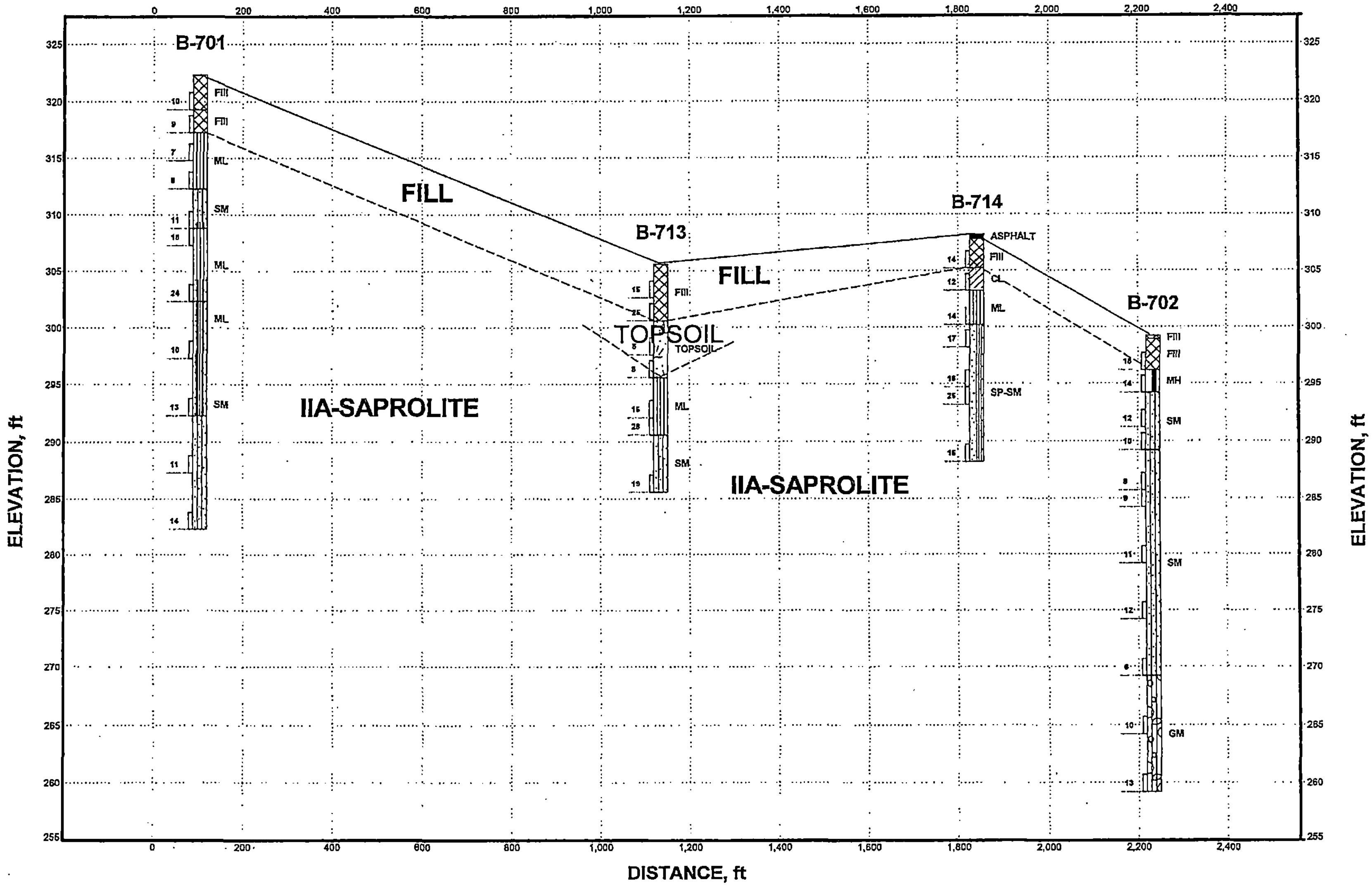
Figure 2-17
EARTHQUAKE LOCATIONS



Security-Related Information
Figure Withheld Under 10 CFR 2.390

Figure 2-18
ALTERNATE TRANSPORT ROUTE BORING LOCATIONS

Figure 2-19
ALTERNATE TRANSPORT ROUTE SUBSURFACE CROSS SECTIONS



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Appendix 2A
Boring Logs

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(1994 BORINGS)

FIELD EXPLORATION PROCEDURES

Disturbed Sampling

Soil test borings were drilled and tested in accordance with ASTM D 1452 and ASTM D 1586 procedures with a CME-55 truck mounted drill rig, by mechanically advancing hollow stem auger flights into the ground. At regular intervals, the plug was removed from the auger head, and soil samples were obtained with a standard 1.4"I.D., 2"O.D., 20" long split tube sampler. The sampler was attached to the end of "A" size drill rods and lowered through the augers to sampling elevation. The sampler was first seated to penetration loose cuttings and disturbed soil, then driven an additional foot with blows of a 140 lb. hammer falling 30". The sampler was then extracted from the soil, the plug reinserted into the auger head, and the auger advanced to the next sampling elevation. The number of blows required to drive the sampler each 6" increment of penetration was recorded and is shown on the boring logs. The number of blows required to drive the sampler the final foot is termed the "penetration resistance". Penetration resistance, when properly evaluated, is an index to soil density, strength, and foundation support capacity.

Undisturbed Sampling

Split tube samples are suitable for visual examination and classification tests but are not sufficiently intact for quantitative laboratory testing. Relatively undisturbed samples were obtained by forcing sections of 3"O.D., 16 gauge, steel tubing into the soil at the desired sampling levels. This sampling procedure is described by ASTM Specification D-1587. Each tube, together with the encased soil, was carefully removed from the ground, made airtight, and transported to the laboratory. Locations and depths of undisturbed samples are shown on the test boring records.

ROCK CORING PROCEDURES

Rock coring procedures are used to evaluate subsurface conditions below the depth of auger refusal. Auger refusal typically reflects the presence of obstructions (e.g., boulders) or the presence of bedrock.

Water is used to drill a diamond studded drill bit through bedrock or obstructions. The drill pipe at the bottom of the boring contains a steel sleeve, or core barrel, that accepts the drill core as the bit is advanced. Typically, the core barrel can accommodate 5 or 10 feet of core. When bedrock is encountered, a run number is designated each time the core barrel is filled with sample and removed from the boring.

The percent of recovery is calculated for every run. Percent recovery is the ratio of the recovered length of core to the length of the core run.

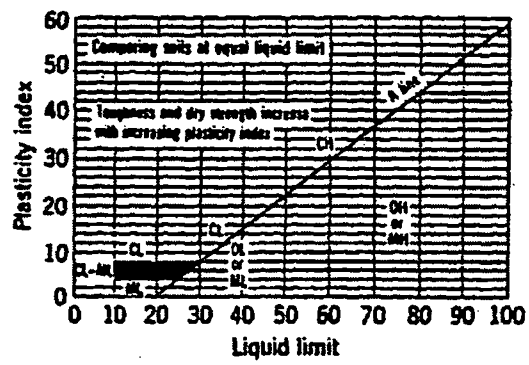
The rock quality designation (RQD) is calculated for each core run when N-sized core sampling procedures are used. N-sized core is approximately 2-inches in diameter. The RQD is the ratio of the cumulative length of core greater than 4-inches long and the length of core run. The RQD is often used to evaluate the engineering properties of bedrock.

KEY TO BORING LOG SOIL CLASSIFICATIONS

Soils Identification

ASTM SOIL CLASSIFICATION IS BASED ON THE DISTRIBUTION OF THE SAND AND GRAVEL SEED PARTICLES, THE PLASTICITY (E.G. ATTERBERG LIMITS) OF THE FINE SAND, SILT AND CLAY FRACTION, AND THE RELATIVE DENSITY/CONSISTENCY AS DETERMINED FROM THE STANDARD PENETRATION TEST N-VALUE.

Soil Type		Particle Size
Boulder		12 in.
Cobble		3 - 12 in.
Gravel	- Coarse	3/4 - 3 in.
	- Fine	#4 - 3/4 in.
Sand	- Coarse	#10 - #4
	- Medium	#40 - #10
	- Fine	#200 - #40
Silt (non-cohesive)		<#200
Clay (cohesive)		<#200



Plasticity chart

NOTE: Particle Size is Designated by U.S. Standard Sieve Sizes.

Relative Density or Consistency

THE STANDARD PENETRATION TEST N-VALUES ARE USED TO EVALUATE THE RELATIVE DENSITY OF COARSE-GRAINED SOILS OR THE CONSISTENCY OF FINE-GRAINED SOILS.

RELATIVE DENSITY		CONSISTENCY	
Term	N-Value	Term	N-Value
Very Loose	0 - 4	Very Soft	0 - 1
Loose	5 - 9	Soft	2 - 4
Medium Dense	10 - 30	Firm	5 - 8
Dense	31 - 50	Stiff	9 - 16
Very Dense	Over 50	Very Stiff	17 - 30
		Hard	31 - 50
		Very Hard	Over 50

BORING LOG

FROEHLING & ROBERTSON, INC.
SINCE 1881
FULL SERVICE LABORATORIES • ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date: April 19, 1994

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-2 (1 of 2) Total Depth 70.0' Elev: 319.9'± Location:

Type of Boring: Hollow Stem Auger Started: 4/5/94 Completed: 4/5/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Stiff to Very Stiff, Reddish Brown Clayey SILT, Trace Fine Sand and Mica - Moist (ML)	4/6/7	0.0 – 1.5		Groundwater was Encountered at 24.0' During Drilling
			6/9/11	3.0 – 4.5		Groundwater was Observed at 20.0' Upon Removal of Auger
			7/8/10	7.0 – 8.5		Cave-in Depth at 6.5' on 4/7/94
			4/8/10	9.0 – 10.5		Groundwater was not Observed on 4/7/94
308.9	11.0	Medium Dense, Pinkish Brown Silty Fine SAND - Moist (SM) (Relict Rock Structure Apparent)	3/6/8	14.0 – 15.5		
			6/8/10	19.0 – 20.5		
295.9	24.0	Medium Dense, Light Brown Silty Fine SAND - Moist (Micaceous) (SM)	6/8/10	24.0 – 25.5		
			6/10/12	29.0 – 30.5		
289.4	30.5	Medium Dense to Very Dense, Brown Silty Micaceous Fine SAND - Moist (SM) (Relict Rock Structure Apparent)	3/6/8	34.0 – 35.5		
			5/7/10	39.0		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

BORING LOG

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FULL SERVICE LABORATORIES • ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date: April 19, 1994

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-2 (2 of 2) Total Depth 70.0' Elev: 319.9'± Location:

Type of Boring: Hollow Stem Auger Started: 4/5/94 Completed: 4/5/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Medium Dense to Very Dense, Brown Silty Micaceous Fine SAND - Moist (SM)		40.5		
		(Relict Rock Structure Apparent)	3/7/11	44.0 45.5		
			10/18/25	49.0 50.5		
			8/18/36	54.5 56.0		
			10/32/46	59.0 60.5		
254.9	65.0			65.0		*50/0.3' No Sample Recovery
		Driller Reported "Gray Schist"		65.3	0%/0%	Started Coring Rock at 65.3' with NX Dia. Bit No Sample Recovery
249.9	70.0			70.0		
		Boring Terminated at 70.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

BORING LOG

FROEHLING & ROBERTSON, INC.
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FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-4 (1 of 2) Total Depth 59.1' Elev: 316.6' Location:

Type of Boring: Hollow Stem Auger Started: 6/27/94 Completed: 6/27/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
316.0	0.6	Driller Reported "Surficial Organic Soil"	8/11/14	0.0		Groundwater was Encountered at 25.0' During Drilling
		Very Stiff to Stiff, Red Clayey SILT with Fine Sand, Trace Mica and Organics (0.6'-3.0') - Moist (MH)		1.5		
			9/11/18	3.0		
			7/8/11	4.5		Groundwater was Observed at 20.5' Approximately 24 hrs. after Drilling
				6.0		
309.6	7.0		7/8/11	7.5		
		Medium Dense to Very Dense, Brown to Gray Micaceous Silty Fine to Medium SAND - Moist (SM)		9.0		Groundwater was observed at 20.5' on 7/12/94
		(Relict Rock Structure Present)	7/7/8	10.5		
				14.0		
			7/9/12	15.5		
				19.0		
			6/7/9	20.5		
				24.0		
			6/8/15	25.5		
				29.0		
			15/*	29.9		*50/0.4'
282.6	34.0			34.0		
		Very Dense, Light Brown Silty Fine SAND, Trace Mica - Moist (SM)	*	34.4		*50/0.4'
		(Relict Rock Structure Present)		39.0		*50/0.4'
			*	39.4		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

BORING LOG

SINCE 1881 **FROEHLING & ROBERTSON, INC.**
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-4 (2 of 2) Total Depth 59.1' Elev: 316.6' Location:

Type of Boring: Hollow Stem Auger Started: 6/27/94 Completed: 6/27/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Very Dense, Light Brown Silty Fine SAND, Trace Mica - Moist (SM) (Relict Rock Structure Present)		44.0 44.3 49.0		*50/0.3'- No Sample Recovery *50/0.1 - No Sample Recovery
267.5	49.1	Extremely Weathered Gray Biotite Granite GNEISS - Foliation Dips Approximately 35 Degrees from Horizontal. Up to Four Fractures Per Foot of Core. Fractures Highly Weathered and Iron Stained.		49.1	21.6%/0%	Started Coring Rock at 49.1' with "NX" Dia. Bit
262.5	54.1	Moderately Weathered Gray Biotite Granite GNEISS - Foliation Dips Approximately 35 Degrees from Horizontal. Up to One Fracture Per Foot		54.1	78.3%/40%	
257.5	59.1	Boring Terminated at 59.1'		59.1		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

BORING LOG

FROEHLING & ROBERTSON, INC.
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"OVER ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No.: V60-073 Date: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-5 (1 of 3) Total Depth 114.5' Elev: 318.5' Location:

Type of Boring: Hollow Stem Auger Started: 6/30/94 Completed: 7/5/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
318.0	0.5	Driller Reported "Surficial Organic Soil"	6/11/14	0.0		Groundwater was Encountered at 24.0' During Drilling
		Very Stiff, Red Clayey SILT, Trace to Some Fine Sand - Moist (MH)	11/14/11	1.5		Groundwater was Observed at 27.0' on 7/12/94
			6/8/10	3.0		Cave-in Depth at 16.0'
				4.5		
			8/10/11	6.0		
				7.5		
310.5	8.0	Stiff, Red Clayey SILT with Mica and Fine Sand - Moist (MH)	3/4/5	9.0		
				10.5		
304.5	14.0	Stiff to Hard, Brown Clayey Micaceous SILT, Trace to Some Fine Sand - Moist (MH) (Relict Rock Structure Present)	5/6/7	14.0		
				15.5		
			3/4/5	19.0		
				20.5		
			4/5/7	24.0		
				25.5		
			5/6/8	29.0		
				30.5		
			5/12/14	34.0		
				35.5		
			8/14/17	39.0		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

BORING LOG

FROEHLING & ROBERTSON, INC.
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SINCE 1881

Report No: V60-073 Date:

Client: Virginia Power			
Project: Phase 2 - ISFSI North Anna Power Station			
Boring No: F-5 (2 of 3)	Total Depth 114.5'	Elev: 318.5'	Location:
Type of Boring: Hollow Stem Auger	Started: 6/30/94	Completed: 7/5/94	Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Stiff to Hard, Brown Clayey Micaceous SILT, Trace to Some Fine Sand - Moist (MH) (Relict Rock Structure Present)		40.5		
274.5	44.0	Very Stiff to Hard, Grayish-Green Micaceous SILT, Trace Fine Sand - Moist (MH) (Relict Rock Structure Present)	5/11/16	44.0 / 45.5		
			8/20/24	49.0 / 50.5		
			7/12/15	54.0 / 55.5		
			10/16/24	59.0 / 60.5		
254.5	64.0	SEE NOTE (1)		64.0 / 64.3		*50/0.3'
254.0	64.5	Extremely Weathered AMPHIBOLITE		64.5	0%/0%	Started Coring Rock at 64.5' with "NX" Dia. Bit
249.0	69.5	Extremely Weathered Hornblende GNEISS		69.5	13.3%/0%	NOTE (1) Very Dense, Gray Silty Medium SAND with Rock Fragments - Moist (SM) "Weathered Rock"
				74.5	3.3%/0%	
				79.5		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments.

BORING LOG

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SINCE 1881

Report No.: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-5 (3 of 3) Total Depth: 114.5' Elev: 318.5' Location:

Type of Boring: Hollow Stem Auger Started: 6/30/94 Completed: 7/5/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Extremely Weathered Hornblende GNEISS			0%/0%	Core is Saprolitic with Parent Structure Still Visible
				84.5	6.6%/0%	
				89.5	0%/0%	
				94.5	0%/0%	
				99.5	0%/0%	
				104.5	50%/0%	
209.0	109.5	Moderately Weathered Biotite Hornblende GNEISS - Interlayered with Quartz Biotite Gneiss		109.5	80%/0%	
204.0	114.5			114.5		
		Boring Terminated at 114.5'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

BORING LOG

FROEHLING & ROBERTSON, INC.
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SINCE 1881

Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-5A (1 of 1) Total Depth 20.0' Elev: Location:

Type of Boring: Hollow Stem Auger Started: 6/30/94 Completed: 7/5/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
		AUGER PROBE TO OBTAIN SHELBY TUBE SAMPLE				
			UD-1	18.0		"UD" denotes Undisturbed Thin-Walled Shelby Tube Sample
	20.0			20.0		
		Boring Terminated at 20.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

BORING LOG

FROEHLING & ROBERTSON, INC.
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"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-6 (1 of 2) Total Depth 59.0' Elev: 316.0' Location:

Type of Boring: Hollow Stem Auger Started: 6/28/94 Completed: 6/28/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
315.5	0.5	Driller Reported "Surficial Organic Soil"	6/8/11	0.0 / 1.5		Groundwater was Encountered at 22.0' During Drilling
		Very Stiff, Red Clayey SILT with Fine Sand, Trace Organics (0.5'-3.0') and Mica - Moist (MH)	8/12/14	1.5 / 3.0		Groundwater was Observed at 21.5' Approximately 24 hrs. After Drilling
			8/11/15	3.0 / 4.5		Groundwater was Observed at 21.5' on 7/12/94
			9/12/14	6.0 / 7.5		
309.0	7.0	Very Stiff, Reddish Brown Fine Sandy SILT with Clay, Some Mica - Moist (MH)	6/9/10	9.0 / 10.5		
304.0	12.0	Stiff, Brown to Gray Clayey SILT, Trace Fine Sand and Mica - Moist (MH)	7/7/7	14.0 / 15.5		
			5/6/7	19.0 / 20.5		
			5/6/7	24.0 / 25.5		
287.0	29.0	Medium Dense to Very Dense, Gray Micaceous Silty Fine to Medium SAND - Moist (SM) (Relict Rock Structure Present)	6/8/9	29.0 / 30.5		
			9/12/11	34.0 / 35.5		
			20/30/*	39.0		*50/0.3'

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

BORING LOG

FROEHLING & ROBERTSON, INC.
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"OVER ONE HUNDRED YEARS OF SERVICE"
1881

Report No: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No: F-6 (2 of 2) Total Depth 59.0' Elev: 316.0' Location:

Type of Boring: Hollow Stem Auger Started: 6/28/94 Completed: 6/28/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Medium Dense to Very Dense, Gray Micaceous Silty Fine to Medium SAND - Moist (SM) (Relict Rock Structure Present)		40.3		
272.0	44.0	Heavily Fractured and Extremely Weathered Light Gray Biotite Granite GNEISS - Foliation Dips Approximately 45 Degrees from Horizontal. Up to Three Fractures Per Foot of Rock Core		44.0		Started Coring Rock at 44.0' with "NX" Dia. Bit
					0%/0%	
				49.0		
					0%/0%	
				54.0		
					70%/18.3%	
257.0	59.0			59.0		
		Boring Terminated at 59.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

BORING LOG

FROEHLING & ROBERTSON, INC. SINCE 1881
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-7 (1 of 3) Total Depth 105.0' Elev. 319.5' Location:

Type of Boring: Hollow Stem Auger Started: 7/12/94 Completed: 7/12/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
319.0	0.5	Driller Reported "Surficial Organic Soil"	3/7/12	0.0		No Groundwater was Encountered During Drilling or Upon Removal of Auger
		Stiff to Hard, Reddish Brown Clayey SILT, Trace Fine Sand - Moist (MH)		1.5		
			18/20/21	3.0		
			12/18/18	4.5		
				6.0		
			8/11/16	7.5		
				9.0		
			3/7/8	10.5		
307.5	12.0	Stiff, Reddish Brown and Black Clayey Micaceous SILT and Fine SAND to Clayey Micaceous SILT with Some Fine Sand - Moist (MH) (Relict Rock Structure Present)		14.0		
			4/5/5	15.5		
				19.0		
			3/5/5	20.5		
				24.0		
			3/5/5	25.5		
				29.0		
			5/7/8	30.5		
				34.0		
			3/7/8	35.5		
				39.0		
			4/5/9			

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

BORING LOG

FROEHLING & ROBERTSON, INC.
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FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No: V60-073 Date:

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No: F-7 (2 of 3) Total Depth 105.0' Elev. 319.5' Location:

Type of Boring: Hollow Stem Auger Started: 7/12/94 Completed: 7/12/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
				40.5		
		SEE NOTE (1)				NOTE (1) Stiff, Reddish Brown and Black Clayey Micaceous SILT and Fine SAND to Clayey Micaceous SILT with Some Fine Sand - Moist (MH) (Relict Rock Structure Present)
275.5	44.0			44.0		
		Very Stiff to Hard, Brown and Gray SILT, Trace Fine Sand, Some Mica - Moist (MH) (Relict Rock Structure Present)	4/8/9	45.5		
				49.0		
			3/8/14	50.5		
				54.0		
			6/14/22	55.5		
				59.0		
			12/18/20	60.5		
255.5	64.0			64.0		
		Very Dense, Brown Micaceous Silty Fine SAND - Moist (SM) (Relict Rock Structure Present)	9/22/32	65.5		
				69.0		
			19/31/40	70.5		
				74.0		*50/0.3'
244.5	75.0		38/*	74.8		
		Extremely Weathered Hornblende GNEISS		75.0	0%/0%	Started Coring Rock at 75.0' with "NX" Dia. Bit
				80.0		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

BORING LOG

FROEHLING & ROBERTSON, INC. SINCE 1881
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-7 (3 of 3) Total Depth: 105.0' Elev.: 319.5' Location:

Type of Boring: Hollow Stem Auger Started: 7/12/94 Completed: 7/12/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Extremely Weathered Hornblende GNEISS			0%/0%	Core Recovery is Saprolitic - Almost Soil-like
				85.0	0%/0%	
				90.0	3.3%/0%	
				95.0	0%/0%	
				100.0	63%/0%	
214.5	105.0	Some Joints Visible When They Cross Foliation		105.0		
		Boring Terminated at 105.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

BORING LOG

SINCE 1881 **FROEHLING & ROBERTSON, INC.**
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-7A (1 of 1) Total Depth 22.0' Elev: Location:

Type of Boring: Hollow Stem Auger Started: 7/12/94 Completed: 7/12/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
		AUGER PROBE TO OBTAIN SHELBY TUBE SAMPLES		4.0		
			UD-1	6.0		
						"UD" Denotes Undisturbed Thin Walled Shelby Tube Samples
				16.0		
			UD-2	18.0		
			UD-3	20.0		
	22.0		UD-4	22.0		
		Boring Terminated at 22.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No.: V60-073 Date: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-8 (1 of 2) Total Depth 69.2' Elev: 317.9' Location:

Type of Boring: Hollow Stem Auger Started: 7/6/94 Completed: 7/6/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	REMARKS
		Medium Dense, Brown Silty Clayey SAND - Moist (SC)	5/8/10	0.0	
316.4	1.5			1.5	Groundwater was Encountered at 42.0' During Drilling
			10/15/18	3.0	
		Hard to Very Stiff Brown and Reddish Brown Silty CLAY, Trace Fine Sand - Moist (CL)	8/12/17	4.5	Groundwater was Observed at 40.0' Upon Removal of Auger
				6.0	
			11/16/20	7.5	
309.9	8.0	Very Stiff, Brown Clayey SILT, Trace Fine Sand - Moist (MH)		9.0	Groundwater was Observed at 26.5' on 7/12/94
			5/7/10	10.5	
				14.0	
			6/8/10	15.5	
298.9	19.0	Stiff to Very Hard, Gray and Green Fine Sandy SILT - Moist (ML) (Relict Rock Structure Present)		19.0	
			6/11/14	20.5	
				24.0	
			8/10/14	25.5	
				29.0	
			6/7/9	30.5	
				34.0	
			12/*	34.9	*50/0.4'
				39.0	
			*	39.5	*50/0.5'

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

BORING LOG

SINCE 1881 F&R **FROEHLING & ROBERTSON, INC.**
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date:

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-8 (2 of 2) Total Depth 69.2' Elev: 317.9' Location:

Type of Boring: Hollow Stem Auger Started: 7/6/94 Completed: 7/6/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Stiff to Very Hard, Gray and Green Fine Sandy SILT - Moist (ML)				
		(Relict Rock Structure Present)		44.0 44.4		*50/0.4'
				49.0 49.3		*50/0.3'
				54.0 54.3		*50/0.3'
				59.0 59.4		*50/0.4'
253.7	64.2			64.0 64.2		*50/0.2'
		Heavily Fractured and Weathered PEGMATITE, Less Severely Weathered from 67.0'- 68.0'			80%/0%	Started Coring Rock at 64.2' with an "NX" Dia. Bit
248.7	69.2			69.2		
		Boring Terminated at 69.2'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

BORING LOG

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Report No.: V60-073 Date: August 11, 1994

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-9 (1 of 3) Total Depth 105.0' Elev: 310.9' Location:

Type of Boring: Hollow Stem Auger Started: 6/28/94 Completed: 6/28/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
310.3	0.6	Driller Reported "Surficial Organic Soil"	6/8/9	0.0		Groundwater was Encountered at 20.0' During Drilling
		Medium Dense, Red Clayey Silty Fine SAND - Moist (SM)	8/11/14	1.5		
			8/11/12	3.0		
				4.5		
				6.0		
304.4	6.5	Loose to Very Dense, Brown to Gray Micaceous Silty Fine SAND - Moist (SM)	9/11/13	7.5		
				9.0		
		(Relict Rock Structure Present)	6/8/8	10.5		
				14.0		
			5/6/8	15.5		
				19.0		
			3/4/8	20.5		
				24.0		
			3/3/4	25.5		
				29.0		
			5/6/8	30.5		
				34.0		
			7/9/12	35.5		
				39.0		
			8/12/14			

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

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SINCE 1881

Report No.: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-9 (2 of 3) Total Depth 105.0' Elev. 310.9' Location:

Type of Boring: Hollow Stem Auger Started: 6/28/94 Completed: 6/28/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Loose to Very Dense, Brown to Gray Micaceous Silty Fine SAND - Moist (SM)		40.5		
				44.0		
		(Relict Rock Structure Present)	10/22/30	45.5		
				49.0		
			20/22/34	50.5		
				54.0		
			*	54.4		*50/0.4' - No Sample Recovery
				59.0		
251.8	59.1		*	59.1		*50/0.1' - No Sample Recovery
		Hornblende GNEISS (Several Small Pieces of Hornblende Gneiss Obtained)			0%/0%	Started Coring Rock at 59.1' with an "NX" Dia. Bit
				64.1		
					0%/0%	
				69.1		
					12.5%/0%	
236.8	74.1			74.1		
		Biotite GNEISS with Some Hornblende GNEISS Interlayers. Foliation Dips Approximately 45 to 50 Degrees from Horizontal Up to Three Fractures Per Foot of Core		75.0		
					47%/7.5%	
230.9	80.0			80.0		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three [illegible]

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Report No.: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-9 (3 of 3) Total Depth 105.0' Elev. 310.9' Location:

Type of Boring: Hollow Stem Auger Started: 6/28/94 Completed: 6/28/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Hornblende GNEISS			20%/6.6%	
				85.0		
					0%/0%	
				90.0		
					13%/0%	
216.9	94.0					
215.9	95.0	Quartz Granite GNEISS		95.0		
		Biotite Granite GNEISS, Light Gray, Foliation Dips Approximately 45 to 50 Degrees from Horizontal			31%/6.6%	
				100.0		
					60%/17.5%	
206.9	104.0					
205.9	105.0	Hornblende GNEISS		105.0		
		Boring Terminated at 105.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

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Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-9A (1 of 1) Total Depth 6.0' Elev: Location:

Type of Boring: Hollow Stem Auger Started: 6/28/94 Completed: 6/28/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
	6.0	AUGER PROBE TO OBTAIN SHELBY TUBE SAMPLE	UD-1	4.0 6.0		"UD" Denotes Undisturbed Thin Walled Shelby Tube Sample
		Boring Terminated at 6.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

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Report No.: V60-073 Date: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-10 (1 of 2) Total Depth 74.0' Elev. 315.1' Location:

Type of Boring: Hollow Stem Auger Started: 7/11/94 Completed: 7/11/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
314.6	0.5	Driller Reported "Surficial Organic Soil"	8/9/14	0.0		Groundwater was Encountered at 36.0' During Drilling
		Medium Dense, Brown Silty Clayey SAND - Moist (SC)	13/14/16	1.5		
			10/14/14	3.0		
				4.5		
			11/12/15	6.0		
				7.5		
			8/10/10	9.0		
				10.5		
303.1	12.0	Medium Dense to Very Dense, Brown Silty Fine SAND to Fine SAND with Some Silt - Moist (SM) (Relict Rock Structure Present)	10/12/12	14.0		
				15.5		
			12/16/16	19.0		
				20.5		
			9/10/12	24.0		
				25.5		
			9/20/28	29.0		
				30.5		
			14/30/31	34.0		No Sample Recovery
				35.5		
			12/30/50	39.0		No Sample Recovery

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments.
The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

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Report No.: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-10 (2 of 2) Total Depth 74.0' Elev: 315.1' Location:

Type of Boring: Hollow Stem Auger Started: 7/11/94 Completed: 7/11/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Medium Dense to Very Dense, Brown Silty Fine SAND to Fine SAND with Some Silt - Moist (SM) (Relict Rock Structure Present)		40.5		
			6/10/16	44.0 / 45.5		
				49.0 / 49.4		*50/0.4'
				54.0 / 54.4		*50/0.4'
				59.0 / 59.3		*50/0.3'
				64.0 / 64.2		*50/0.2' - No Sample Recovery
						*50/0.0' - No Sample Recovery
246.1	69.0	Coarse PEGMATITE - Near Horizontal Fractures - Iron Stained		69.0	95%/35.8%	Started Coring Rock at 69.0' with an "NX" Dia. Bit
241.1	74.0			74.0		
		Boring Terminated at 74.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

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Report No.: V60-073 Date: August 11, 1994

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-11 (1 of 2) Total Depth 69.0' Elev: 308.8' Location:

Type of Boring: Hollow Stem Auger Started: 7/6/94 Completed: 7/6/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Hard to Very Hard, Brown Clayey SILT, Trace Fine Sand - Moist (MH)	8/19/24	0.0		Groundwater was Encountered at 26.0' During Drilling
			29/30/32	1.5		
				3.0		
			12/18/23	4.5		Groundwater was Observed at 19.0' on 7/12/94
				6.0		
			11/14/18	7.5		
				9.0		
			10/14/24	10.5		
				14.0		
293.8	15.0		34/*	14.8		*50/0.3'
		Hard, Gray and Green Micaceous SILT, Trace Fine Sand - Moist (ML) (Relict Rock Structure Present)		19.0		
			11/18/21	20.5		
284.8	24.0			24.0		NOTE (1) Mafic Zone from 39 to 40 ft. Heavily Weathered PEGMATITE
		Very Dense, Brown Micaceous Silty Fine SAND - Moist (SM) (Relict Rock Structure Present)	12/20/41	25.5		
279.8	29.0			29.0		
		Very Dense, Gray and Green Silty Fine SAND, Trace Clay - Moist (SM) (Relict Rock Structure Present)	*	29.4		*50/0.4'
				34.0		*50/0.3'- No Sample Recovery
			*	34.3		From 39.0 - 39.3' - 50/0.3' No Sample Recovery Started Coring Rock at 39.0 with an "NX" Dia. Bit
269.8	39.0	SEE NOTE (1)		39.0		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three

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Report No.: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-11 (2 of 2) Total Depth 69.0' Elev: 308.8' Location:

Type of Boring: Hollow Stem Auger Started: 7/6/94 Completed: 7/6/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Mafic Zone from 39 to 40 ft.			10%/0%	
		Heavily Weathered PEGMATITE		44.0		
					13.3%/0%	
259.8	49.0			49.0		
		Medium Weathered Hornblende GNEISS with Predominantly Vertical Fractures. Fractures are Infilled with Weathered Zeolites or Orthoclase			23%/0%	
				54.0		
					70%/0%	
				59.0		
					58%/28%	
				64.0		
					70%/22.5%	
239.8	69.0			69.0		
		Boring Terminated at 69.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

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Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-1 (1 of 1) Total Depth 5.0' Elev: 311.3' Location:

Type of Boring: Hollow Stem Auger Started: 6/30/94 Completed: 6/30/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
309.8	1.5	Loose, Dark Brown Clayey Fine SAND, Trace Micaceous Silt and Organics - Moist (SC)	2/3/4	0.0 1.5		No Groundwater was Encountered During Drilling or Upon Removal of Auger
307.8	3.5	Firm, Brown and Gray Silty CLAY, Trace Sand and Mica - Moist (CH)	2/3/4	3.0 3.5		
306.3	5.0	Stiff, Gray Fine Sandy Micaceous SILT with Clay - Moist (MH)	4/6/7	5.0		Cave-in Depth at 4.0'
		Boring Terminated at 5.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

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Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-2 (1 of 1) Total Depth 5.0' Elev: 317.0' Location:

Type of Boring: Hollow Stem Auger Started: 6/30/94 Completed: 6/30/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
316.4	0.6	Driller Reported "Surficial Organic Soil"	10/10/10	0.0 1.5		No Groundwater was Encountered During Drilling or Upon Removal of Auger
		Medium Dense to Dense, Brown Clayey Fine SAND with Silt - Moist (SC)	10/20/21	3.0 3.5		
312.0	5.0		6/10/12	5.0		Cave-in Depth at 4.0'
		Boring Terminated at 5.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

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Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-3 (1 of 1) Total Depth 5.0' Elev: 312.6' Location:

Type of Boring: Hollow Stem Auger Started: 6/30/94 Completed: 6/30/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
312.0	0.6	Driller Reported "Surficial Organic Soil"	6/8/12	0.0		No Groundwater was Encountered During Drilling or Upon Removal of Auger
		Very Stiff, Brown Silty CLAY/Clayey SILT with Fine Sand - Moist (CH-MH)		1.5		
			8/12/16	3.0		
				3.5		
307.6	5.0		8/14/15	5.0		Cave-in Depth at 4.0
		Boring Terminated at 5.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

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Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-4 (1 of 1) Total Depth 1.8' Elev: Location:

Type of Boring: Hollow Stem Auger Started: 7/13/94 Completed: 7/13/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
	0.3	Driller Reported "Bituminous Concrete - Asphalt	24/12/8	0.3 1.8		
	0.8	Gray Crushed Stone Base (21A)				
	1.8	Very Stiff, Reddish Brown Fine Sandy SILT, Trace Clay - Moist (ML)				No Groundwater was Encountered During Drilling or Upon Removal of Auger
		Boring Terminated at 1.8'				0 - 4" Base Course Bituminous Concrete 4"- 10" Gray Crushed Stone Base (21A) 10"- 22" Reddish Brown Silty CLAY, Trace Fine Sand

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

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Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-5 (1 of 1) Total Depth 5.0' Elev: Location:

Type of Boring: Hollow Stem Auger Started: 7/13/94 Completed: 7/13/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
	0.5	Driller Reported "Surficial Organic Soil"	8/12/15	0.0 1.5		No Groundwater was Encountered During Drilling or Upon Removal of Auger
		Stiff to Very Stiff, Brown Fine Sandy SILT - Moist (ML)	8/11/11	3.0 3.5		
	5.0		6/8/8	5.0		Cave-in Depth at 4.0'.
		Boring Terminated at 5.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

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Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-6 (1 of 1) Total Depth 0.9' Elev: Location:

Type of Boring: Hollow Stem Auger Started: 7/13/94 Completed: 7/13/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
	0.3	Driller Reported "Bituminous Concrete - Asphalt	40/*	0.3		*50/0.1'
	0.9	Very Dense, Brown SAND and Gray GRAVEL		0.9		No Groundwater was Encountered During Drilling or Upon Removal of Auger 0 - 3.5" Base Course Bituminous Concrete 3.5"- 7" Brown SAND and Gray GRAVEL
		Boring Terminated at 0.9'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

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Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-7 (1 of 1) Total Depth 3.2' Elev. ± Location:

Type of Boring: Hollow Stem Auger Started: 7/13/94 Completed: 7/13/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
	0.2	Driller Reported "Asphaltic Concrete"	12/18/22	0.2		
	0.6	Gravel Base (21A Stone)		1.7		
	1.8	Dense, Brown SAND and GRAVEL	6/26/31	3.2		
	3.2	Very Hard, Brown and Gray Silty CLAY, Trace Fine Sand				No Groundwater was Encountered During Drilling or Upon Removal of Auger
		Boring Terminated at 3.2'				0 - 2.5" Base Course Bituminous Concrete
						2.5"- 7.5" Gravel Base (21A Stone)
						7.5"- 21" Brown SAND and GRAVEL
						21"- 36" Brown and Gray Silty CLAY, Trace Fine Sand

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

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Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: WP-2 (1 of 1) Total Depth 34.3' Elev. 298.2' Location:

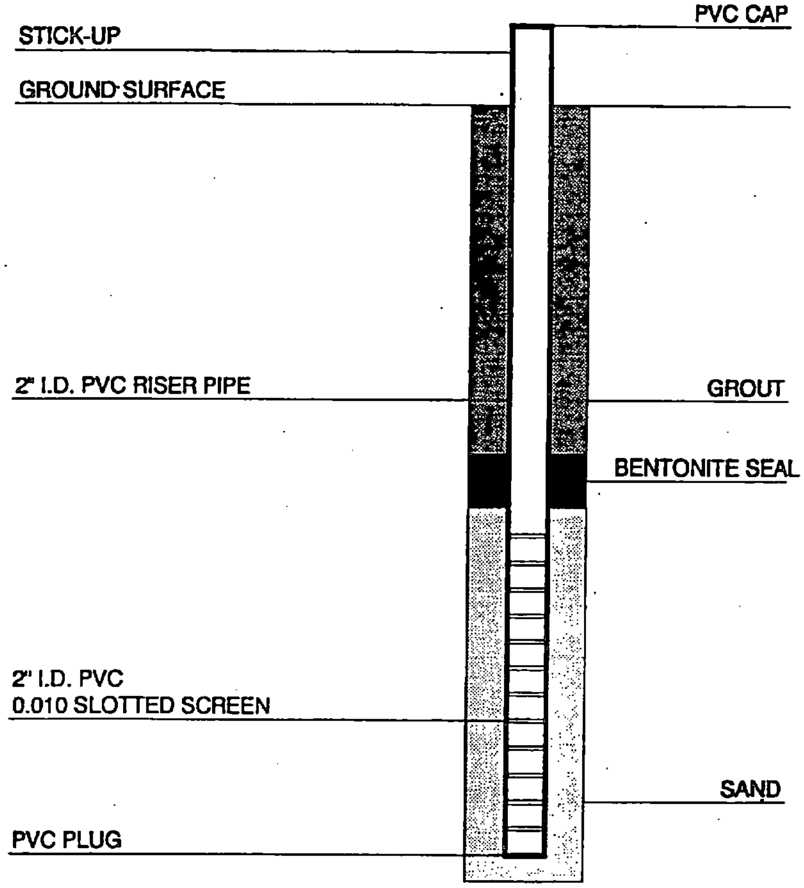
Type of Boring: Hollow Stem Auger Started: 6/30/94 Completed: 6/30/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
		Very Stiff to Stiff, Brown and Gray Fine Sandy CLAY, Trace Silt and Mica - Moist (CL)	6/10/12	0.0		Groundwater was Encountered at 14.0' During Drilling
				1.5		
			6/10/11	3.0		
			6/8/8	4.5		
292.2	6.0			6.0		
		Medium Dense, Brown and Gray Clayey Fine SAND, Trace Silt and Mica - Moist (SC)	7/8/9	7.5		
289.2	9.0			9.0		
		Medium Dense, Brown Silty Fine SAND, Trace Clay and Mica - Moist (SM) (Relict Rock Structure Present)	6/12/16	10.5		
				14.0		
			8/11/16	15.5		
279.2	19.0			19.0		
		Medium Dense to Very Dense, Brown and Green Clayey Fine SAND, Trace Silt and Mica - Moist (SC) (Relict Rock Structure Present)	6/12/14	20.5		
				24.0		
			30/*	24.8		*50/0.3'
				29.0		
			8/*	29.9		*50/0.4'
				34.0		
263.9	34.3		*	34.3		*50/0.3'
		Boring Terminated at 34.3'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

MONITOR WELL DIAGRAM

WELL WP-1



GROUT	26.5 ft.	CASING TOP EL	323.22
BENTONITE	2.0 ft.	RISER PIPE	33.1 ft.
SAND	7.0 ft.	SCREEN	5.0 ft.
TOTAL DEPTH	35.5 ft.	STICK-UP	2.6 ft.

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ENGINEERS • LABORATORIES
"OVER ONE HUNDRED YEARS OF SERVICE"

DATE: August, 1994
SCALE: NONE
DRWN: TMM V60-073

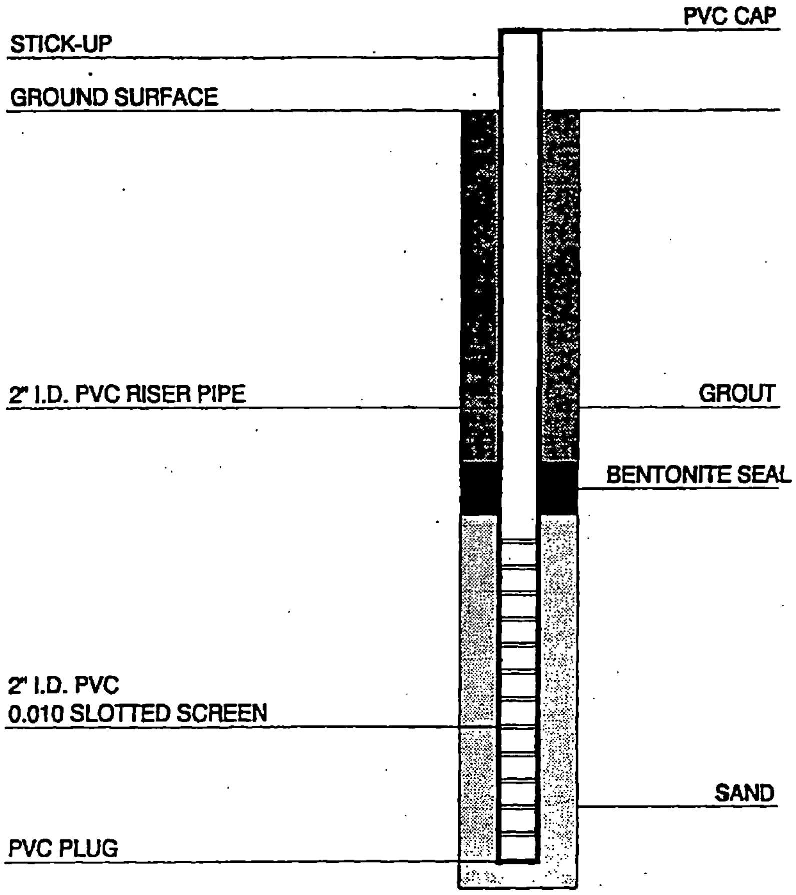
MONITOR WELL DIAGRAM
PHASE 2 - ISFSI - NORTH ANNA POWER STATION
MINERAL, VIRGINIA VIRGINIA POWER

DWG. NO. WP-1

Form No 103

MONITOR WELL DIAGRAM

WELL WP-2



GROUT	24.0 ft.	CASING TOP EL	298.20
BENTONITE	2.0 ft.	RISER PIPE	31.7 ft.
SAND	8.3 ft.	SCREEN	5.0 ft.
TOTAL DEPTH	34.3 ft.	STICK-UP	2.4 ft.

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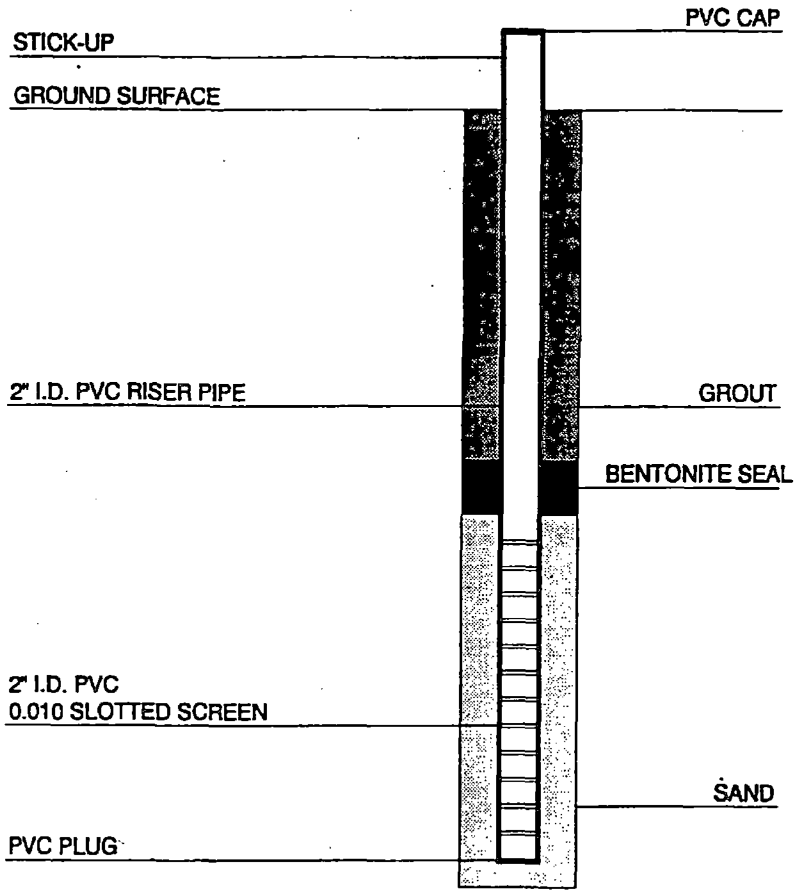
MONITOR WELL DIAGRAM
PHASE 2 - ISFSI - NORTH ANNA POWER STATION
MINERAL, VIRGINIA VIRGINIA POWER

DWG. NO. WP-2

Form No 103

MONITOR WELL DIAGRAM

WELL WP-3



GROUT	30.0 ft.	CASING TOP EL	311.32
BENTONITE	2.0 ft.	RISER PIPE	36.5 ft.
SAND	7.0 ft.	SCREEN	5.0 ft.
TOTAL DEPTH	39.0 ft.	STICK-UP	2.5 ft.

SINCE 1881
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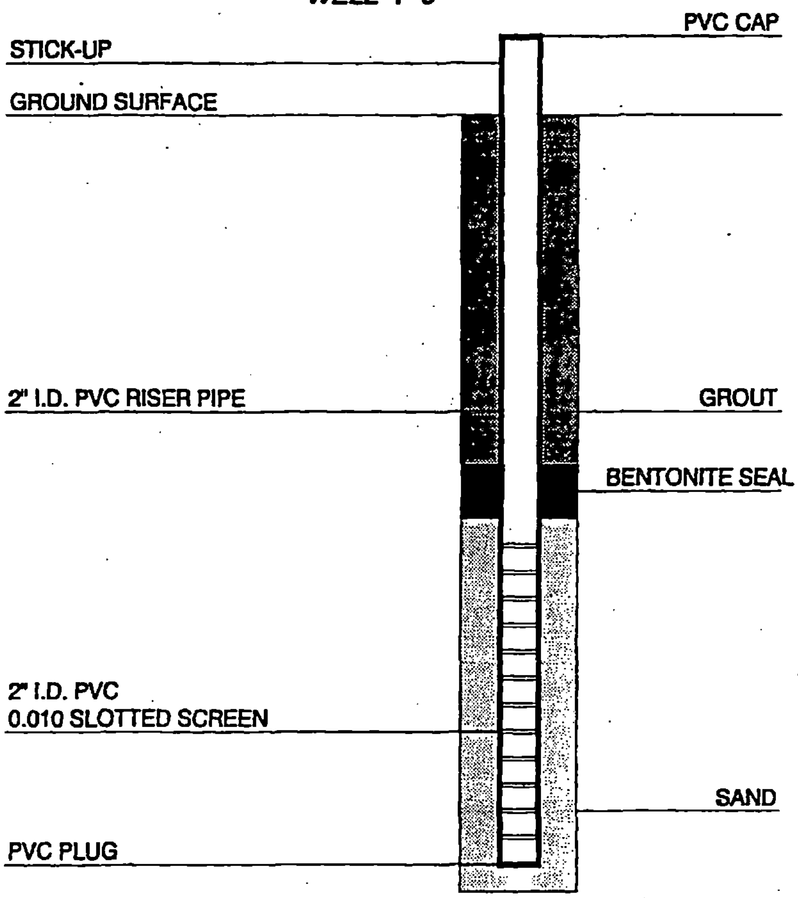
DATE: August, 1994
SCALE: NONE
DRWN: TMM | V60-073

MONITOR WELL DIAGRAM
PHASE 2 - ISFSI - NORTH ANNA POWER STATION
MINERAL, VIRGINIA VIRGINIA POWER

DWG. NO. WP-3

MONITOR WELL DIAGRAM

WELL F-6



GROUT	35.0 ft.	CASING TOP EL	315.98
BENTONITE	2.0 ft.	RISER PIPE	41.6 ft.
SAND	7.0 ft.	SCREEN	5.0 ft.
TOTAL DEPTH	44.0 ft.	STICK-UP	2.6 ft.

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DATE: August, 1994
SCALE: NONE
DRWN: TMM V60-073

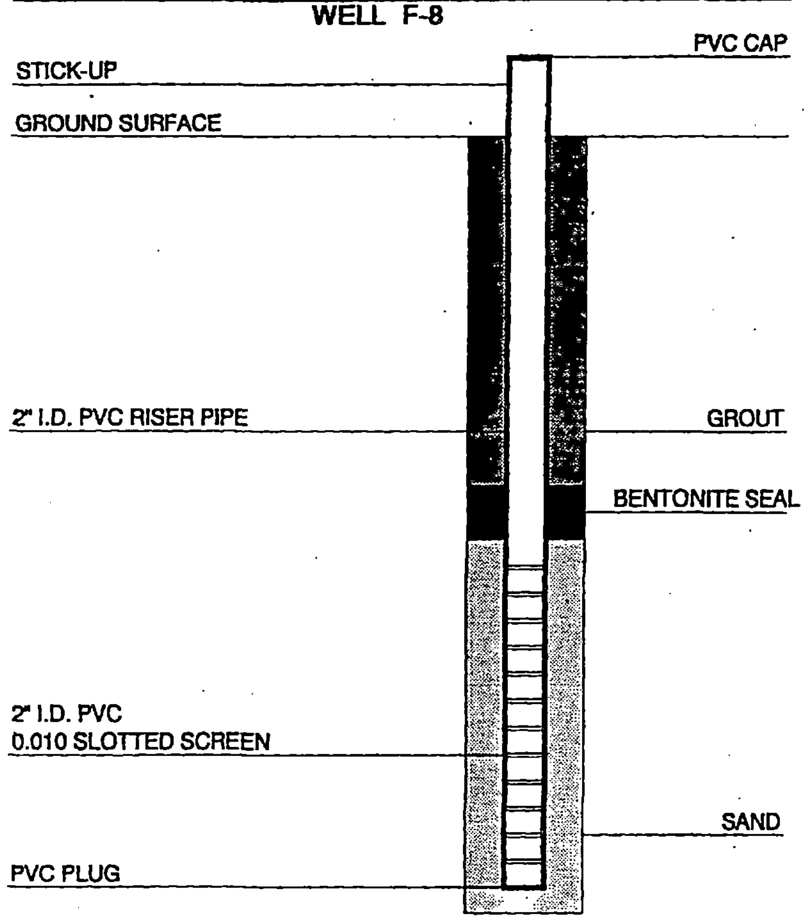
MONITOR WELL DIAGRAM
PHASE 2 - ISFSI - NORTH ANNA POWER STATION
MINERAL, VIRGINIA VIRGINIA POWER

DWG. NO. F-6

Form No 103

MONITOR WELL DIAGRAM

WELL F-8



GROUT	**50.1 ft.**	**CASING TOP EL**	**317.92**
BENTONITE	**2.0 ft.**	**RISER PIPE**	**56.4 ft.**
SAND	**7.0 ft.**	**SCREEN**	**5.0 ft.**
TOTAL DEPTH	**59.1 ft.**	**STICK-UP**	**2.3 ft.**

SINCE 1881 F&R **FROEHLING & ROBERTSON, INC.**
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS
ENGINEERS • LABORATORIES
"OVER ONE HUNDRED YEARS OF SERVICE"

DATE: August, 1994
SCALE: NONE
DRWN: TMM V60-073

MONITOR WELL DIAGRAM
PHASE 2 - ISFSI - NORTH ANNA POWER STATION
MINERAL, VIRGINIA VIRGINIA POWER

DWG. NO. F-8

Form No 103

2008 BORINGS

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS (More than 50% of material is LARGER than No. 200 sieve size)	GRAVELS (More than 50% of coarse fraction is LARGER than the No. 4 sieve size)	CLEAN GRAVELS (Little or no fines)	GW	Well graded gravels, gravel - sand mixtures, little or no fines.
			GP	Poorly graded gravels or grave - sand mixtures, little or no fines.
		GRAVELS WITH FINES (Appreciable amount of fines)	GM	Silty gravels, gravel - sand - silt mixtures.
			GC	Clayey gravels, gravel - sand - clay mixtures.
	SANDS (More than 50% of coarse fraction is SMALLER than the No. 4 Sieve Size)	CLEAN SANDS (Little or no fines)	SW	Well graded sands, gravelly sands, little or no fines.
			SP	Poorly graded sands or gravelly sands, little or no fines.
		SANDS WITH FINES (Appreciable amount of fines)	SM	Silty sands, sand - silt mixtures
			SC	Clayey sands, sand - clay mixtures.
FINE GRAINED SOILS (More than 50% of material is SMALLER than No. 200 sieve size)	SILTS AND CLAYS (Liquid limit LESS than 50)		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts and with slight plasticity.
			CL	Inorganic lays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL	Organic silts and organic silty clays of low plasticity.
	SILTS AND CLAYS (Liquid limit GREATER than 50)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS			PT	Peat and other highly organic soils.

BOUNDARY CLASSIFICATIONS: Soils possessing characteristics of two groups are designated by combinations of group symbols.

SILT OR CLAY	SAND			GRAVEL		Cobbles	Boulders
	Fine	Medium	Coarse	Fine	Coarse		

No.200 No.40 No.10 No.4 3/4" 3" 12"

U.S. STANDARD SIEVE SIZE

Reference: The Unified Soil Classification System, Corps of Engineers, U.S. Army Technical Memorandum No. 3-357, Vol. 1, March, 1953 (Revised April, 1960)

	GROUP SYMBOLS	TYPICAL NAMES
ROCK	WR	Weathered Rock
	HR-WR	Hard Rock-Weathered Rock
	HR	Hard Rock

WEATHERING

FRESH - Rock fresh, crystals bright, few joints may show slight staining, rock rings under hammer blows.

VERY SLIGHT - Rock generally fresh, joints stained, may show thin clay coatings, crystals on a broken face shine brightly, rock rings under hammer blows.

SLIGHT - Rock generally fresh, joints stained, discoloration extends into rock, joints may contain clay, some feldspar crystals are dull and discolored, rock rings under hammer blows.

MODERATE - Significant portions show discoloration and weathering effects, feldspar crystals dull and discolored, dull sound under hammer blows.

MODERATELY SEVERE - All rock except quartz discolored or stained, feldspars dull and discolored and show kaolinization, dull sound under hammer blows, severe loss of strength.

SEVERE - All rock except quartz discolored or stained, very severe loss in strength, some fragments of strong rock may remain.

VERY SEVERE - All rock except quartz discolored or stained, only fragments of strong rock remain, saprolite.

COMPLETE - Rock reduced to soil, may show rock fabric, quartz may be present as dikes or veins.

ROCK HARDNESS

VERY HARD - Cannot be scratched by knife or pick, very hard blows with hammer required to break.

HARD - Can be scratched by knife or pick only with difficulty, hard hammer blows required to break.

MODERATELY HARD - Can be scratched by knife or pick, can be broken with moderate hammer blows.

MEDIUM HARD - Can be grooved or gouged by knife or pick, breaks easily.

SOFT - Easily grooved or gouged by knife or pick, weak, small pieces may be broken with finger pressure.

VERY SOFT - Can be carved with knife, very weak, scratched with finger nail.

FRACTURE SPACING

VERY WIDE => 10 feet
WIDE = 3 to 10 feet
MODERATELY CLOSE = 1 to 3 feet
CLOSE = 0.15 to 1 feet
VERY CLOSE = Less than 0.15 feet

Correlation of Penetration Resistance with Relative Density and Consistency

SAND & GRAVEL		SILT & CLAY	
No. of Blows	Relative Density	No. of Blows	Consistency
<4	Very Loose	<2	Very Soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium Dense	4 - 8	Medium Stiff
30 - 50	Dense	8 - 15	Stiff
>50	Very Dense	15 - 30	Very Stiff
		>30	Hard

▽ Water Table at time of drilling ▼ Water Table after 24 hours

KEY TO SYMBOLS AND DESCRIPTIONS

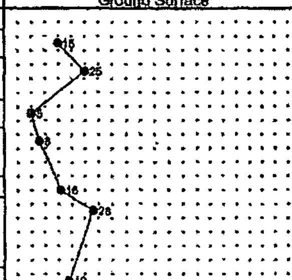
MACTEC

GEOTECHNICAL BORING LOG

MACTEC

SHEET 1 OF 1

MACTEC PROJECT NO.: 6468-07-1952	COUNTY Louisa	GEOLOGIST D. Vass	
SITE DESCRIPTION North Anna Power Station U3 Separation Project			GROUND WATER (ft)
BORING NO. B713	DRILL METHOD: Hollow-Stem Auger	SAMPLE METHODS: SPT	0 HR. Dry
COLLAR ELEV. 305.6 ft (NAVD88)	NORTHING 3908515.3 US ft (NAD83)	EASTING 11687032.9 US ft (NAD83)	24 HR. Dry
TOTAL DEPTH 20.0 ft	DRILL MACHINE CME 550x	DRILLER: Fishburne Drilling (Sequist)	HAMMER TYPE 140-lb Automatic
DATE STARTED 4/4/08	COMPLETED 4/4/08	CORE BARREL TYPE: NA	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
305.6					Ground Surface				305.6 0.0
304.1	1.5	5	6	9		1	M		Fill - Very stiff, brown, sandy CLAY (CL) with broken rock pieces 1.5ft: PP = 2.00 tsf
302.1	3.5	20	15	10		2	M		3.5ft: PP = 1.50 tsf 300.6 5.0
299.1	6.5	6	3	2		3	M		Top Soil - Medium stiff, brown, silty CLAY (CL) with roots and scattered rock fragments 6.5ft: PP = 2.00 tsf
297.1	8.5	1	3	5		4	M		8.5ft: PP = 1.75 tsf 295.6 10.0
293.6	12.0	3	6	10		5	M		Very stiff, light brown, sandy SILT (ML) with mica 12.0ft: PP = 2.50 tsf
292.1	13.5	10	13	15		6	M		13.5ft: PP = 1.75 tsf 290.6 15.0
287.1	18.5	7	8	11		7	M		Medium dense, light brown, silty, fine SAND (SM) with mica 285.6 20.0
									Boring Terminated at 20.0ft (Elevation 285.6ft) Bore hole caved to 13ft and dry at time of boring

GEOTECHNICAL BORING LOG

MACTEC

SHEET 1 OF 1

MACTEC PROJECT NO.: 6468-07-1952	COUNTY Louisa	GEOLOGIST D. Vass
SITE DESCRIPTION North Anna Power Station U3 Separation Project		GROUND WATER (ft)
BORING NO. B714 Rev. 1	DRILL METHOD: Hollow-Stem Auger / SAMPLE METHODS: SPT	0 HR. Dry
COLLAR ELEV. 308.2 ft (NAVD88)	NORTHING 3908690.2 US ft (NAD83) / EASTING 11687717.2 US ft (NAD83)	24 HR. ND
TOTAL DEPTH 20.0 ft	DRILL MACHINE CME 550x / DRILLER: Fishburne Drilling (Sequist)	HAMMER TYPE 140-lb Automatic
DATE STARTED 4/7/08	COMPLETED 4/7/08	CORE BARREL TYPE: NA

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT (0–100)	SAMP. NO.	MOI	SOIL AND ROCK DESCRIPTION
308.2					Ground Surface			308.2 — 0.0
306.7	1.5	23	7	7	14	1	M	2" of asphalt, 3" of gravel
304.7	3.5	8	5	7	12	2	M	305.2 — 3.0 Fill - Stiff, light brown-gray, fine sandy CLAY (CL) with broken rock fragments, trace roots 1.5ft: PP = 4.50+ tsf
301.7	6.5	4	6	8	14	3	M	303.2 — 5.0 Stiff, red-brown, sandy CLAY (CL) 3.5ft: PP = 3.00 tsf
299.7	8.5	4	7	10	17	4	M	300.2 — 8.0 Stiff, light red-brown, slightly fine sandy, slightly clayey SILT (ML), trace mica 6.5ft: PP = 2.50 tsf Rev. 1
296.2	12.0							Medium dense, brown, tan and black, slightly silty, fine SAND (SP-SM), trace mica 8.5ft: PP = 1.25 tsf 12ft: PP = 1.00 tsf Rev. 1
294.7	13.5	3	5	11	16	5	M	
		8	10	18	28	6	M	
289.7	18.5	5	7	9	16	7	M	288.2 — 20.0

Boring Terminated at 20.0ft (Elevation 288.2ft)

Bore hole caved to 13.2ft and dry at time of boring

NORTH ANNA COL BORE 6468071952.GPJ NORTH ANNA COL.GDT 6/23/08

Intentionally Blank

Appendix 2B
Laboratory Tests

Intentionally Blank

PHASE 2 - ISFSI
NORTH ANNA POWER STATION - MINERAL, VIRGINIA
VIRGINIA POWER
F&R #V60-073

LABORATORY TEST RESULTS

Boring	F-5A	F-5	F-6	F-6	F-6	F-7A	F-7A
Sample No.	UD-1	S-7	S-2	S-5	S-9	UD-l	UD-2
Depth (ft.)	18.0-20.0	19.0-20.5	1.5-3.0	9.0-10.5	29.0-30.5	4.0-6.0	16.0-18.0
Gradation % Passing Sieve							
No. 4	....	....	....	100	100	....	100
No. 10	100	100	100	97.9	99.9	100	99.8
No. 40	92.5	96.1	96.6	84.4	77.8	96.8	83.1
No. 100	67.7	79.5	90.3	61.7	35.9	77.9	50.8
No. 200	53.9	70.2	87.9	54.3	24.8	72.0	38.0
Liquid Limit (%)	...	65	85	62	...	84	...
Plasticity Index	...	19	31	19	...	30	...
Natural Moisture (%)	53.3	55.7	37.4	29.0	29.3	34.1	31.8
ASTM Classification	...	MH	MH	MH	...	MH	...

PHASE 2 - ISFSI
NORTH ANNA POWER STATION - MINERAL, VIRGINIA
VIRGINIA POWER
F&R #V60-073

LABORATORY TEST RESULTS

Boring	F-7	F-7	F-8	F-8	F-9A	F-9	F-10
Sample No.	S-7	S-18	S-4	S-7	UD-1	S-13	S-3
Depth (ft.)	19.0-20.5	74.0-74.8	9.0-10.5	19.0-20.5	4.0-6.0	49.0-50.5	3.0-4.5
Gradation % Passing Sieve							
3/8 inch	...	...	...	...	...	...	...
No. 4	100	100	100	100	100	100	100
No. 10	98.6	97.6	99.9	99.9	99.8	97.7	99.7
No. 40	80.7	70.7	93.1	84.9	84.3	78.8	69.0
No. 100	60.8	47.2	81.3	64.4	52.3	39.3	44.5
No. 200	53.1	34.2	76.3	51.2	44.9	26.2	36.8
Liquid Limit (%)	60	40	58	...	64	...	46
Plasticity Index	16	6	26	...	18	...	15
Natural Moisture (%)	30.3	25.4	34.7	27.0	27.1	22.7	13.6
ASTM Classification	MH	SM	MH	...	SM	...	SM

PHASE 2 - ISFSI
NORTH ANNA POWER STATION - MINERAL, VIRGINIA
VIRGINIA POWER
F&R #V60-073

LABORATORY TEST RESULTS

Boring	F-10	F-10	P-2	P-3	P-4
Sample No.	S-5	S-10	BAG	BAG	BAG
Depth (ft.)	9.0-10.5	34.0-35.5	0.0-5.0	0.0-5.0	0.0-5.0
Gradation % Passing Sieve					
3/8 inch	...	100	100	...	...
No. 4	100	99.2	98.7	100	100
No. 10	99.4	90.9	94.8	99.4	99.1
No. 40	65.4	55.4	81.1	83.5	90.9
No. 100	41.5	33.9	57.8	67.7	64.9
No. 200	31.6	24.8	49.5	62.1	55.7
Liquid Limit (%)	41	...	41	60	48
Plasticity Index	12	...	20	30	19
Natural Moisture (%)	14.9	22.1	8.5	15.0	8.5
ASTM Classification	SM	...	SC	CH	ML

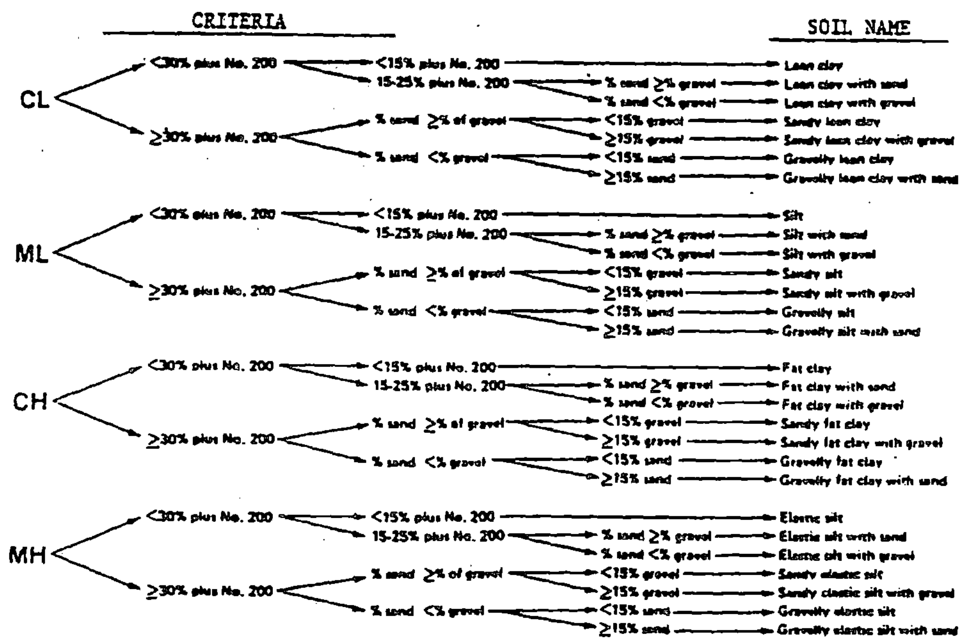
PHASE 2 - ISFSI
NORTH ANNA POWER STATION - MINERAL, VIRGINIA
VIRGINIA POWER
F&R #V60-073

CBR TEST RESULTS

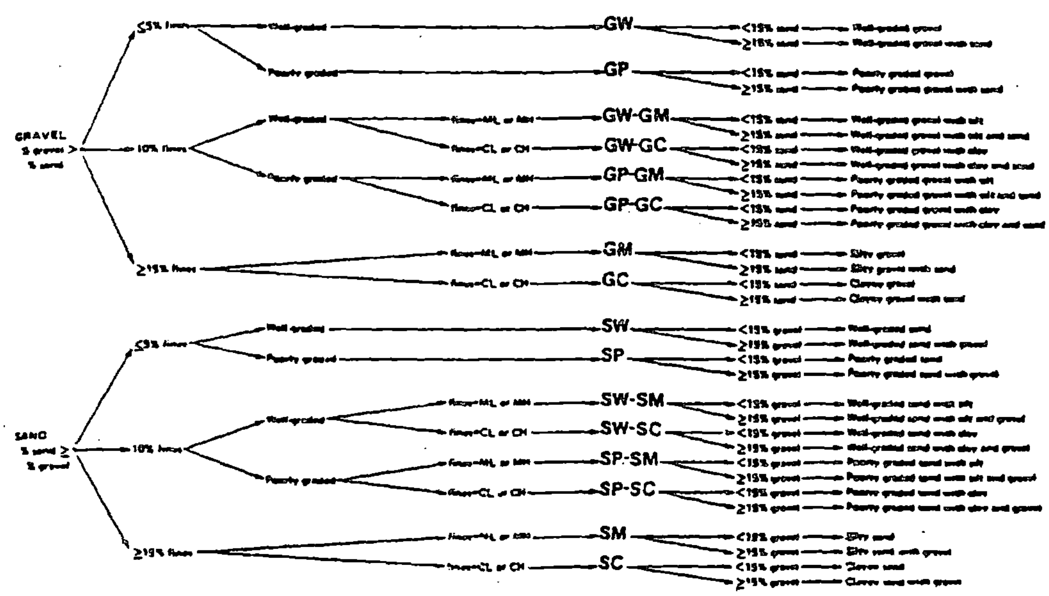
Boring	P-2	P-3	F-7A
Sample No.	Bulk	Bulk	Composite
Depth (ft.)	0.0-5.0	0.0-5.0	16.0-22.0
ASTM Classification	SC	CH	SM
Moisture-Density Relationship Test			
Maximum Dry Density (pcf)	117.5	111.2	109.0*
Optimum Moisture (%)	12.4	16.6	35.0*
CBR (Unsoaked)	39.2	38.9	6.4
CBR (Soaked)	7.6	7.3	NA

*Sample was molded at natural moisture content and unit weight.

ASTM SOIL CLASSIFICATION



Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)



Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

PARTICLE SIZE ANALYSIS TEST

Objective: The grain size data are used to aid in the classification of soils and in the estimation of soil behavior.

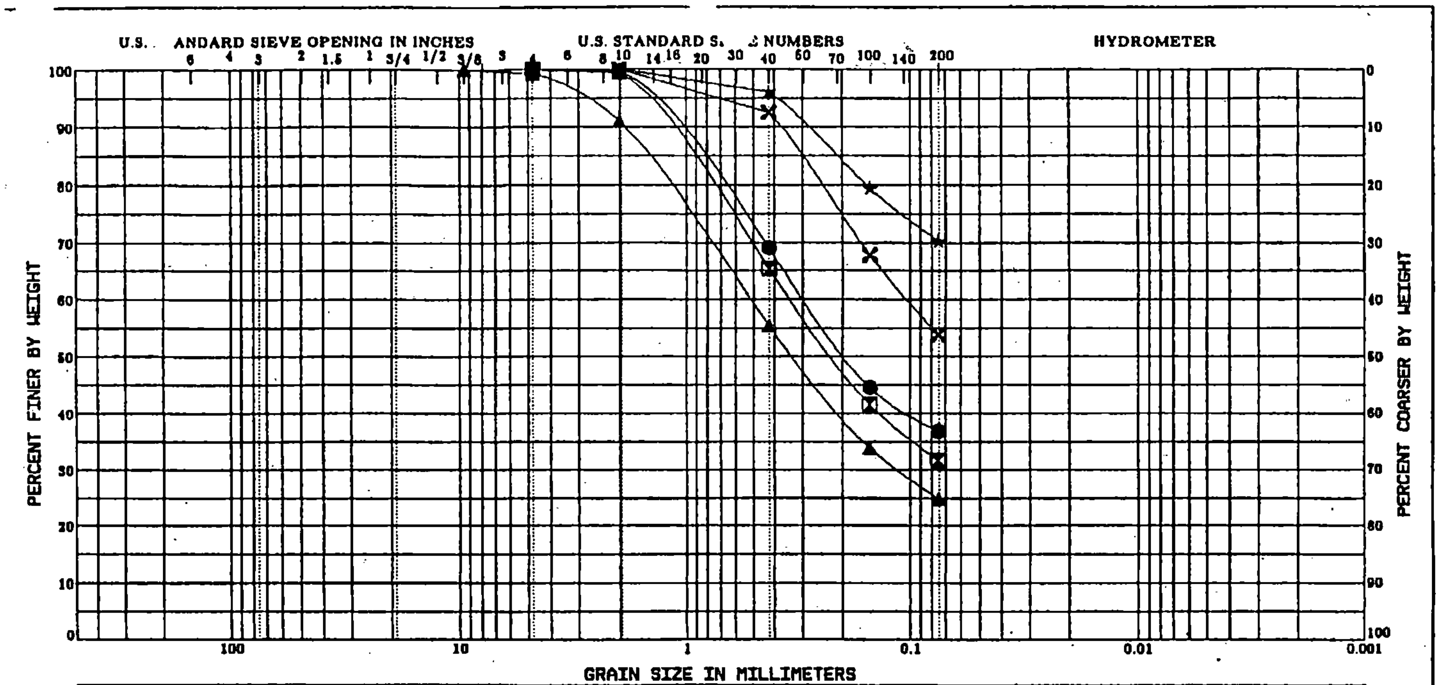
Procedure: The test can be divided into two parts, the determination of the size and distribution of the coarse fraction and the determination of the size and distribution of the fine fraction. The division between the coarse and fine fraction is the No. 200 sieve. The coarse fraction is tested using the sieve method; the fine fraction is tested using the hydrometer method. If both tests are performed, the test is referred to as the combined analysis.

For the analysis of the coarse fraction, the dried soil is soaked and then washed through a #200 sieve. The sand and gravel remaining on the sieve is oven dried. The dried sand and gravel is then passed through a series of sieves, and the weight retained on each sieve is determined. The distribution of weights is then computed and the percent passing each sieve is plotted as a curve.

In the hydrometer method, the particle size is determined by Stoke's equation. The soil is mixed with water to form a heavy slurry. The rate of sedimentation is measured using a hydrometer. Hydrometer data can be reduced to develop the weight percent distribution curve for the fine grained soil fraction.

References: ASTM Specification D-422, "Particle Size Analysis of Soils."

Laboratory Soils Testing, EM 1110-2-1906 by The Department of the Army, Appendix V.



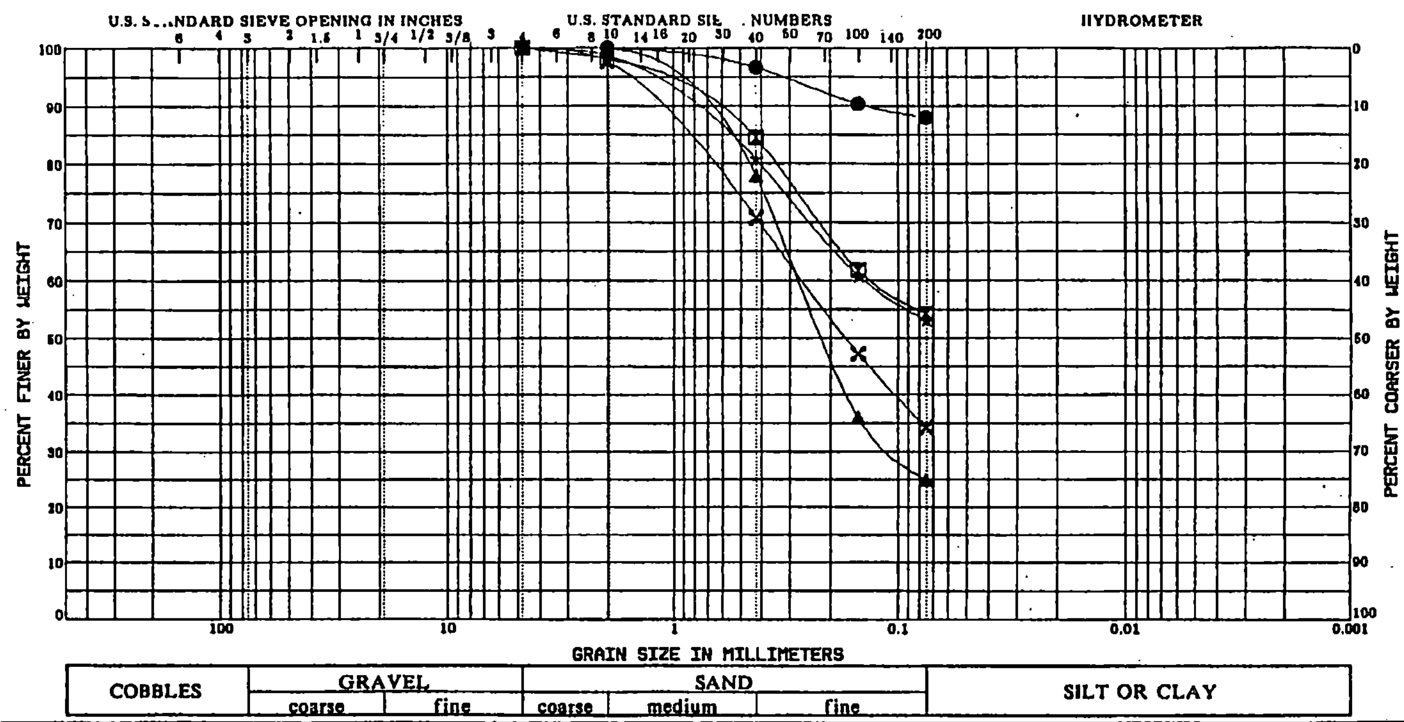
COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification	Classification (ASTM)	WC%	LL	PL	PI	Cc	Cu
●	F-10 at 3.0 ft.	Silty Sand (SM)	13.6	46	31	15		
⊠	F-10 at 9.0 ft.	Silty Sand (SM)	14.9	41	29	12		
▲	F-10 at 34.0 ft.	()	22.1					
★	F-5 at 19.0 ft.	Sandy Elastic Silt (MH)	55.7	65	46	19		
✕	F-5A at 18.0 ft.	()	46.0					

	Specimen Identification	D100 (mm)	D60 (mm)	D30 (mm)	D10 (mm)	%Gravel	%Sand	%Silt	%Clay
●	F-10 at 3.0 ft.	4.75	0.29			0.0	63.2	36.8	
⊠	F-10 at 9.0 ft.	4.75	0.34			0.0	68.4	31.6	
▲	F-10 at 34.0 ft.	9.50	0.52	0.112		0.8	74.4	24.8	
★	F-5 at 19.0 ft.	2.00				0.0	29.8	70.2	
✕	F-5A at 18.0 ft.	2.00	0.10			0.0	46.1	53.9	

F&R Richmond Virginia

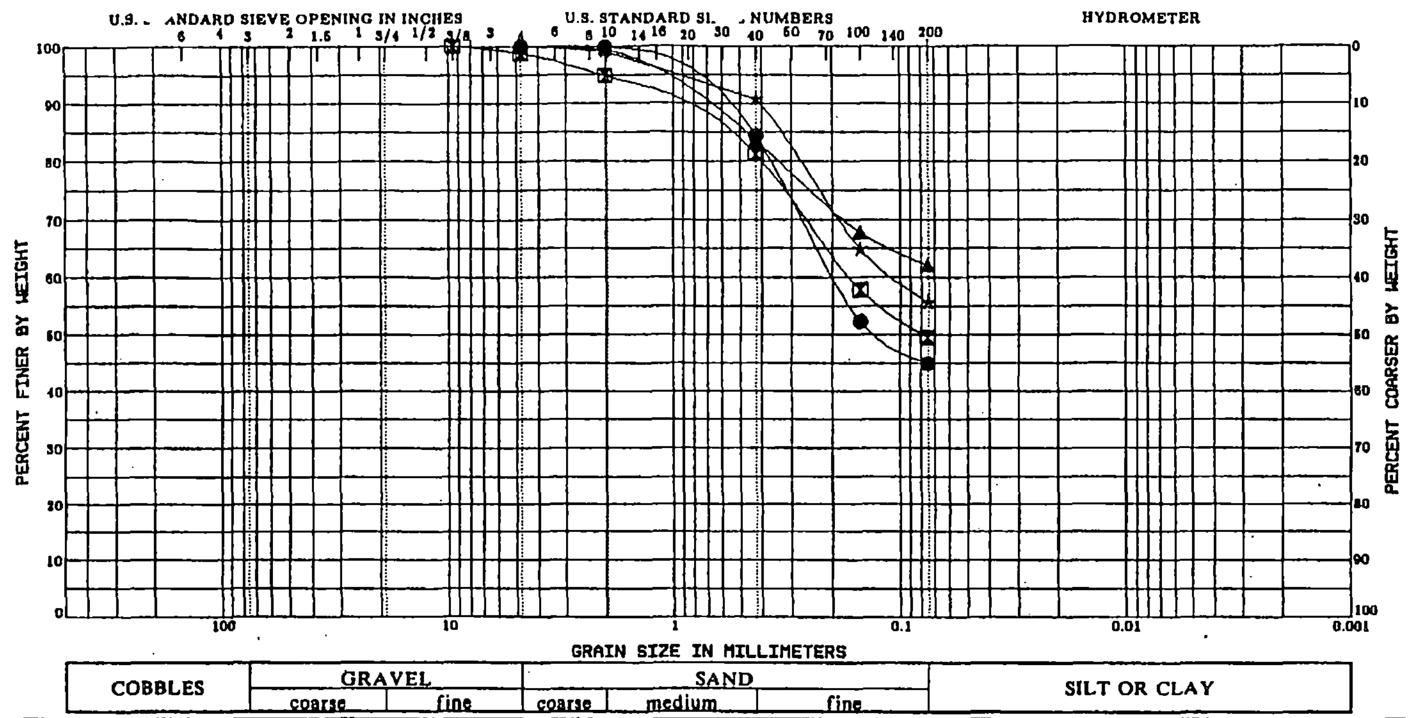
Project: Phase 2 - ISFSI North Anna Power Station	Location: Mineral, Virginia	
Client: Virginia Power	F+R No: V60-073	
Date: September 1994	GRADATION CURVES	



	Specimen Identification				Classification (ASTM)	WC%	LL	PL	PI	Cc	Cu
●	F-6	at	1.5	ft.	Elastic Silt (MH)	37.4	85	54	31		
⊠	F-6	at	9.0	ft.	Sandy Elastic Silt (MH)	29.0	62	43	19		
▲	F-6	at	29.0	ft.	()	29.3					
★	F-7	at	19.0	ft.	Sandy Elastic Silt (MH)	30.3	60	44	16		
✕	F-7	at	74.0	ft.	Silty Sand (SM)	25.4	40	34	6		

	Specimen Identification				D100 (mm)	D60 (mm)	D30 (mm)	D10 (mm)	%Gravel	%Sand	%Silt	%Clay
●	F-6	at	1.5	ft.	2.00				0.0	12.1	87.9	
⊠	F-6	at	9.0	ft.	4.75	0.13			0.0	45.7	54.3	
▲	F-6	at	29.0	ft.	4.75	0.27	0.104		0.0	75.2	24.8	
★	F-7	at	19.0	ft.	4.75	0.14			0.0	46.9	53.1	
✕	F-7	at	74.0	ft.	4.75	0.26			0.0	65.8	34.2	

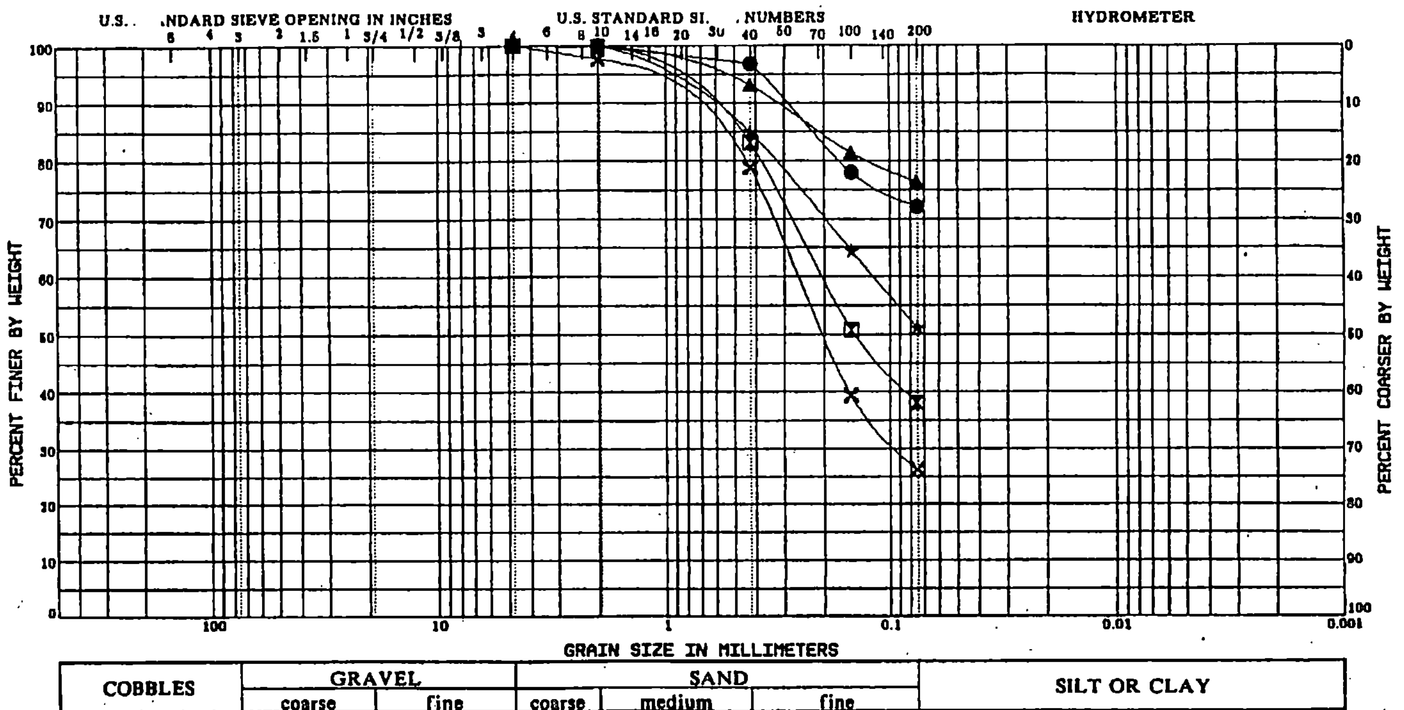
F&R Richmond Virginia	Project: Phase 2 - ISFSI North Anna Power Station	Location: Mineral, Virginia
	Client: Virginia Power	F+R No: V60-073
	Date: September 1994	GRADATION CURVES



	Specimen Identification				Classification (ASTM)	WC%	LL	PL	PI	Cc	Cu
●	F-9A	at	4.0	ft.	Silty Sand (SM)	27.1	64	46	18		
⊠	P-2	at	0.0	ft.	Clayey Sand (SC)	8.5	41	21	20		
▲	P-3	at	0.0	ft.	Sandy Fat Clay (CH)	15.0	60	30	30		
★	P-4	at	0.0	ft.	Sandy Silt (ML)	8.5	48	29	19		
		at		ft.							

	Specimen Identification				D100 (mm)	D60 (mm)	D30 (mm)	D10 (mm)	%Gravel	%Sand	%Silt	%Clay
●	F-9A	at	4.0	ft.	4.75	0.19			0.0	55.1	44.9	
⊠	P-2	at	0.0	ft.	9.50	0.17			1.3	49.2	49.5	
▲	P-3	at	0.0	ft.	4.75				0.0	37.9	62.1	
★	P-4	at	0.0	ft.	4.75	0.10			0.0	44.3	55.7	
		at		ft.								

F&R Richmond Virginia	Project: Phase 2 - ISFSI North Anna Power Station	Location: Mineral, Virginia
	Client: Virginia Power	F+R No: V60-073
	Date: September 1994	GRADATION CURVES



	Specimen Identification				Classification (ASTM)	WC%	LL	PL	PI	Cc	Cu
●	F-7A	at	4.0	ft.	Elastic Silt with Sand (MH)	34.1	84	54	30		
⊠	F-7A	at	16.0	ft.	()	31.8					
▲	F-8	at	9.0	ft.	Elastic Silt with Sand (MH)	34.7	58	32	26		
★	F-8	at	19.0	ft.	()	27.0					
✕	F-9	at	49.0	ft.	()	22.7					

	Specimen Identification				D100 (mm)	D60 (mm)	D30 (mm)	D10 (mm)	%Gravel	%Sand	%Silt	%Clay
●	F-7A	at	4.0	ft.	2.00				0.0	28.0	72.0	
⊠	F-7A	at	16.0	ft.	4.75	0.20			0.0	62.0	38.0	
▲	F-8	at	9.0	ft.	4.75				0.0	23.7	76.3	
★	F-8	at	19.0	ft.	4.75	0.12			0.0	48.8	51.2	
✕	F-9	at	49.0	ft.	4.75	0.26	0.092		0.0	73.8	26.2	

F&R Richmond Virginia	Project: Phase 2 - ISFSI North Anna Power Station	Location: Mineral, Virginia
	Client: Virginia Power	F+R No: V60-073
	Date: September 1994	GRADATION CURVES

ATTERBERG LIMITS

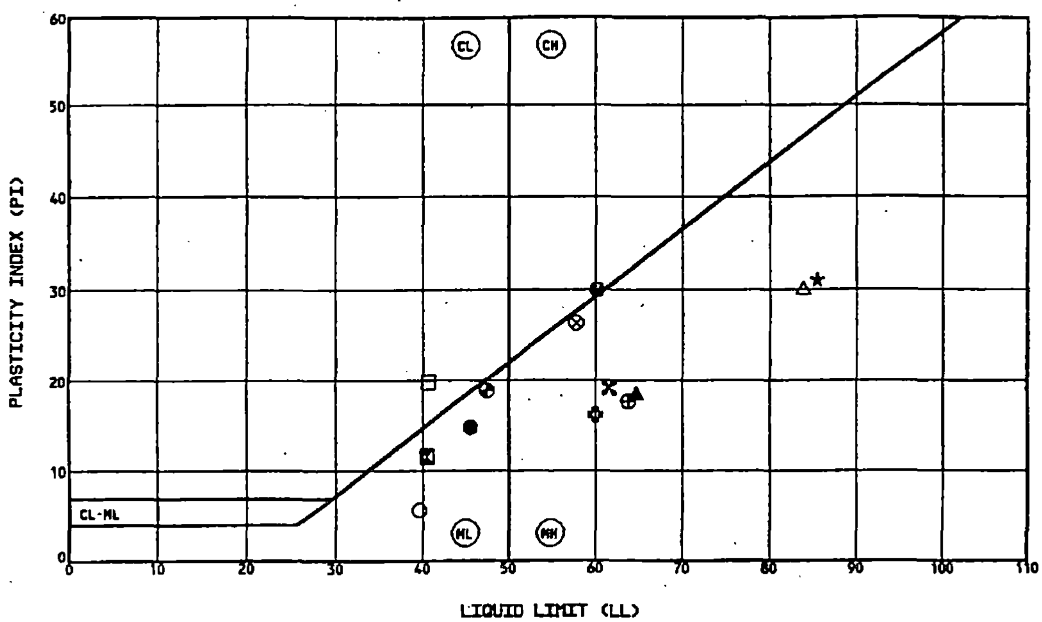
Purpose: Dr. Atterberg (1911) defined the liquid limit of a soil as the water content, expressed as a percentage of the dry weight of the soil, at the boundary between the liquid and plastic states. The plastic limit is the water content expressed as a percentage of the dry weight of the soil, at the boundary between the plastic and semisolid states. The difference between these two values is the Plasticity Index (PI).

Liquid and Plastic limits are performed to determine the soil classification and plasticity properties of the soil specimen. Atterberg limits can be correlated with approximate values for compressibility and strength.

Procedure: The liquid limit is the water content when a soil will flow under a specific dynamic force. The soil is wetted, placed in a special liquid limit device, and grooved into two halves. The water content is measured when the two halves flow together over a specified distance.

The plastic limit is determined, as described by ASTM Specification D-4318, by obtaining the water content when a soil can be rolled by hand into thin threads on a surface of ground glass. The plastic limit is defined as the moisture content at which the soil can not be rolled into threads smaller than 1/8 inch in diameter.

References: ASTM Specification D4318 "Standard Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils."



	BORING	DEPTH	LL	PL	PI	FINES	CLASSIFICATION
●	F-10	3.0	46	31	15	37	SM
⊠	F-10	9.0	41	29	12	32	SM
▲	F-5	19.0	65	46	19	70	MH
★	F-6	1.5	85	54	31	88	MH
✕	F-6	9.0	62	43	19	54	MH
✿	F-7	19.0	60	44	16	53	MH
○	F-7	74.0	40	34	6	34	SM
△	F-7A	4.0	84	54	30	72	MH
⊗	F-8	9.0	58	32	26	76	MH
⊕	F-9A	4.0	64	46	18	45	SM
□	P-2	0.0	41	21	20	50	SC
⊖	P-3	0.0	60	30	30	62	CH
◒	P-4	0.0	48	29	19	56	ML

F+R No. V60-073 September 1994

Phase 2 - ISFSI North Anna Power Station

Mineral, Virginia

ATTERBERG LIMITS' RESULTS

Froehling & Robertson, Inc. Richmond, Virginia FIGURE 1

MOISTURE CONTENT TEST

Objective: To determine the ratio between the moisture contained in the soil and the weight of the solid soil grains, expressed as a percentage. The in-situ moisture content with other index properties are used to evaluate anticipated soil behavior. For controlled fill placement, the moisture content is critical in achieving maximum compaction.

Procedure: A moist sample is weighed and then oven dried. The dry sample is then weighed. The moist sample weight minus the dry sample weight is used to determine the weight of water removed. The weight of the sample remaining after oven-drying is used as the weight of the solid soil grains. The moisture content, in percent, is the ratio of the weight of moisture to the weight of dry soil multiplied by 100.

References: ASTM Specification D-2216 "Standard Method of Laboratory Determination of Moisture Content of Soil."

Laboratory Soils Testings, EM 1110-2-1906 by the Department of the Army, Appendix I.

UNIT WEIGHT TEST

Objective: The unit weight test is performed to determine the density of moist soil, expressed in terms of weight per volume. The dry unit weight is calculated from the moist unit weight and the natural moisture content. The unit weight is used in soils engineering calculations.

Procedure: The volumetric method consists of computing the total volume of a regular-shaped sample. The weight and volume of the sample is measured. The moist unit weight equals the weight of sample divided by the volume of the sample. To determine the dry unit weight, the moisture content of the sample needs to be determined. The moist unit weight divided by the moisture content plus one equals the dry unit weight.

The displacement method consists of determining the total volume of a soil by measuring the volume or weight of water displaced by the soil mass. The sample is placed in a wire cage and submerged in water. The volume of the displaced water is measured. The weight of the sample is determined. The moist unit weight is estimated by dividing the sample weight by the volume of water displaced.

References: Laboratory Soils Testing, EM 1110-2-1906, by the Department of the Army, Appendix II.

MOISTURE-DENSITY (MODIFIED)

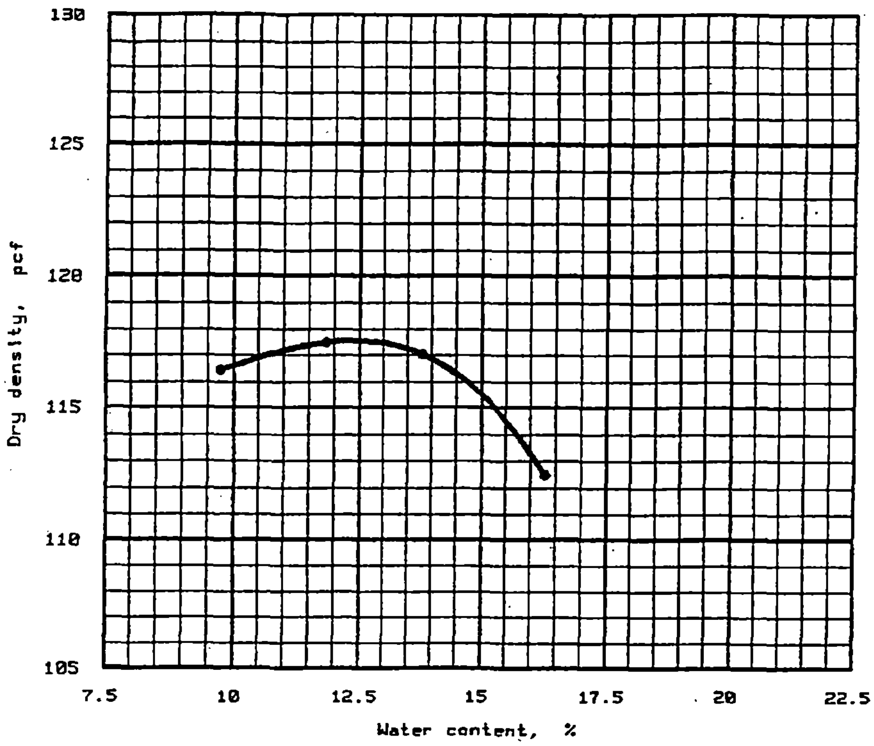
Purpose: The moisture-density relationship of a given soil is determined to provide an index unit weight that can be compared to the field compacted unit weight. The maximum dry unit weight determined using this test method is termed 100 percent of Modified Proctor.

Procedure: The Modified Proctor Test is performed on a bulk soil sample. Gravel (plus No. 4 or plus 3/4 inch, depending on the test method) is removed from the bulk sample. The prepared bulk sample is split to form four to five test specimens. The moisture content of each prepared specimen is adjusted in the laboratory to vary by 1-1/2 to 2 percent from the other prepared specimens.

The prepared soil specimens are compacted in a cylindrical mold in five equal layers to give a total compacted depth of about 5 inches. Each layer is compacted by uniformly distributed blows using a 10 pound, sliding weight hammer and a 18-inch drop. The number of blows used for compaction (25 or 56) depends on the test method. The dry density and compaction moisture content is determined for each compacted test specimen and plotted to provide the moisture-density curve. The maximum dry density and the optimum compaction moisture content for the sample with the gravel removed is determined from the moisture-density curve. The maximum dry density for the bulk sample with gravel is determined using the gravel correction factor as outlined in ASTM Procedures D-4718.

References: ASTM Specification D-1557, "Standard Methods of Test for Moisture-Density Relations of Soils using 10.0 lb. (4.5 Kg) Rammer and 18-inch (457 mm) Drop".

MOISTURE-DENSITY RELATIONSHIP TEST



Test specification: ASTM D 1557-91 Method A, Modified

Elev/ Depth	Classification USCS	Classification AASHTO	Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.200
0-5'								

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 117.5 pcf Optimum moisture = 12.4 %	Tan sandy silt P-2

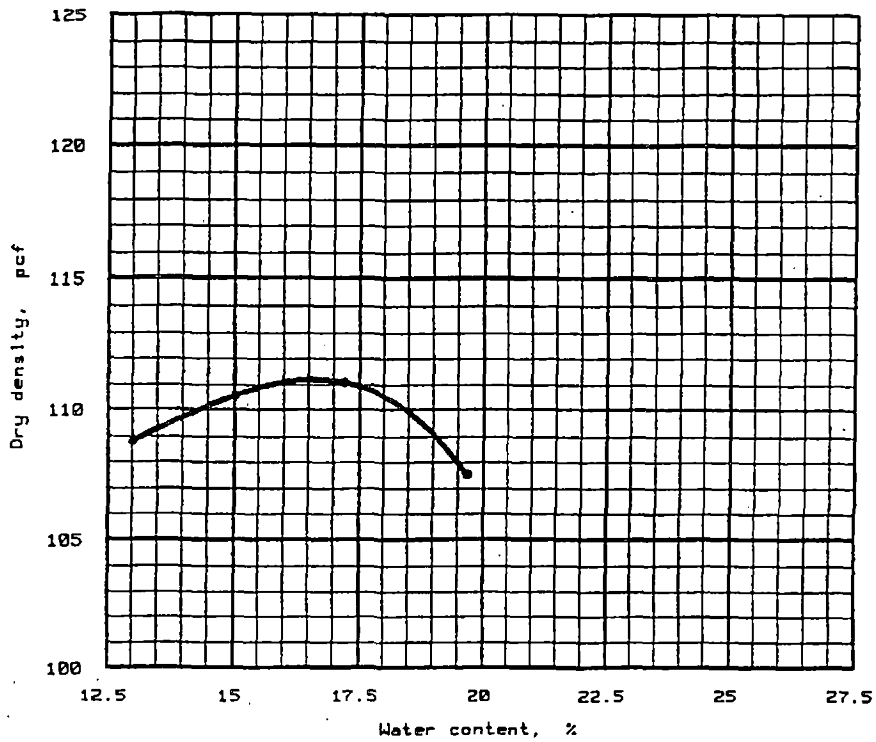
Project No.: V60-073
Project: Soil Borings & Lab Testing
Location: Mineral, Virginia
Control No. 36791
Date: 7-25-1994

Remarks:
Virginia Power
5000 Dominion Boulevard
Glen Allen, VA 23060

MOISTURE-DENSITY RELATIONSHIP TEST
FROEHLING & ROBERTSON, INC.

Fig. No. ______

MOISTURE-DENSITY RELATIONSHIP TEST



Test specification: ASTM D 1557-91 Method A, Modified

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.200
	USCS	AASHTO						
0-5'								

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density • 111.2 pcf Optimum moisture • 16.6 %	Red sandy clay P-3

Project No.: V60-073
Project: Soil Borings & Lab Testing
Location: Mineral, Virginia
Control No. 36781
Date: 7-25-1994

Remarks:
Virginia Power
5000 Dominion Boulevard
Glen Allen, VA 23060

MOISTURE-DENSITY RELATIONSHIP TEST
FROEHLING & ROBERTSON, INC.

Fig. No. ____

CALIFORNIA BEARING RATIO

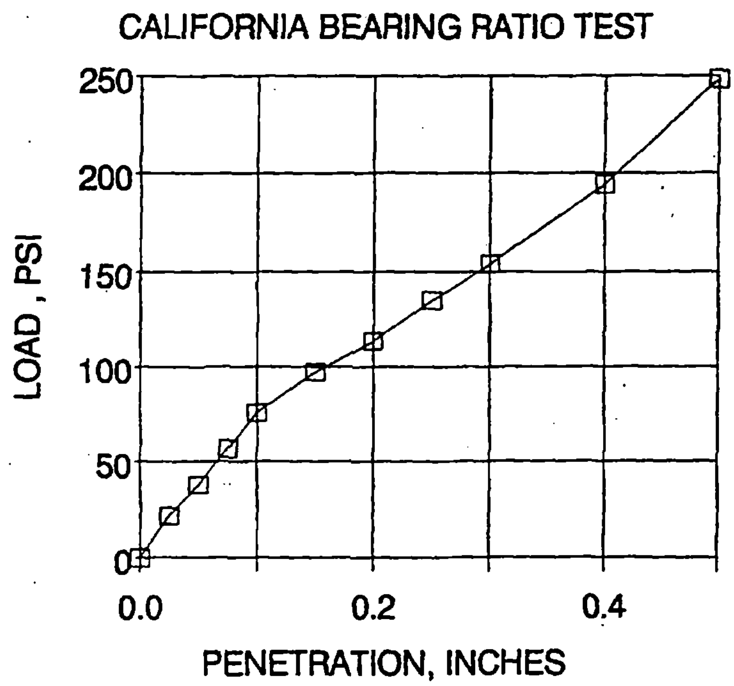
Purpose: The California Bearing Ratio test is performed on subgrade, subbase and base course materials to provide supporting values of various roadway materials which can be used as a basis for pavement design.

Procedure: A sample of the subgrade soil is compacted in a cylindrical mold to the density and moisture anticipated in actual construction. Cohesive soils are allowed to soak, immersed in water for 96 hours. By means of a hydraulic jack, a penetration "needle" is forced into sample at a controlled rate. Load values and corresponding strain or deformation are noted. The ratios of the load values in pounds per square inch at 0.1 inch and 0.2 inch penetration, respectively, are compared to the standard loads of 1000 and 1500 pounds per square inch respectively. (The latter are those loads required to produce the same penetration in a compacted limestone sample.) The CBR in percent is the ratio of the loads at 0.1 penetration multiplied by 100.

References: ASTM Specification D-1883-67", Standard Method of Test for Bearing Ratio of Laboratory-Compacted Soils."

CALIFORNIA BEARING RATIO TEST

Record No.:	V60-073	**Date:**	August 3, 1994
Client:	Virginia Power	**Date Tested:**	August 2, 1994
Project:	Soil Borings & Lab Testing		
Location:	Mineral, Virginia		



CBR (Soaked):	7.6
Swell (%):	0.08
Dry Density Before Soaking:	115.3
% Moisture Before Soaking:	13.3
% Moisture (top 1 in.):	19.1

Sample: P-2 (0-5')
Control No. 36791
Molded in accordance with D-1557

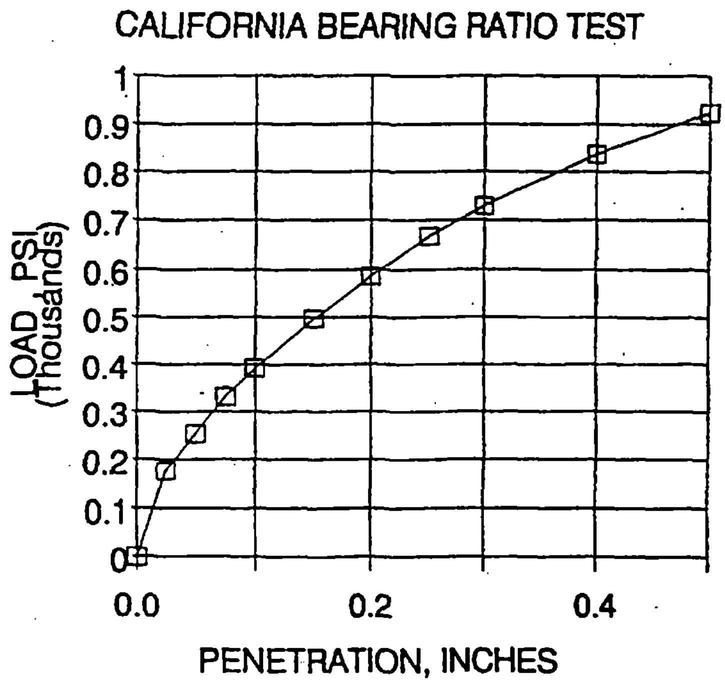
FROEHLING & ROBERTSON, INC.

Reviewed by: [signature]

By: Clyde Mallory
Manager - Soil's Department

CALIFORNIA BEARING RATIO TEST

Record No.:	V60-073	**Date:**	August 16, 1994
Client:	Virginia Power	**Date Tested:**	August 15, 1994
Project:	Soil Borings & Lab Testing		
Location:	Mineral, Virginia		



CBR (DRY)	39.2
Dry Density Before Soaking:	115.5
% Moisture Before Soaking:	13.3

Sample: P-2 (0-5')
Control No. 50055
Molded in accordance with D-1557(dry break)

FROEHLING & ROBERTSON, INC.

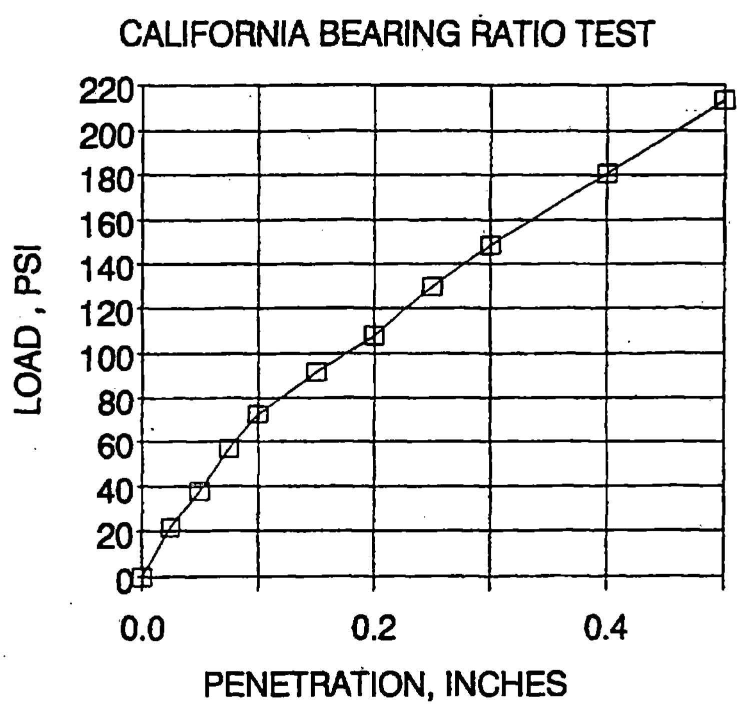
Reviewed by:

By: Clyde Mallory
Manager - Soil's Department

CALIFORNIA BEARING RATIO TEST

Record No.: V60-073
Client: Virginia Power
Project: Soil Borings & Lab Testing
Location: Mineral, Virginia

Date: August 3, 1994
Date Tested: August 2, 1994



CBR (Soaked):	7.3
Swell (%):	1.62
Dry Density Before Soaking:	108.7
% Moisture Before Soaking:	17.5
% Moisture (top 1 in.):	24.2

Sample: P-3 (0-5')
Control No. 36781
Molded in accordance with D-1557

FROEHLING & ROBERTSON, INC.

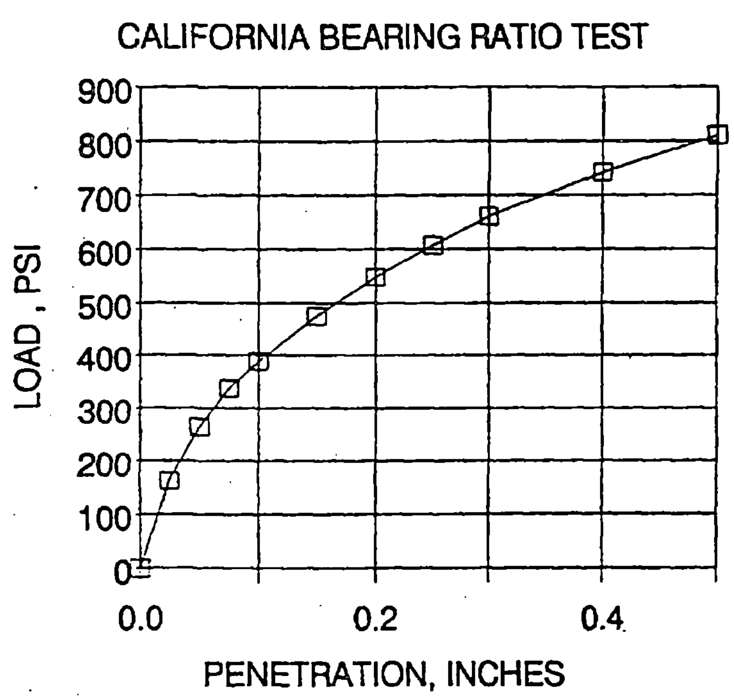
Reviewed by: [signature]

By: Clyde Mallory
Manager - Soil's Department

CALIFORNIA BEARING RATIO TEST

Record No.: V60-073
Client: Virginia Power
Project: Soil Borings & Lab Testing
Location: Mineral, Virginia

Date: August 16, 1994
Date Tested: August 15, 1994



CBR (DRY) 38.9
Dry Density Before Soaking: 108.4
% Moisture Before Soaking: 17.1

Sample: P-3 (0-5')
Control No. 50054
Molded in accordance
with D-1557(dry break)

FROEHLING & ROBERTSON, INC.

By: Clyde Mallory
Manager - Soil's Department

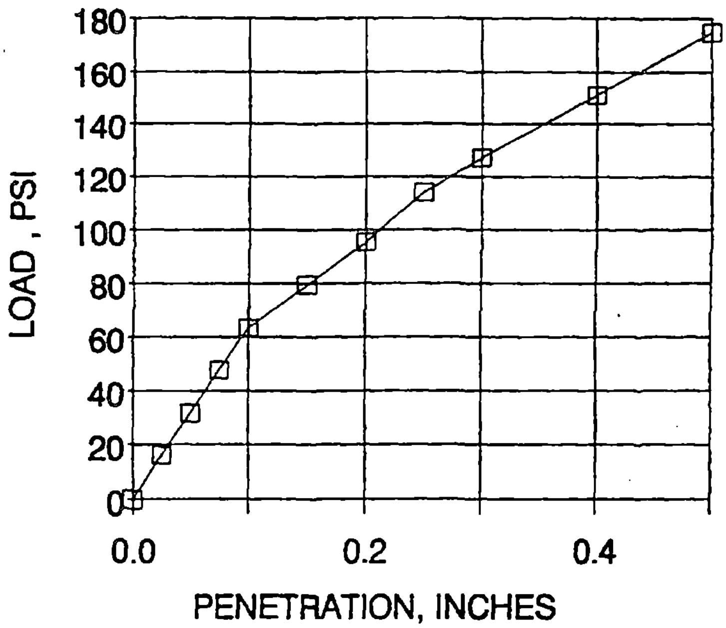
Reviewed by: [signature]

CALIFORNIA BEARING RATIO TEST

Record No.: V60-073
Client: Virginia Power
Project: Soil Borings & Lab Testing
Location: Mineral, Virginia

Date: September 15, 1994
Date Tested: September 15, 1994

CALIFORNIA BEARING RATIO TEST



CBR (DRY)	6.4
Dry Density	79.5
% Moisture	37.1

Sample: *
Control No. 49752

FROEHLING & ROBERTSON, INC.

Reviewed by: [signature]

By: Clyde Mallory
Manager - Soil's Department

* Composite Sample:	F-7A	UD-2	16.0'-18.0'
		UD-3	18.0'-20.0'
		UD-4	20.0'-22.0'

CONSOLIDATION TEST

Objective: Consolidation tests are performed on undisturbed soil samples in order to estimate the settlement resulting from imposed loads. The time required for consolidation and the amount of consolidation settlement can be predicted from this test data.

Procedure: An undisturbed sample is trimmed to fit a consolidometer ring. The trimmed sample has a diameter of 2.5 inches and a height of 1.0 inch. The soil sample is sandwiched between porous stones. A seating pressure is applied and the micrometer dial gauge is adjusted to zero. Load increments are placed on the soil sample at regular intervals (e.g. every 24 hours.) Load increments are determined from anticipated field loading conditions and project requirements. The test results are presented in the form of a void ratio, or an axial strain versus applied pressure curve on a semilogrithmitic graph.

References:

ASTM Specification D-2435, "One-Dimensional Consolidation Properties of Soils".

Engineering Properties of Soil & Their Measurements by Joseph E. Bowles, McGraw-Hill, Inc., "Consolidation Test".

Laboratory Soils Testing, EM-1110-2-1906 by The Department of the Army, Appendix VIII.

Froehling & Robertson, Inc.

CONSOLIDATION TEST

ASTM 2435

CLIENT: Virgina Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V60-073

DATE: August 24, 1994

BORING NO: F-7A SAMPLE NO: UD-1 DEPTH (ft): 4.0-6.0

DESCRIPTION OF SAMPLE: Reddish Brown Clayey Silt

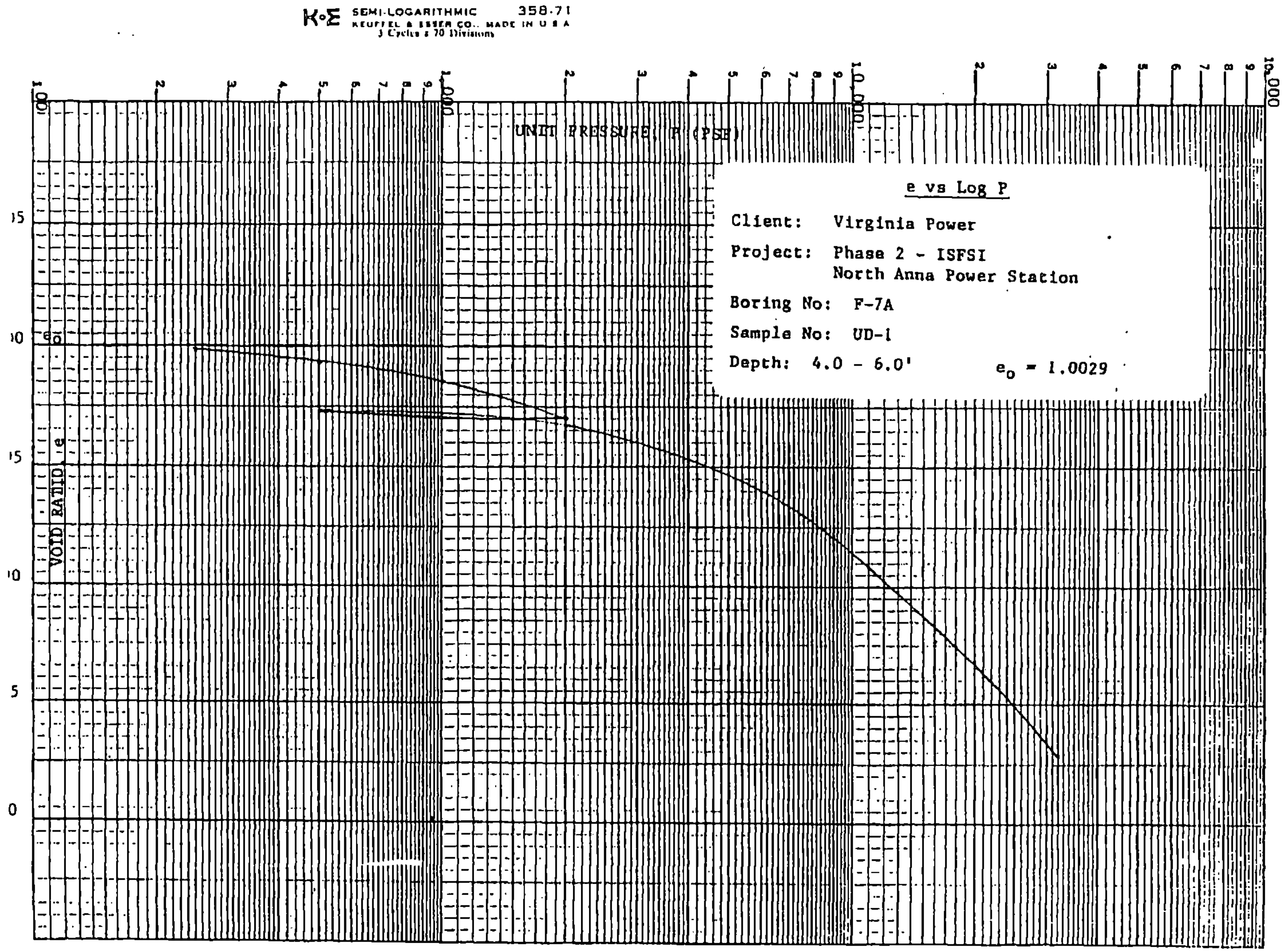
SAMPLE HT: 1.0 in. Specific Gravity: 2.64

RING AREA: 4.909 in^2

Initial Conditions		Final Conditions	
Wt. Cup + Soil Wet	31.20 g	Wt. Ring + Soil Wet	614.70 g
Wt. Cup + Soil Dry	23.40 g	Wt. Ring + Soil Dry	576.30 g
Wt. Water	7.80 g	Wt. Water	38.40 g
Wt. Cup + Soil Dry	23.40 g	Wt. Ring + Soil Dry	576.30 g
Wt. of Cup	1.39 g	Wt. of Ring	473.00 g
Wt. Dry Soil	22.01 g	Wt. Dry Soil	103.30 g
Initial Moisture	35.44 %	Final Moisture	37.17 %

Wt. Ring + Soil Wet	616.60 g
Wt. Ring	473.00 g
Wt. Soil, Wet	143.60 g
Wt. Water	37.57 g
Wt. Dry Soil	0.2337 lbs
Ht. Solids	0.4993 in.
Void Ratio	1.0029
Wet Unit Wt.	111.44 pcf

LOAD INCR. (TSF)	UNIT PRESSURE P (PSF)	INITIAL DIAL READING D_0 (IN.)	FINAL DIAL READING D_{100} (IN.)	RD HS	VOID RATIO e	H (IN.)	T_{90} (MIN.)	CV (IN^2/MIN.)
0.125	250	0.0016	0.0020	0.0040	0.9988	0.9982	0.20	1.0431
0.250	500	0.0033	0.0041	0.0082	0.9946	0.9963	0.49	0.4295
0.500	1000	0.0076	0.0086	0.0172	0.9856	0.9919	0.42	0.4937
1.000	2000	0.0148	0.0164	0.0328	0.9700	0.9844	0.42	0.4862
0.500	1000	0.0161	0.0157	0.0314	0.9714	0.9841	0.16	1.2832
0.250	500	0.0150	0.0146	0.0292	0.9736	0.9852	0.25	0.8231
0.500	1000	0.0148	0.0152	0.0304	0.9724	0.9850	0.25	0.8226
1.000	2000	0.0164	0.0171	0.0342	0.9686	0.9833	0.25	0.8198
2.000	4000	0.0233	0.0250	0.0501	0.9528	0.9759	0.42	0.4778
4.000	8000	0.0392	0.0413	0.0827	0.9201	0.9598	0.36	0.5424
8.000	16000	0.0601	0.0633	0.1268	0.8761	0.9383	0.42	0.4418
16.000	32000	0.0803	0.0864	0.1730	0.8298	0.9167	0.56	0.3167


K·E SEMI-LOGARITHMIC 358-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 Cycles x 70 Divisions
UNIT PRESSURE, P (PSF)
VOID RATIO, e
e vs Log P
Client: Virginia Power
Project: Phase 2 - ISFSI
North Anna Power Station
Boring No: F-7A
Sample No: UD-1
Depth: 4.0 - 6.0'
e0 = 1.0029

Froehling & Robertson, Inc.

CONSOLIDATION TEST

ASTM 2435

CLIENT: Virgina Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V60-073

DATE: August 24, 1994

BORING NO: F-7A SAMPLE NO: UD-2 DEPTH (ft.): 16.0-18.0

DESCRIPTION OF SAMPLE: Red and Brown Silty Fine Sand

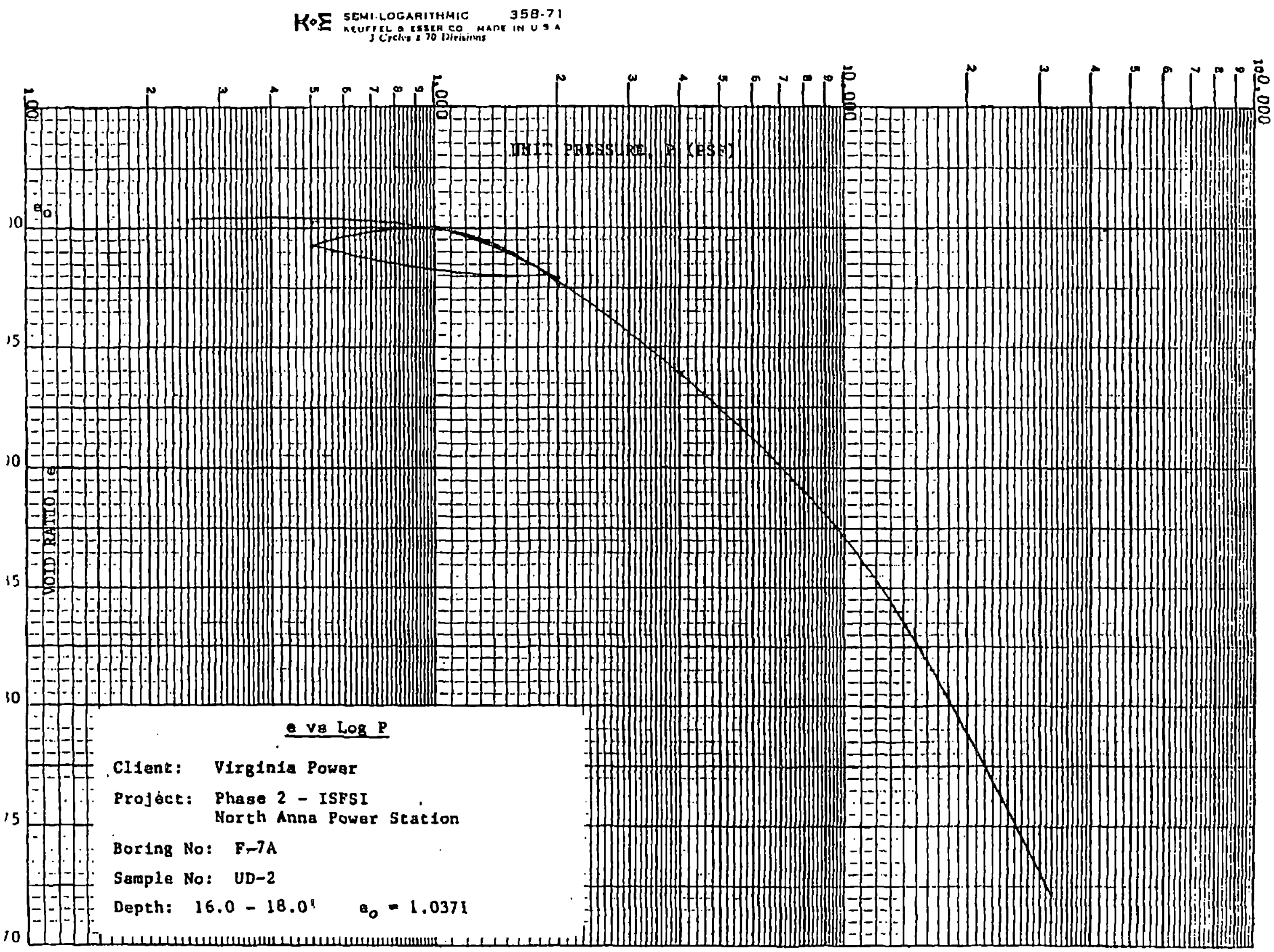
SAMPLE HT: 1.0 in. Specific Gravity: 2.64

RING AREA: 4.909 in^2

Initial Conditions		Final Conditions	
Wt. Cup + Soil Wet	13.98 g	Wt. Ring + Soil Wet	795.50 g
Wt. Cup + Soil Dry	10.93 g	Wt. Ring + Soil Dry	761.80 g
Wt. Water	3.05 g	Wt. Water	33.70 g
Wt. Cup + Soil Dry	10.93 g	Wt. Ring + Soil Dry	761.80 g
Wt. of Cup	1.34 g	Wt. of Ring	657.80 g
Wt. Dry Soil	9.59 g	Wt. Dry Soil	104.00 g
Initial Moisture	31.80 %	Final Moisture	32.40 %

Wt. Ring + Soil Wet	795.20 g
Wt. Ring	657.80 g
Wt. Soil, Wet	137.40 g
Wt. Water	33.15 g
Wt. Dry Soil	0.2298 lbs
Ht. Solids	0.4909 in.
Void Ratio	1.0371
Wet Unit Wt.	106.63 pcf

LOAD INCR. (TSF)	UNIT PRESSURE P (PSF)	INITIAL DIAL READING D_0 (IN.)	FINAL DIAL READING D_{100} (IN.)	RD HS	VOID RATIO e	H (IN.)	T_{50} (MIN.)	CV (IN^2/MIN.)
0.125	250	0.0015	0.0022	0.0045	1.0326	0.9982	0.30	0.6982
0.250	500	0.0053	0.0063	0.0128	1.0242	0.9942	0.42	0.4960
0.500	1000	0.0126	0.0144	0.0293	1.0077	0.9865	0.36	0.5731
1.000	2000	0.0254	0.0288	0.0587	0.9784	0.9729	0.36	0.5574
0.500	1000	0.0273	0.0265	0.0540	0.9831	0.9731	0.42	0.4751
0.250	500	0.0237	0.0221	0.0450	0.9920	0.9771	0.49	0.4131
0.500	1000	0.0134	0.0141	0.0287	1.0083	0.9863	0.36	0.5728
1.000	2000	0.0285	0.0297	0.0605	0.9766	0.9709	0.42	0.4730
2.000	4000	0.0441	0.0477	0.0972	0.9399	0.9541	0.42	0.4568
4.000	8000	0.0674	0.0720	0.1467	0.8904	0.9303	0.36	0.5097
8.000	16000	0.1166	0.1226	0.2497	0.7873	0.8804	0.30	0.5432
16.000	32000	0.1466	0.1545	0.3147	0.7223	0.8495	0.56	0.2719


SEMI-LOGARITHMIC 358-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 Cycles x 70 Divisions
UNIT PRESSURE, P (PSF)
VOID RATIO, e
e vs Log P
Client: Virginia Power
Project: Phase 2 - ISFSI
North Anna Power Station
Boring No: F-7A
Sample No: UD-2
Depth: 16.0 - 18.0' e_o = 1.0371

ehling & Robertson, Inc.

CONSOLIDATION TEST

ASTM 2435.

CLIENT: Virgina Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V60-073

DATE: August 24, 1994

BORING NO: F-9A SAMPLE NO: UD-1 DEPTH (ft.): 4.0-6.0

DESCRIPTION OF SAMPLE: Red & Brown Silty Fine Sand

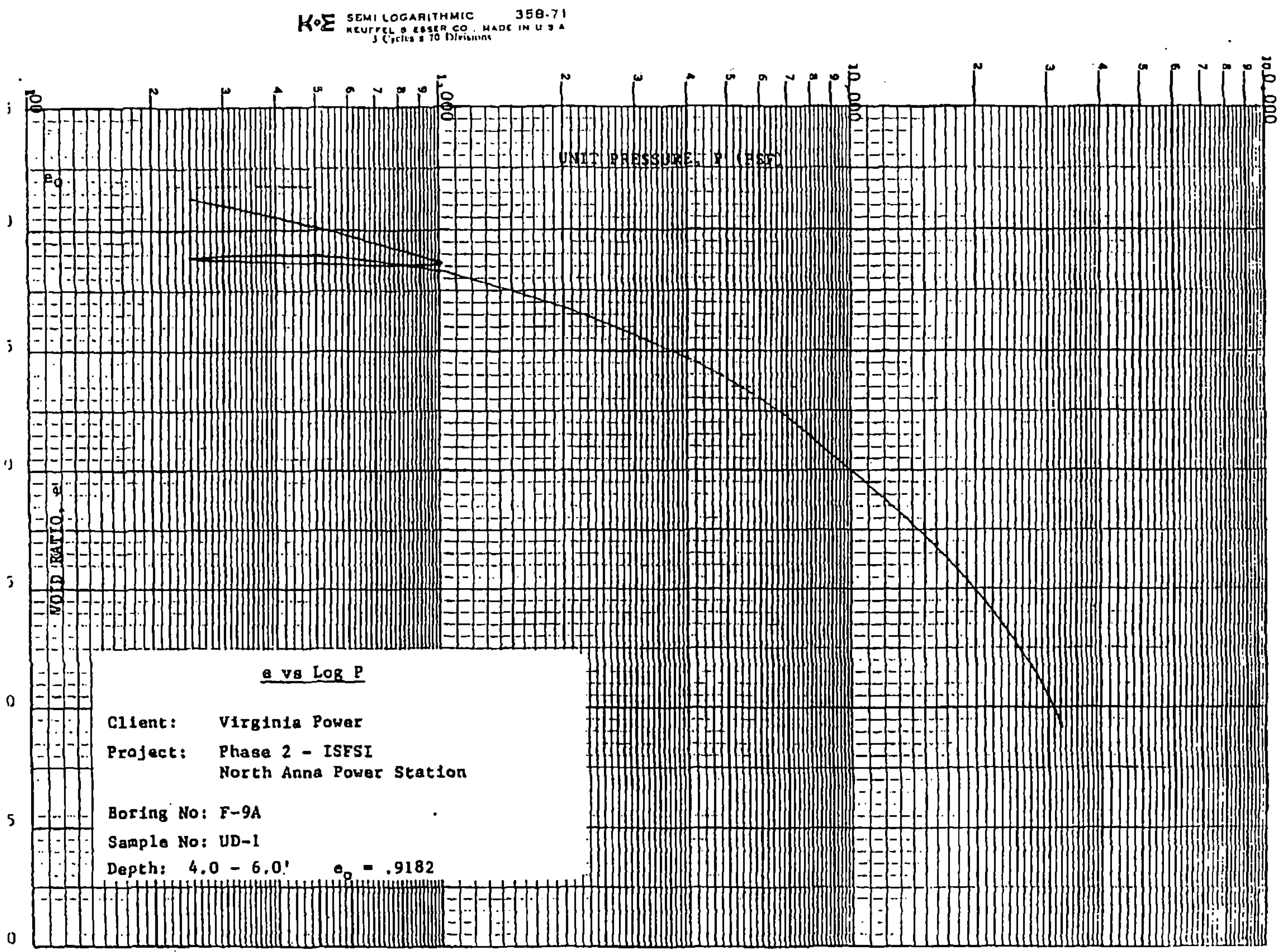
SAMPLE HT: 1.0 in. Specific Gravity: 2.64

RING AREA: 4.909 in²

Initial Conditions		Final Conditions	
Wt. Cup + Soil Wet	24.52 g	Wt. Ring + Soil Wet	615.80 g
Wt. Cup + Soil Dry	19.49 g	Wt. Ring + Soil Dry	579.20 g
Wt. Water	5.03 g	Wt. Water	36.60 g
Wt. Cup + Soil Dry	19.49 g	Wt. Ring + Soil Dry	579.20 g
Wt. of Cup	1.35 g	Wt. of Ring	471.60 g
Wt. Dry Soil	18.14 g	Wt. Dry Soil	107.60 g
Initial Moisture	27.73 %	Final Moisture	34.01 %

Wt. Ring + Soil Wet	613.00 g
Wt. Ring	471.60 g
Wt. Soil, Wet	141.40 g
Wt. Water	30.70 g
Wt. Dry Soil	0.2441 lbs
Ht. Solids	0.5213 in.
Void Ratio	0.9182
Wet Unit Wt.	109.74 pcf

LOAD INCR. (TSF)	UNIT PRESSURE P (PSF)	INITIAL DIAL READING D_0 (IN.)	FINAL DIAL READING D_{100} (IN.)	RD HS	VOID RATIO e	H (IN.)	T_{90} (MIN.)	CV (IN²/MIN.)
0.125	250	0.0013	0.0023	0.0044	0.9138	0.9982	0.36	0.5868
0.250	500	0.0080	0.0092	0.0176	0.9006	0.9914	0.81	0.2572
0.500	1000	0.0153	0.0166	0.0318	0.8864	0.9841	0.30	0.6786
0.250	500	0.0173	0.0166	0.0318	0.8864	0.9831	0.25	0.8195
0.125	250	0.0158	0.0155	0.0297	0.8885	0.9844	0.09	2.2824
0.250	500	0.0157	0.0161	0.0309	0.8873	0.9841	0.25	0.8212
0.500	1000	0.0171	0.0178	0.0341	0.8841	0.9826	0.16	1.2792
1.000	2000	0.0248	0.0262	0.0503	0.8680	0.9745	0.42	0.4765
2.000	4000	0.0358	0.0371	0.0712	0.8471	0.9636	0.36	0.5467
4.000	8000	0.0520	0.0539	0.1034	0.8148	0.9471	0.30	0.6286
8.000	16000	0.0732	0.0778	0.1492	0.7690	0.9245	0.25	0.7248
16.000	32000	0.1090	0.1166	0.2237	0.6946	0.8872	0.56	0.2967


K&E SEMI LOGARITHMIC 358-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 Cycles x 10 Divisions
UNIT PRESSURE, P (PSF)
100
1,000
10,000
100,000
VOID RATIO, e
e vs Log P
Client: Virginia Power
Project: Phase 2 - ISFSI
North Anna Power Station
Boring No: F-9A
Sample No: UD-1
Depth: 4.0 - 6.0' e_o = .9182

TRIAXIAL COMPRESSION TEST

Objective: The triaxial compression test is performed to estimate the shear strength of a soil under controlled drainage conditions. Sheer strength is expressed in terms of the angle of internal friction (O) and the cohesion intercept (c).

Procedure: Triaxial tests on undisturbed soil samples may be: (1) unconsolidated undrained, "UU"; (2) consolidated undrained, "CU"; or (3) consolidated drained, "CD". The type of test is selected to best represent the field and loading conditions. Back pressure is often applied to facilitate complete saturation. Pore water pressure readings may also be taken to determine the effective stresses and defective angle of internal friction.

In the triaxial test, a cylindrical specimen of soil, encased in a rubber membrane, is placed in a compression chamber, subjected to a confining fluid pressure and then loaded axially to failure. Connections at the ends of the specimen permit controlled drainage of pore water from the specimen. Also, pore pressure readings can be recorded as the axial load is applied. In general, a minimum of three specimens, each under a different confining pressure, are tested to establish the relation between shear stress and normal stress. The test results are represented by a plot of shear versus axial stress (Mohr Circle Diagram).

References: ASTM Specification D-2850, "Standard Method of Test for Unconsolidated Undrained Strength of Cohesive Soils in Triaxial Compression."

Laboratory Soils Testing, EM 1110-2-1906, by The Department of the Army, Appendixes X, XA, & XB

Engineering Properties of Soils & Their Measurements, by Joseph E. Bowles, McGraw-Hill Book Company

The Measurement of Soil Properties in the Triaxial Test, by Bishop & Henkel, 2nd Edition 1962, Edward Arnold Publishers, LTD.

FROEHLING & ROBERTSON, INC.

TRIAXIAL COMPRESSION TEST

Date: August 28, 1984

TEST TYPE: Consolidated Undrained with Pore Pressure Readings
CLIENT: Virginia Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V80-073

BORING NO: F-7A DEPTH (FT.): 18.0-20.0 SAMPLE NO: UD-3

SAMPLE DIAMETER	2.81 IN.
SAMPLE HEIGHT	6.00 IN.
SAMPLE AREA	6.20 SQ. IN.
SAMPLE VOLUME	37.21 CU. IN.
SAMPLE WEIGHT	1055.1 GRAMS
MOISTURE CONTENT	39.0 %
UNIT WEIGHT (WET)	108.0 PCF
UNIT WEIGHT (DRY)	77.7 PCF

CHAMBER PRESSURE	65.0 PSI
BACKPRESSURE	60.0 PSI
CONFINING PRESSURE	5.0 PSI
B CHECK	
PISTON FRICTION	259 IN.x10-4
LOADING RATE	0.06 IN./MIN.
VOLUME CHANGE	ML.
CORRECTED AREA	6.20 SQ. IN.
CORRECTED HEIGHT	6.00 IN.

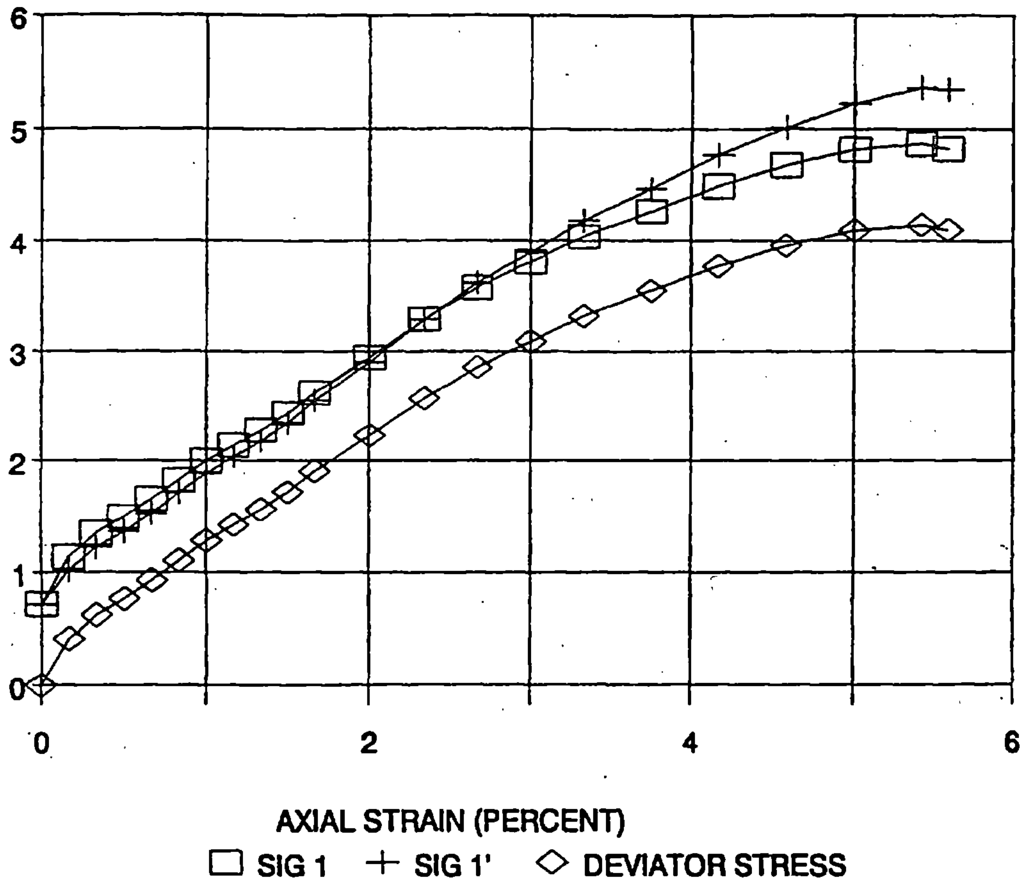
-ADING MBER	LOAD DIAL (IN.-4)	PORE PRESSURE (PSI)	DEFORMA-TION (IN.)	UNIT STRAIN (%)	AXIAL LOAD (LBS)	AREA CORR. (in.²)	SIG 1 (PSF)	SIG 3 (PSF)	SIG 1' (PSF)	SIG 3' (PSF)	DEVIATOR STRESS (PSF)	STRESS RATIO	Ā
0	259.0	60.0	0.000	0.00	0.0	6.20	720.0	720.0	720.0	720.0	0.0	1.0	0.0
1	261.0	60.8	0.010	0.17	17.9	6.21	1134.9	720.0	1018.7	604.8	414.9	1.7	0.3
2	293.0	60.9	0.020	0.33	27.1	6.22	1348.0	720.0	1218.4	590.4	628.0	2.1	0.1
3	301.0	60.9	0.030	0.50	33.3	6.23	1489.3	720.0	1359.7	590.4	769.3	2.3	0.0
4	310.0	60.9	0.040	0.67	40.2	6.24	1647.8	720.0	1518.2	590.4	927.8	2.6	0.0
5	320.0	60.8	0.050	0.83	47.9	6.25	1823.8	720.0	1708.4	604.8	1103.8	2.8	-0.1
6	330.0	60.8	0.060	1.00	55.6	6.26	1998.7	720.0	1883.5	604.8	1278.7	3.1	0.0
7	338.0	60.7	0.070	1.17	61.8	6.27	2138.0	720.0	2037.2	619.2	1418.0	3.3	-0.1
8	346.0	60.7	0.080	1.33	67.9	6.28	2276.7	720.0	2175.9	619.2	1556.7	3.5	0.0
9	355.0	60.6	0.090	1.50	74.9	6.30	2432.8	720.0	2348.2	633.6	1712.8	3.7	-0.1
10	366.0	60.5	0.100	1.67	83.3	6.31	2623.1	720.0	2551.1	648.0	1903.1	3.9	-0.1
11	385.0	60.3	0.120	2.00	98.0	6.33	2949.5	720.0	2906.3	676.8	2229.5	4.3	-0.1
12	405.0	60.0	0.140	2.33	113.4	6.35	3291.2	720.0	3291.2	720.0	2571.2	4.6	-0.1
13	422.0	59.7	0.160	2.67	126.5	6.37	3578.3	720.0	3621.5	763.2	2858.3	4.7	-0.2
14	436.0	59.4	0.180	3.00	137.2	6.39	3811.3	720.0	3897.7	806.4	3091.3	4.8	-0.2
15	450.0	59.0	0.200	3.33	148.0	6.42	4042.7	720.0	4186.7	864.0	3322.7	4.8	-0.2
16	464.0	58.6	0.225	3.75	158.8	6.44	4268.3	720.0	4470.8	921.6	3548.3	4.9	-0.3
17	478.0	58.1	0.250	4.17	169.6	6.47	4493.8	720.0	4787.4	993.6	3773.8	4.8	-0.3
18	490.0	57.7	0.275	4.58	178.8	6.50	4682.1	720.0	5013.3	1051.2	3962.1	4.8	-0.3
19	499.0	57.2	0.300	5.00	185.6	6.53	4817.7	720.0	5220.9	1123.2	4097.7	4.6	-0.5
20	503.0	56.6	0.325	5.42	188.8	6.56	4867.3	770.0	5358.9	1209.6	4147.3	4.4	-1.7
21	501.0	56.4	0.335	5.58	187.3	6.57	4826.3	720.0	5344.7	1238.4	4106.3	4.3	0.7

MAX. DEVIATOR STRESS: 4147.3 PSF
MAX. STRESS RATIO: 4.9

02B032

STRESS VS STRAIN

CONFINING PRESSURE, 5 psi



FROEHLING & ROBERTSON, INC.

TRIAXIAL COMPRESSION TEST

Date: August 26, 1994

TEST TYPE: Consolidated Undrained with Pore Pressure Readings
CLIENT: Virginia Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V60-073

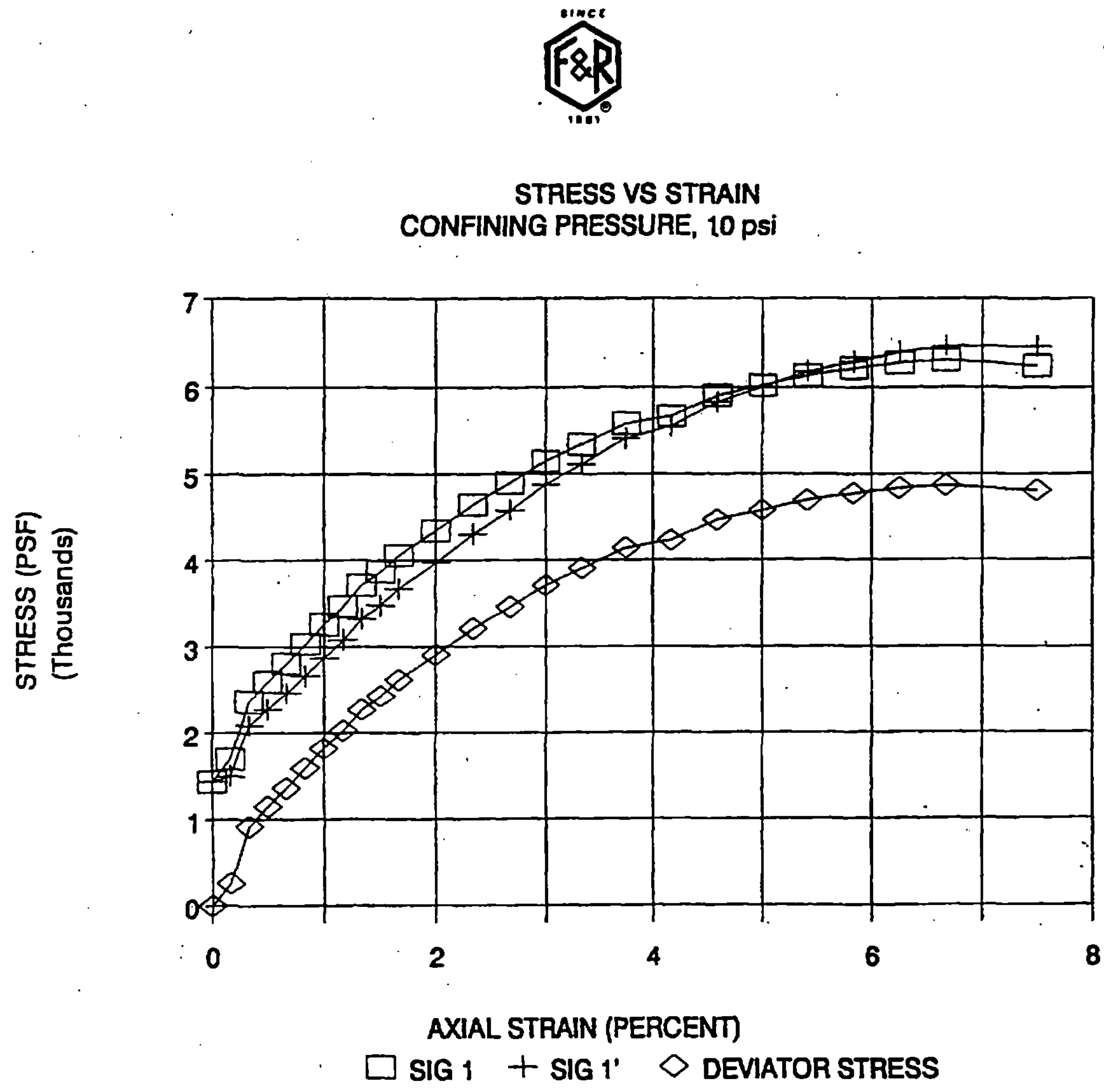
BORING NO: F-7A DEPTH (FT.): 18.0-20.0 SAMPLE NO: UD-3

SAMPLE DIAMETER	2.81 IN.
SAMPLE HEIGHT	6.00 IN.
SAMPLE AREA	6.20 SQ. IN.
SAMPLE VOLUME	37.21 CU. IN.
SAMPLE WEIGHT	1065.6 GRAMS
MOISTURE CONTENT	32.6 %
UNIT WEIGHT (WET)	109.1 PCF
UNIT WEIGHT (DRY)	82.3 PCF

CHAMBER PRESSURE	80.0 PSI
BACKPRESSURE	70.0 PSI
CONFINING PRESSURE	10.0 PSI
B CHECK	
PISTON FRICTION	270 IN.x10-4
LOADING RATE	0.06 IN./MIN.
VOLUME CHANGE	ML
CORRECTED AREA	6.20 SQ. IN.
CORRECTED HEIGHT	6.00 IN.

ADING NUMBER	LOAD DIAL (IN.-4)	PORE PRESSURE (PSI)	DEFORMATION (IN.)	UNIT STRAIN (%)	AXIAL LOAD (LBS)	AREA CORR. (in.²)	SIG 1 (PSF)	SIG 3 (PSF)	SIG 1' (PSF)	SIG 3' (PSF)	DEVIATOR STRESS (PSF)	STRESS RATIO	Ā
0	270.0	70.0	0.000	0.00	5.2	6.20	1440.0	1440.0	1440.0	1440.0	0.0	1.0	0.0
1	278.0	71.4	0.010	0.17	11.4	6.21	1704.4	1440.0	1502.8	1238.4	264.4	1.2	0.8
2	315.0	71.9	0.020	0.33	38.9	6.22	2363.3	1440.0	2068.7	1166.4	923.3	1.8	0.1
3	328.0	72.2	0.030	0.50	48.9	6.23	2593.0	1440.0	2278.2	1123.2	1153.0	2.0	0.2
4	340.0	72.4	0.040	0.67	58.1	6.24	2804.2	1440.0	2458.8	1094.4	1364.2	2.2	0.1
5	353.0	72.8	0.050	0.83	68.2	6.25	3032.4	1440.0	2658.0	1065.6	1592.4	2.5	0.1
6	368.0	72.7	0.060	1.00	78.2	6.26	3258.8	1440.0	2871.0	1051.2	1818.8	2.7	0.1
7	378.0	72.7	0.070	1.17	88.4	6.27	3468.8	1440.0	3080.0	1051.2	2028.8	2.9	0.0
8	392.0	72.7	0.080	1.33	99.2	6.28	3712.4	1440.0	3323.6	1051.2	2272.4	3.2	0.0
9	401.0	72.7	0.090	1.50	106.1	6.30	3867.0	1440.0	3478.2	1051.2	2427.0	3.3	0.0
10	412.0	72.7	0.100	1.67	114.8	6.31	4058.3	1440.0	3667.5	1051.2	2618.3	3.5	0.0
11	429.0	72.8	0.120	2.00	127.7	6.33	4345.3	1440.0	3870.9	1065.6	2905.3	3.7	0.0
12	447.0	72.4	0.140	2.33	141.5	6.35	4649.8	1440.0	4304.2	1094.4	3209.8	3.8	-0.1
13	462.0	72.2	0.160	2.67	153.1	6.37	4899.9	1440.0	4583.1	1123.2	3459.9	4.1	-0.1
14	477.0	71.9	0.180	3.00	164.6	6.39	5148.2	1440.0	4874.6	1166.4	3708.2	4.2	-0.2
15	489.0	71.6	0.200	3.33	173.9	6.42	5342.6	1440.0	5112.4	1209.6	3902.6	4.2	-0.2
16	504.0	71.2	0.225	3.75	185.4	6.44	5584.2	1440.0	5411.4	1267.2	4144.2	4.3	-0.2
17	510.0	70.8	0.250	4.17	190.0	6.47	5669.0	1440.0	5553.8	1324.8	4229.0	4.2	-0.7
18	525.0	70.5	0.275	4.58	201.6	6.50	5908.5	1440.0	5834.5	1368.0	4468.5	4.3	-0.2
19	533.0	70.1	0.300	5.00	207.8	6.53	6022.9	1440.0	6008.5	1425.6	4582.9	4.2	-0.5
20	541.0	69.7	0.325	5.42	213.9	6.56	6136.1	1440.0	6181.3	1483.2	4696.1	4.2	-0.5
21	547.0	69.5	0.350	5.83	218.5	6.59	6218.4	1440.0	6290.4	1512.0	4778.4	4.2	-0.4
22	552.0	69.2	0.375	6.25	222.4	6.62	6281.1	1440.0	6386.3	1555.2	4841.1	4.1	-0.7
23	555.0	68.9	0.400	6.67	224.7	6.64	6308.7	1440.0	6466.1	1598.4	4868.7	4.0	-1.5
24	554.0	68.5	0.450	7.50	223.8	6.70	6249.8	1440.0	6465.6	1656.0	4809.8	3.8	1.0

X. DEVIATOR STRESS: 4868.7 PSF
. STRESS RATIO: 4.3


STRESS VS STRAIN
CONFINING PRESSURE, 10 psi
STRESS (PSF)
(Thousands)
7
6
5
4
3
2
1
0
0
2
4
6
8
AXIAL STRAIN (PERCENT)
SIG 1
SIG 1'
DEVIATOR STRESS

FROEHLING & ROBERTSON, INC.

TRIAXIAL COMPRESSION TEST

Date: August 24, 1994

TEST TYPE: Consolidated Undrained with Pore Pressure Readings
CLIENT: Virginia Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V60-073

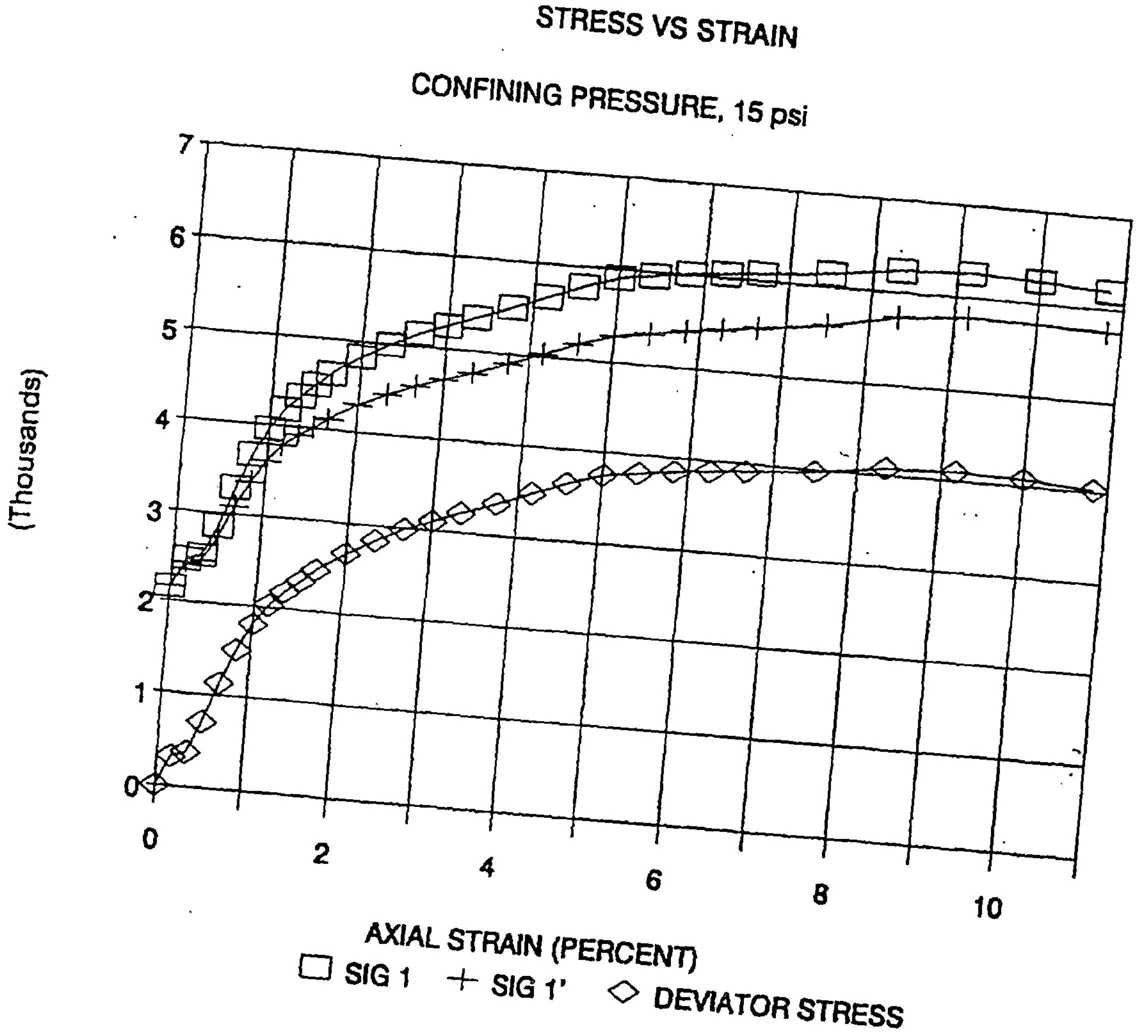
BORING NO: F-7A DEPTH (FT.): 16.0-18.0 SAMPLE NO: UD-2

SAMPLE DIAMETER	2.81 IN.
SAMPLE HEIGHT	6.00 IN.
SAMPLE AREA	6.20 SQ. IN.
SAMPLE VOLUME	37.21 CU. IN.
SAMPLE WEIGHT	1039.9 GRAMS
MOISTURE CONTENT	38.8 %
UNIT WEIGHT (WET)	106.5 PCF
UNIT WEIGHT (DRY)	76.7 PCF

CHAMBER PRESSURE	45.0 PSI
BACKPRESSURE	30.0 PSI
CONFINING PRESSURE	15.0 PSI
B CHECK	
PISTON FRICTION	173 IN.x10-4
LOADING RATE	0.06 IN./MIN.
VOLUME CHANGE	ML
CORRECTED AREA	6.20 SQ. IN.
CORRECTED HEIGHT	6.00 IN.

READING NUMBER	LOAD DIAL (IN.-4)	PORE PRESSURE (PSI)	DEFORMA-TION (IN.)	UNIT STRAIN (%)	AXIAL LOAD (LBS)	AREA CORR. (in.²)	SIG 1 (PSF)	SIG 3 (PSF)	SIG 1' (PSF)	SIG 3' (PSF)	DEVIATOR STRESS (PSF)	STRESS RATIO	Ā
0	173.0	30.0	0.000	0.00	0.0	6.20	2160.0	2160.0	2160.0	2160.0	0.0	1.0	0.0
1	209.0	30.3	0.010	0.17	13.7	6.21	2477.3	2160.0	2434.1	2116.8	317.3	1.1	0.1
2	215.0	30.4	0.020	0.33	18.0	6.22	2529.8	2160.0	2472.0	2102.4	369.8	1.2	0.3
3	253.0	30.9	0.030	0.50	30.4	6.23	2862.8	2160.0	2733.2	2030.4	702.8	1.3	0.2
4	279.0	31.4	0.040	0.67	49.1	6.24	3291.5	2160.0	3089.9	1958.4	1131.5	1.6	0.2
5	300.0	32.1	0.050	0.83	65.2	6.25	3661.9	2160.0	3358.5	1857.6	1501.9	1.8	0.3
6	317.0	32.5	0.060	1.00	78.3	6.26	3960.3	2160.0	3600.3	1800.0	1800.3	2.0	0.2
7	330.0	32.8	0.070	1.17	88.3	6.27	4187.0	2160.0	3783.8	1756.8	2027.0	2.2	0.2
8	339.0	33.0	0.080	1.33	95.3	6.29	4342.4	2160.0	3910.4	1728.0	2182.4	2.3	0.2
9	347.0	33.3	0.090	1.50	101.4	6.30	4478.8	2160.0	4004.4	1684.8	2318.8	2.4	0.3
10	353.0	33.5	0.100	1.67	107.6	6.31	4616.3	2160.0	4112.3	1656.0	2456.3	2.5	0.2
11	368.0	33.7	0.120	2.00	117.9	6.33	4835.8	2160.0	4303.0	1627.2	2675.8	2.6	0.1
12	378.0	33.9	0.140	2.33	125.3	6.35	5001.3	2160.0	4430.7	1598.4	2841.3	2.8	0.2
13	387.0	34.1	0.160	2.67	132.2	6.37	5148.2	2160.0	4557.8	1569.6	2988.2	2.9	0.2
14	394.0	34.2	0.180	3.00	137.6	6.39	5258.4	2160.0	4654.8	1555.2	3098.4	3.0	0.1
15	401.0	34.3	0.200	3.33	143.0	6.42	5369.7	2160.0	4750.5	1540.8	3209.7	3.1	0.1
16	410.0	34.3	0.225	3.75	148.9	6.44	5510.8	2160.0	4891.6	1540.8	3350.8	3.2	0.0
17	419.0	34.3	0.250	4.17	156.8	6.47	5650.5	2160.0	5031.3	1540.8	3490.5	3.3	0.0
18	428.0	34.3	0.275	4.58	163.6	6.50	5788.8	2160.0	5169.6	1540.8	3628.8	3.4	0.0
19	436.0	34.3	0.300	5.00	169.9	6.53	5908.9	2160.0	5289.7	1540.8	3748.9	3.4	0.0
20	440.0	34.3	0.325	5.42	173.0	6.56	5960.1	2160.0	5340.9	1540.8	3800.1	3.5	0.0
21	444.0	34.2	0.350	5.83	176.1	6.59	6010.7	2160.0	5405.9	1555.2	3850.7	3.5	-0.3
22	447.0	34.1	0.375	6.25	178.4	6.62	6043.9	2160.0	5453.5	1569.6	3883.9	3.5	-0.4
23	450.0	34.0	0.400	6.67	180.7	6.64	6078.7	2160.0	5500.7	1584.0	3918.7	3.5	-0.4
24	458.0	33.8	0.450	7.50	185.3	6.70	6141.0	2160.0	5583.8	1612.8	3981.0	3.5	-0.4
25	464.0	33.6	0.500	8.33	191.5	6.77	6236.3	2160.0	5732.3	1656.0	4076.3	3.5	-0.6
26	468.0	33.3	0.550	9.17	194.6	6.83	6264.2	2160.0	5788.0	1684.8	4104.2	3.4	-1.0
27	469.0	33.2	0.600	10.00	196.4	6.89	6242.6	2160.0	5781.8	1699.2	4082.6	3.4	0.7
28	466.0	33.0	0.650	10.83	194.6	6.96	6188.9	2160.0	5756.9	1728.0	4028.9	3.3	0.5

MAX. DEVIATOR STRESS: 4104.2 PSF
MAX. STRESS RATIO: 3.5


STRESS VS STRAIN
CONFINING PRESSURE, 15 psi
(Thousands)
7
6
5
4
3
2
1
0
0
2
4
6
8
10
AXIAL STRAIN (PERCENT)
SIG 1
SIG 1'
DEVIATOR STRESS

FROEHLING & ROBERTSON, INC.

TRIAXIAL COMPRESSION TEST

Date: September 7, 1994

TEST TYPE: Consolidated Undrained with Pore Pressure Readings
CLIENT: Virginia Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V90-073

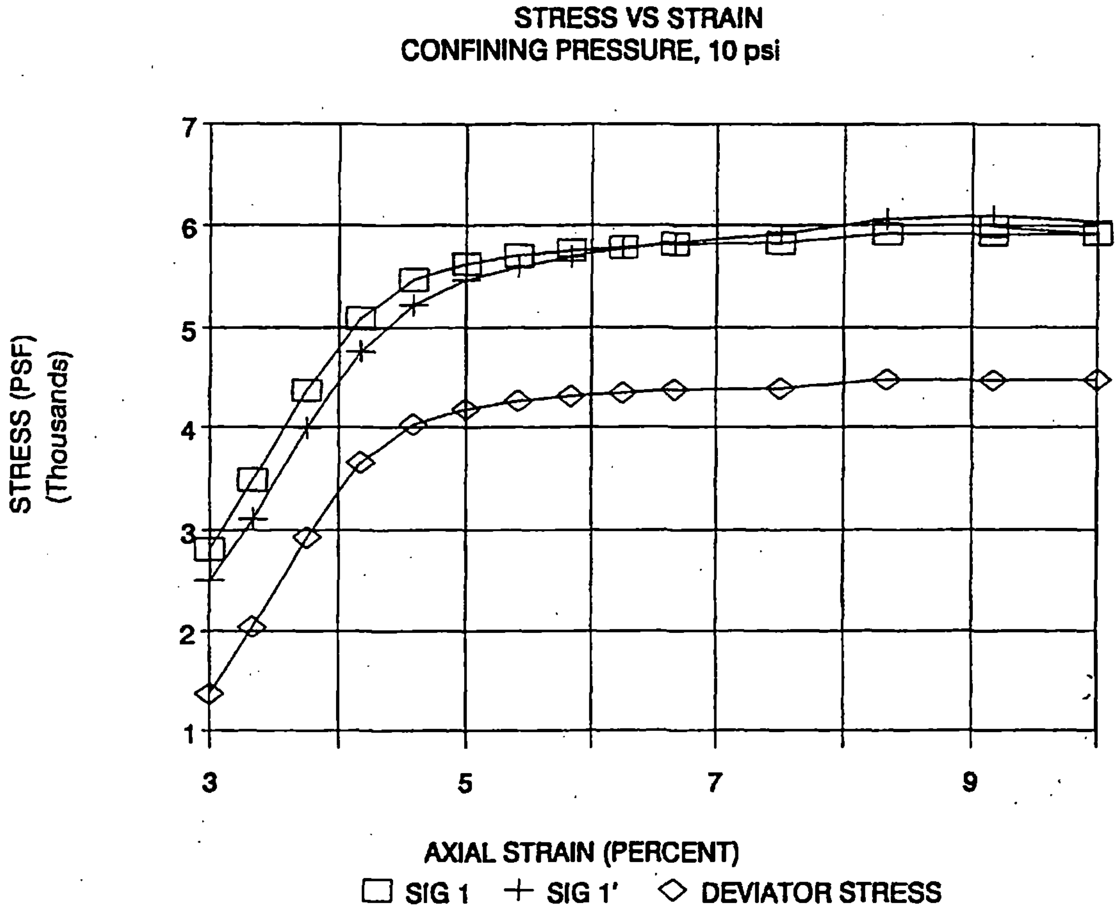
BORING NO: F-7A DEPTH (FT.): 18.0-20.0 SAMPLE NO: UD-3

SAMPLE DIAMETER	2.81 IN.
SAMPLE HEIGHT	6.00 IN.
SAMPLE AREA	6.20 SQ. IN.
SAMPLE VOLUME	37.21 CU. IN.
SAMPLE WEIGHT	1094.9 GRAMS
MOISTURE CONTENT	39.0 %
UNIT WEIGHT (WET)	111.1 PCF
UNIT WEIGHT (DRY)	79.9 PCF

CHAMBER PRESSURE	65.0 PSI
BACKPRESSURE	55.0 PSI
CONFINING PRESSURE	10.0 PSI
B CHECK	
PISTON FRICTION	227 IN.x10-4
LOADING RATE	0.06 IN./MIN.
VOLUME CHANGE	ML.
CORRECTED AREA	6.20 SQ. IN.
CORRECTED HEIGHT	6.00 IN.

READING NUMBER	LOAD DIAL (IN.-4)	PORE PRESSURE (PSI)	DEFORMATION (IN.)	UNIT STRAIN (%)	AXIAL LOAD (LBS)	AREA CORR. (in.²)	SIG 1 (PSF)	SIG 3 (PSF)	SIG 1' (PSF)	SIG 3' (PSF)	DEVIATOR STRESS (PSF)	STRESS RATIO	Ā
1	321.0	57.1	0.180	3.00	60.9	6.39	2810.9	1440.0	2508.6	1137.6	1370.9	2.2	0.0
2	380.0	57.6	0.200	3.33	90.9	6.42	3480.2	1440.0	3105.8	1065.6	2040.2	2.9	0.1
3	412.0	57.6	0.225	3.75	130.9	6.44	4366.3	1440.0	3991.9	1065.6	2926.3	3.7	0.0
4	455.0	57.3	0.250	4.17	164.0	6.47	5090.4	1440.0	4759.2	1108.8	3650.4	4.3	-0.1
5	478.0	56.7	0.275	4.58	181.8	6.50	5467.0	1440.0	5222.2	1195.2	4027.0	4.4	-0.2
6	488.0	56.1	0.300	5.00	189.5	6.53	5618.2	1440.0	5460.8	1281.6	4178.2	4.3	-0.8
7	494.0	55.8	0.325	5.42	194.1	6.56	5702.4	1440.0	5587.2	1324.8	4262.4	4.2	-0.5
8	498.0	55.4	0.350	5.83	197.2	6.59	5750.9	1440.0	5693.3	1382.4	4310.9	4.1	-1.2
9	501.0	55.1	0.375	6.25	198.5	6.62	5782.1	1440.0	5767.7	1425.6	4342.1	4.0	-1.4
10	504.0	54.9	0.400	6.67	201.9	6.64	5812.9	1440.0	5827.3	1454.4	4372.9	4.0	-0.8
11	507.0	54.4	0.450	7.50	204.1	6.70	5823.5	1440.0	5909.9	1526.4	4383.5	3.9	-0.8
12	515.0	54.0	0.500	8.33	210.2	6.77	5915.1	1440.0	6059.1	1584.0	4475.1	3.8	-0.8
13	517.0	53.7	0.550	9.17	211.9	6.83	5906.9	1440.0	6094.1	1627.2	4466.9	3.7	8.3
14	520.0	54.1	0.600	10.00	214.1	6.89	5914.2	1440.0	6043.8	1569.6	4474.2	3.9	7.9
15	522.0	53.4	0.550	9.17	215.8	6.83	5988.1	1440.0	6218.5	1670.4	4548.1	3.7	-1.4

MAX. DEVIATOR STRESS: 4548.1 PSF
MAX. STRESS RATIO: 4.4


STRESS VS STRAIN
CONFINING PRESSURE, 10 psi
STRESS (PSF)
(Thousands)
7
6
5
4
3
2
1
3
5
7
9
AXIAL STRAIN (PERCENT)
SIG 1
SIG 1'
DEVIATOR STRESS

FROEHLING & ROBERTSON, INC.

TRIAXIAL COMPRESSION TEST

Date: September 7, 1994

TEST TYPE: Consolidated Undrained with Pore Pressure Readings
CLIENT: Virginia Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V80-073

BORING NO: F-7A DEPTH (FT): 20.0-22.0 SAMPLE NO: UD-4

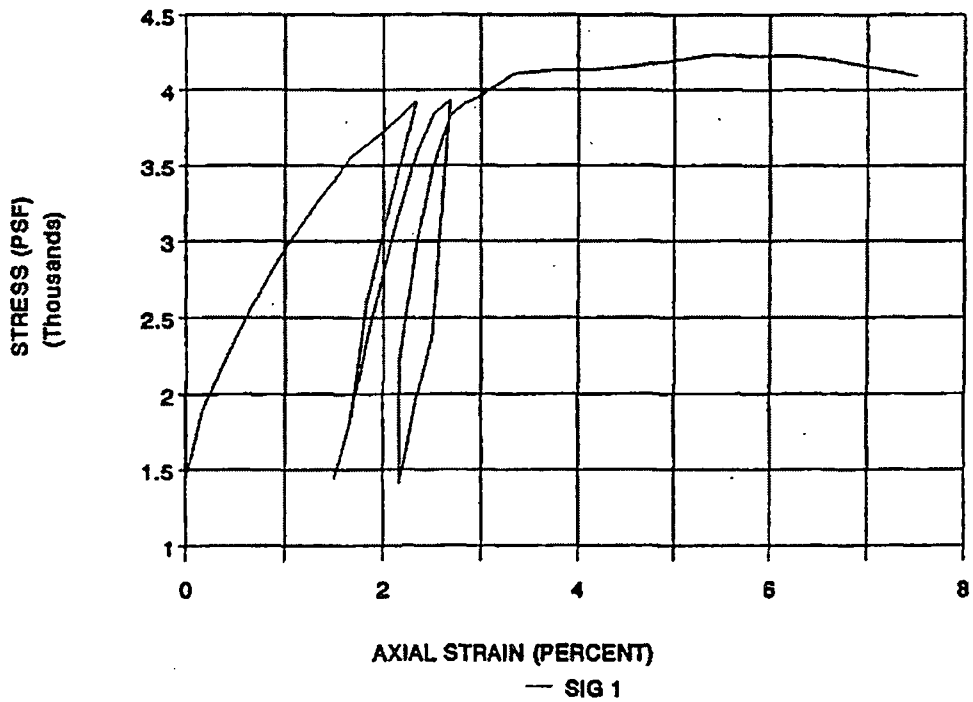
SAMPLE DIAMETER	2.81 IN.
SAMPLE HEIGHT	6.00 IN.
SAMPLE AREA	6.20 SQ. IN.
SAMPLE VOLUME	37.21 CU. IN.
SAMPLE WEIGHT	1043.7 GRAMS
MOISTURE CONTENT	40.8 %
UNIT WEIGHT (WET)	108.8 PCF
UNIT WEIGHT (DRY)	75.8 PCF

CHAMBER PRESSURE	50.0 PSI
BACKPRESSURE	40.0 PSI
CONFINING PRESSURE	10.0 PSI
B CHECK	
PISTON FRICTION	2[illegible] IN.x10-4
LOADING RATE	0.08 IN./MIN.
VOLUME CHANGE	ML.
CORRECTED AREA	6.20 SQ. IN.
CORRECTED HEIGHT	6.00 IN.

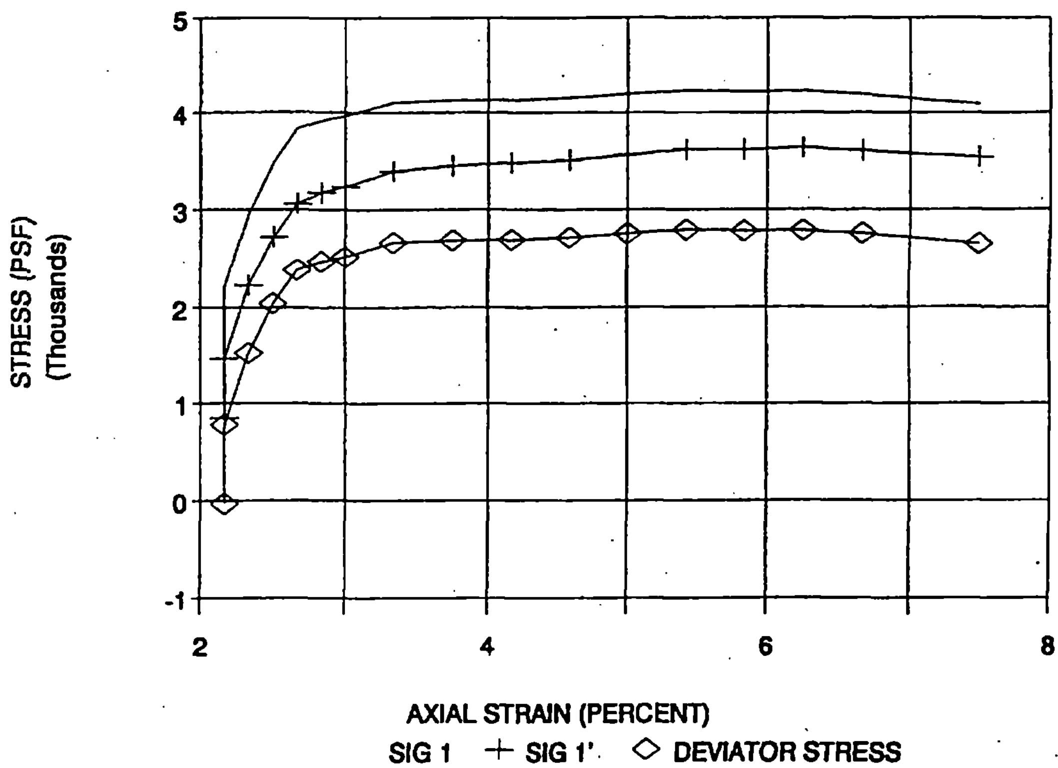
READING NUMBER	LOAD DIAL (IN.-4)	PORE PRESSURE (PSI)	DEFORMATION (IN.)	UNIT STRAIN (%)	AXIAL LOAD (LBS)	AREA CORR. (in.²)	SIG 1 (PSF)	SIG 3 (PSF)	SIG 1' (PSF)	SIG 3' (PSF)	DEVIATOR STRESS (PSF)	STRESS RATIO	Ā
0	290.0	45.0	0.000	0.00	0.0	6.20	1440.0	1440.0	1440.0	1440.0	0.0	1.0	0.0
1	[illegible]	48.0	0.010	0.17	19.4	6.21	1890.6	1440.0	1314.6	864.0	450.6	1.5	1.3
2	297.0	48.4	0.020	0.33	30.2	6.22	2138.3	1440.0	1628.7	830.4	[illegible]	1.9	0.2
3	310.0	48.7	0.030	0.50	40.2	6.23	2368.4	1440.0	1662.8	783.2	[illegible]	2.2	0.2
4	322.0	48.8	0.040	0.67	48.5	6.24	2581.0	1440.0	1873.4	734.4	1141.0	2.6	0.1
5	330.0	50.0	0.050	0.83	57.3	6.25	2774.1	1440.0	2054.1	720.0	1334.1	2.9	0.1
6	343.0	50.1	0.060	1.00	65.8	6.26	2948.9	1440.0	2214.5	705.6	1508.9	3.1	0.1
7	352.0	50.1	0.070	1.17	72.6	6.27	3105.4	1440.0	2371.0	705.6	1665.4	3.4	0.0
8	361.0	50.2	0.080	1.33	78.5	6.28	3261.3	1440.0	2512.5	691.2	1821.3	3.6	0.1
9	369.0	50.1	0.090	1.50	86.7	6.30	3398.1	1440.0	2694.7	705.6	1958.1	3.8	-0.1
10	378.0	50.1	0.100	1.67	92.6	6.31	3554.1	1440.0	2819.7	705.6	2114.1	4.0	0.0
11	389.0	50.1	0.120	2.00	100.3	6.33	3722.1	1440.0	2987.7	705.6	2282.1	4.2	0.0
12	400.0	50.0	0.140	2.33	108.5	6.35	[illegible]	1440.0	[illegible]	720.0	[illegible]	4.4	-0.1
13	375.0	48.8	0.130	2.17	80.3	6.34	3460.6	1440.0	[illegible]	878.4	[illegible]	3.3	0.4
14	350.0	48.7	0.120	2.00	71.0	6.33	[illegible]	1440.0	[illegible]	807.2	1618.3	2.8	0.1
15	325.0	48.8	0.110	1.83	51.8	6.32	2620.2	1440.0	2101.8	921.6	1180.2	2.3	0.0
16	290.0	48.5	0.100	1.67	17.1	6.31	1801.1	1440.0	1227.1	936.0	361.1	1.4	0.0
17	280.0	48.4	0.080	1.50	0.0	6.30	1440.0	1440.0	830.4	830.4	0.0	1.0	0.0
18	290.0	48.0	0.100	1.67	17.1	6.31	1801.1	1440.0	1285.1	864.0	361.1	1.5	0.2
19	310.0	50.0	0.110	1.83	40.2	6.32	[illegible]	1440.0	[illegible]	720.0	[illegible]	2.3	0.3
20	330.0	50.2	0.120	2.00	59.5	6.33	2760.4	1440.0	2044.8	691.2	1320.4	3.0	0.1
21	358.0	50.3	0.130	2.17	77.3	6.34	3163.5	1440.0	2420.3	676.8	1723.5	3.6	0.0
22	380.0	50.3	0.140	2.33	94.1	6.35	3574.7	1440.0	2811.5	676.8	2134.7	4.2	0.0
23	385.0	50.2	0.150	2.50	105.7	6.36	3832.5	1440.0	3080.7	691.2	[illegible]	4.5	-0.1
24	401.0	50.1	0.160	2.67	110.3	6.37	3932.8	1440.0	3198.4	705.6	[illegible]	4.5	-0.1
25	312.0	48.4	0.150	2.50	41.8	6.36	2386.6	1440.0	1730.0	830.4	[illegible]	2.2	0.1
26	[illegible]	48.0	0.140	2.33	23.3	6.35	1968.1	1440.0	1382.1	864.0	528.1	1.6	0.1
27	[illegible]	48.9	0.130	2.17	-1.3	6.34	1405.4	1440.0	[illegible]	678.4	-34.6	1.0	0.0
28	322.0	50.2	0.130	2.17	34.1	6.34	2213.8	1440.0	1488.1	691.2	773.8	2.1	0.2
29	345.0	50.1	0.140	2.33	67.2	6.35	2963.5	1440.0	[illegible]	705.6	[illegible]	3.2	0.0
30	375.0	50.3	0.150	2.50	90.3	6.36	3480.8	1440.0	2720.8	676.8	2040.8	4.0	0.1
31	385.0	50.3	0.160	2.67	102.7	6.37	[illegible]	1440.0	[illegible]	676.8	[illegible]	4.5	0.0
32	400.0	50.1	0.170	2.83	108.5	6.38	3911.2	1440.0	3176.8	705.6	2471.2	4.6	-0.3
33	403.0	50.0	0.180	3.00	111.5	6.39	[illegible]	1440.0	[illegible]	720.0	2518.0	4.5	-0.3
34	412.0	48.9	0.200	3.33	118.8	6.42	4108.9	1440.0	3400.9	734.4	[illegible]	4.6	-0.1
35	414.0	48.7	0.225	3.75	120.3	6.44	4128.8	1440.0	[illegible]	763.2	[illegible]	4.5	-1.5
36	416.0	48.8	0.250	4.17	121.1	6.47	4134.3	1440.0	[illegible]	792.0	[illegible]	4.4	-3.2
37	417.0	48.5	0.275	4.58	122.8	6.50	4138.7	1440.0	3830.7	792.0	2718.7	4.4	0.0
38	420.0	48.4	0.300	5.00	124.8	6.53	4165.8	1440.0	[illegible]	806.4	[illegible]	4.4	-0.4
39	423.0	48.3	0.325	5.42	127.2	6.56	4204.4	1440.0	3818.2	820.8	2764.4	4.4	-0.4
40	423.0	48.2	0.350	5.83	127.2	6.58	4182.1	1440.0	3817.3	835.2	2762.1	4.3	1.2
41	424.0	48.1	0.375	6.25	128.0	6.62	4208.8	1440.0	3808.2	849.6	2768.8	4.3	-0.2
42	423.0	48.1	0.400	6.67	127.2	6.64	4167.8	1440.0	3807.1	849.6	2707.8	4.2	0.0
43	416.0	48.6	0.400	7.50	123.4	6.70	4080.2	1440.0	3543.0	892.8	2600.2	4.0	0.4

MAX. DEVIATOR STRESS: 2764.4 PSF
MAX. STRESS RATIO: 4.6

STRESS VS STRAIN
CONFINING PRESSURE, 10 psi



STRESS VS STRAIN
CONFINING PRESSURE, 10 psi



FROEHLING & ROBERTSON, INC.

TRIAXIAL COMPRESSION TEST

Date: [illegible]

TEST TYPE: [illegible]

CLIENT: [illegible]

PROJECT: [illegible]

F&R NO: [illegible]

BORING NO: [illegible] DEPTH (FT.): [illegible] SAMPLE NO: [illegible]

SAMPLE DIAMETER	[illegible] IN.
SAMPLE HEIGHT	[illegible] IN.
SAMPLE AREA	[illegible] SQ. IN.
SAMPLE VOLUME	[illegible] CU. IN.
SAMPLE WEIGHT	[illegible] GRAMS
MOISTURE CONTENT	[illegible] %
UNIT WEIGHT (WET)	[illegible] PCF
UNIT WEIGHT (DRY)	[illegible] PCF

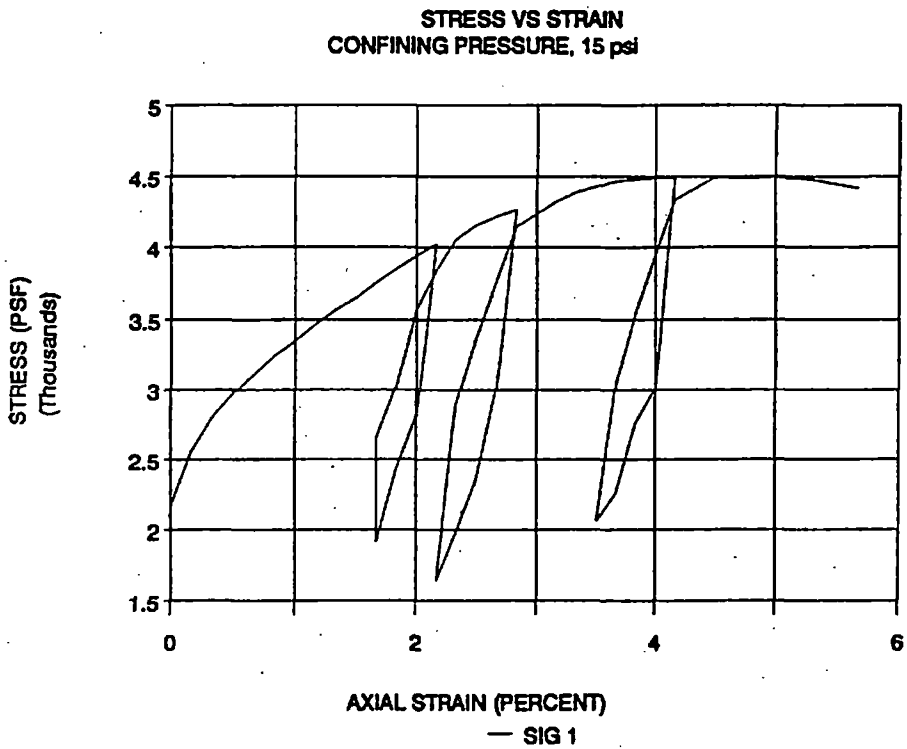
CHAMBER PRESSURE	[illegible] PSI
BACKPRESSURE	[illegible] PSI
CONFINING PRESSURE	[illegible] PSI
B CHECK	
PISTON FRICTION	[illegible]
LOADING RATE	[illegible] IN./MIN.
VOLUME CHANGE	ML.
CORRECTED AREA	[illegible] SQ. IN.
CORRECTED HEIGHT	[illegible] IN.

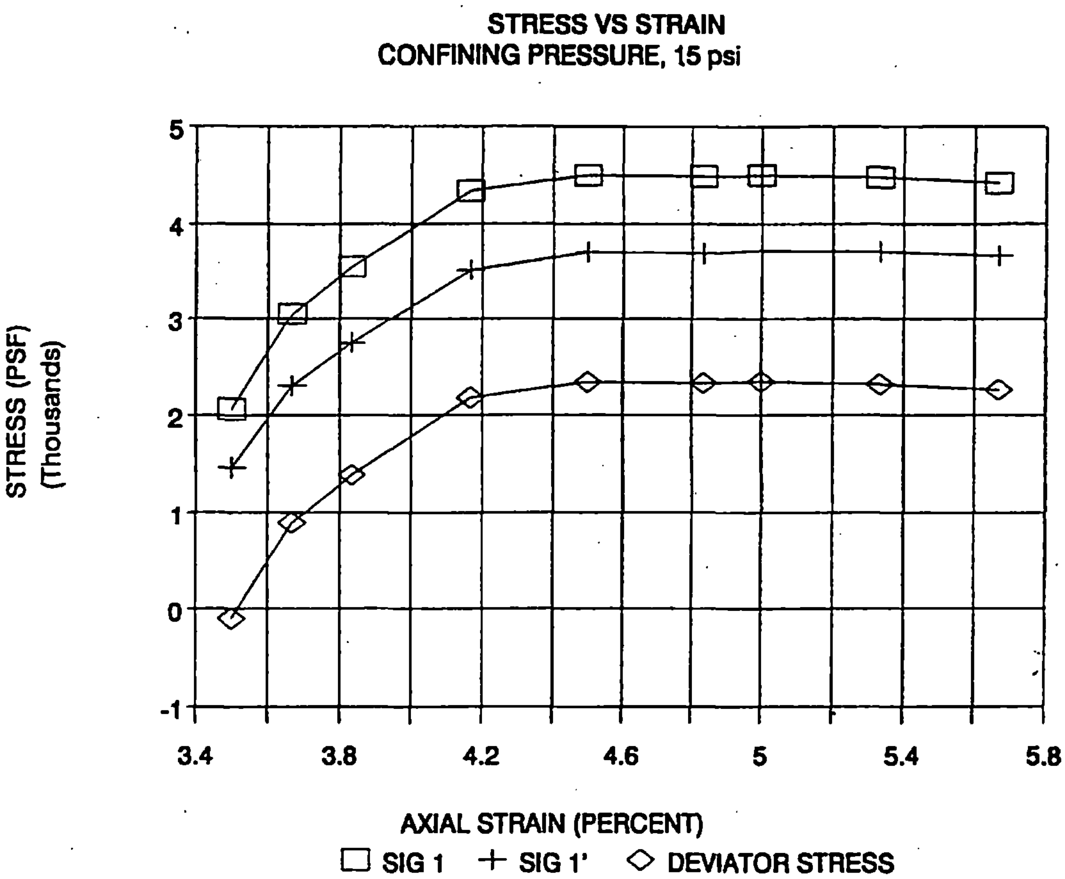
READING NUMBER	LOAD DIAL (IN.-4)	PORE PRESSURE (PSI)	DEFORMATION (IN.)	UNIT STRAIN (%)	AXIAL LOAD (LBS)	AREA CORR (in.²)	SIG 1 (PSF)	SIG 3 (PSF)	SIG 1' (PSF)	SIG 3' (PSF)	DEVIATOR STRESS (PSF)	STRESS RATIO	A
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

MAX. DEVIATOR STRESS: [illegible] PSF

MAX. STRESS RATIO: [illegible]

NI02B043


STRESS VS STRAIN
CONFINING PRESSURE, 15 psi
STRESS (PSF)
(Thousands)
5
4.5
4
3.5
3
2.5
2
1.5
0
2
4
6
AXIAL STRAIN (PERCENT)
— SIG 1


STRESS VS STRAIN
CONFINING PRESSURE, 15 psi
STRESS (PSF)
(Thousands)
5
4
3
2
1
0
-1
3.4
3.8
4.2
4.6
5
5.4
5.8
AXIAL STRAIN (PERCENT)
SIG 1
SIG 1'
DEVIATOR STRESS

TRAIXIAL COMPRESSION TEST

UNCONSOLIDATED UNDRAINED

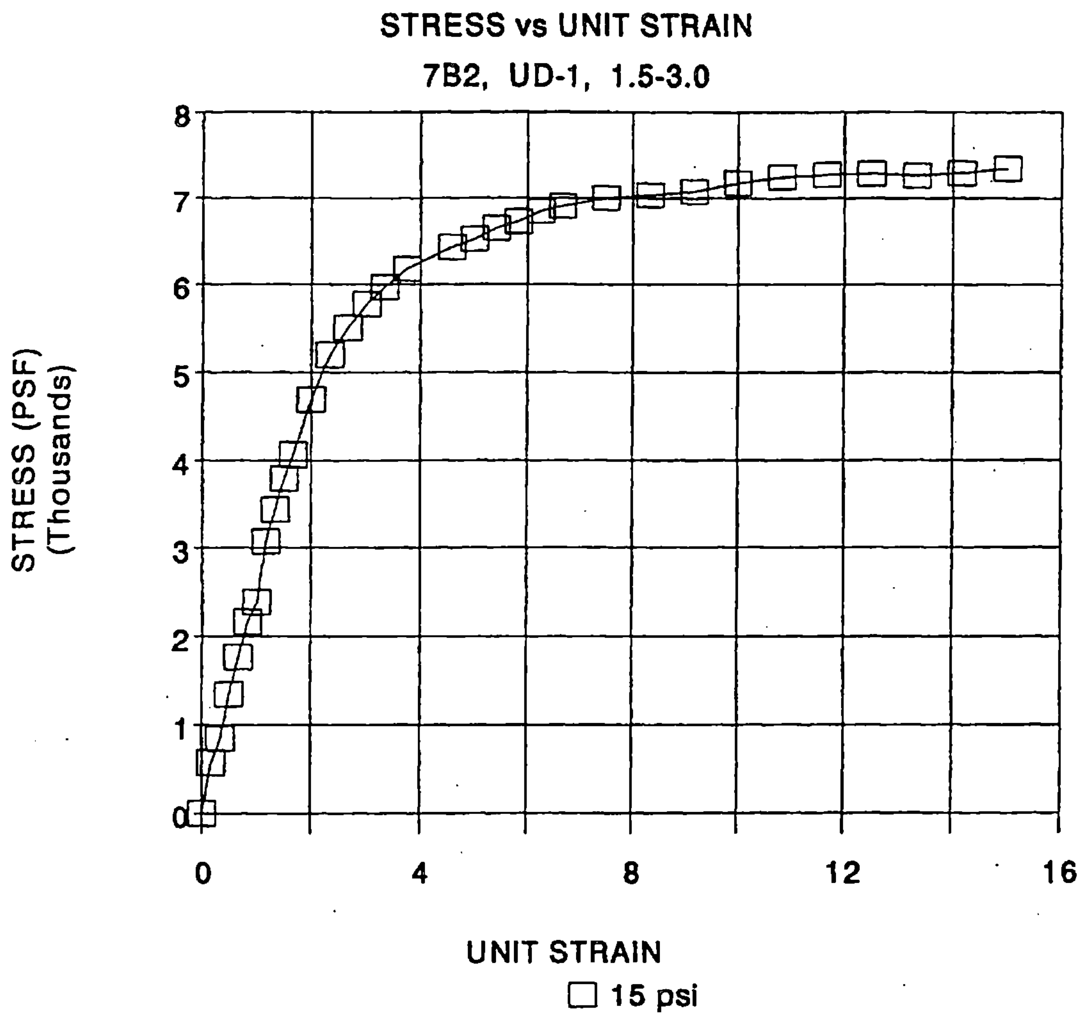
Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Soil Description: Red and Brown Silty Clay
Boring: 7B2
Sample No.: UD-1
Sample Depth (ft): 1.5-3.0

Sample Data: Confining Pressure: 15.0 psi
Diameter 2.81 Inches
Length: 6.0 Inches

READING NUMBER	LOAD DIAL READING	DEFORM. DIAL READING	LOAD	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
0	0	0.000	0.00	0.000	6.20	0.00
1	68	0.010	24.75	0.167	6.21	573.78
2	100	0.020	36.40	0.333	6.22	842.38
3	160	0.030	58.24	0.500	6.23	1345.56
4	210	0.040	76.44	0.667	6.24	1763.09
5	258	0.050	93.91	0.833	6.25	2162.45
6	285	0.060	103.74	1.000	6.26	2384.74
7	305	0.070	134.00	1.167	6.27	3075.16
8	325	0.080	150.00	1.333	6.29	3436.53
9	345	0.090	166.00	1.500	6.30	3796.67
10	360	0.100	178.00	1.667	6.31	4064.24
11	395	0.120	206.00	2.000	6.33	4687.62
12	424	0.140	229.20	2.333	6.35	5197.80
13	442	0.160	243.60	2.667	6.37	5505.51
14	458	0.180	256.40	3.000	6.39	5774.96
15	470	0.200	266.00	3.333	6.42	5970.59
16	483	0.225	276.40	3.750	6.44	6177.29
17	500	0.275	290.00	4.583	6.50	6425.12
18	507	0.300	295.60	5.000	6.53	6520.59
19	516	0.325	302.80	5.417	6.56	6650.12
20	522	0.350	307.60	5.833	6.59	6725.78
21	531	0.375	314.80	6.250	6.62	6852.75
22	536	0.400	318.80	6.667	6.64	6908.98
23	545	0.450	326.00	7.500	6.70	7001.94
24	551	0.500	330.80	8.333	6.77	7041.03
25	557	0.550	335.60	9.167	6.83	7078.25
26	567	0.600	343.60	10.000	6.89	7180.50
27	575	0.650	350.00	10.833	6.96	7246.52
28	581	0.700	354.80	11.667	7.02	7277.25
29	586	0.750	358.80	12.500	7.09	7289.86
30	589	0.800	361.20	13.333	7.16	7268.73
31	595	0.850	366.00	14.167	7.23	7294.51
32	603	0.900	372.40	15.000	7.30	7350.00

MAX AXIAL STRESS: 7350.00

* Shelby tube secured with backhoe


STRESS vs UNIT STRAIN
7B2, UD-1, 1.5-3.0
STRESS (PSF)
(Thousands)
0
1
2
3
4
5
6
7
8
0
4
8
12
16
UNIT STRAIN
15 psi

TRIAXIAL COMPRESSION TEST

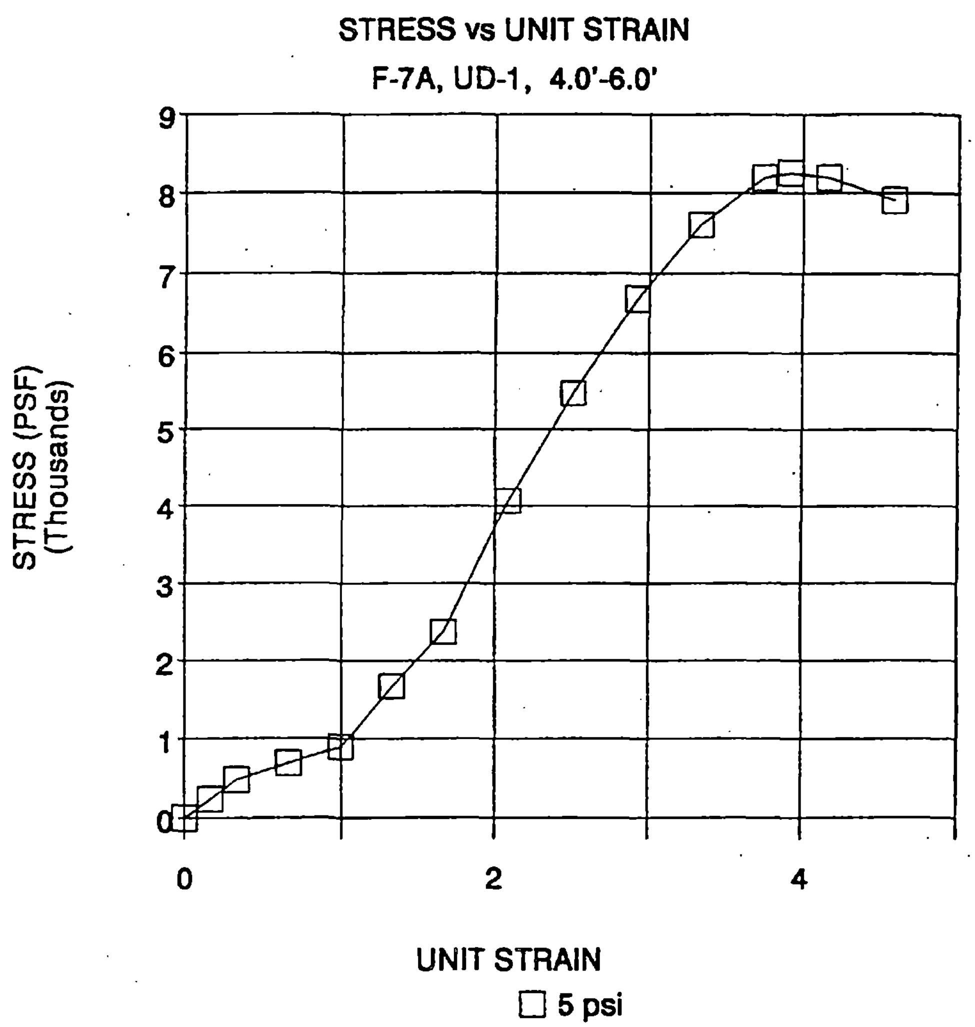
UNCONSOLIDATED UNDRAINED

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Soil Description: Reddish Brown Clayey Silt
Boring: F-7A
Sample No.: UD-1
Sample Depth (ft): 4.0-6.0

Sample Data: Confining Pressure: 5.0 psi
Diameter 2.81 inches
Length: 6.0 inches

READING NUMBER	LOAD DIAL READING	DEFORM. DIAL READING	LOAD	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
0	0	0.000	0.00	0.000	6.20	0.00
1	28	0.010	10.19	0.167	6.21	236.26
2	57	0.020	20.75	0.333	6.22	480.16
3	82	0.040	29.85	0.667	6.24	688.44
4	107	0.060	38.95	1.000	6.26	895.32
5	201	0.080	73.16	1.333	6.29	1676.20
6	286	0.100	104.10	1.667	6.31	2376.99
7	361	0.125	178.80	2.083	6.33	4065.21
8	440	0.150	242.00	2.500	6.36	5478.72
9	508	0.175	296.40	2.917	6.39	6681.62
10	561	0.200	338.80	3.333	6.42	7604.65
11	596	0.225	366.80	3.750	6.44	8197.64
12	600	0.235	370.00	3.917	6.45	8254.84
13	598	0.250	368.40	4.167	6.47	8197.76
14	584	0.275	357.20	4.583	6.50	7913.97

MAX AXIAL STRESS: 8254.84


STRESS vs UNIT STRAIN
F-7A, UD-1, 4.0'-6.0'
STRESS (PSF)
(Thousands)
0
1
2
3
4
5
6
7
8
9
0
2
4
UNIT STRAIN
5 psi

TRIAXIAL COMPRESSION TEST

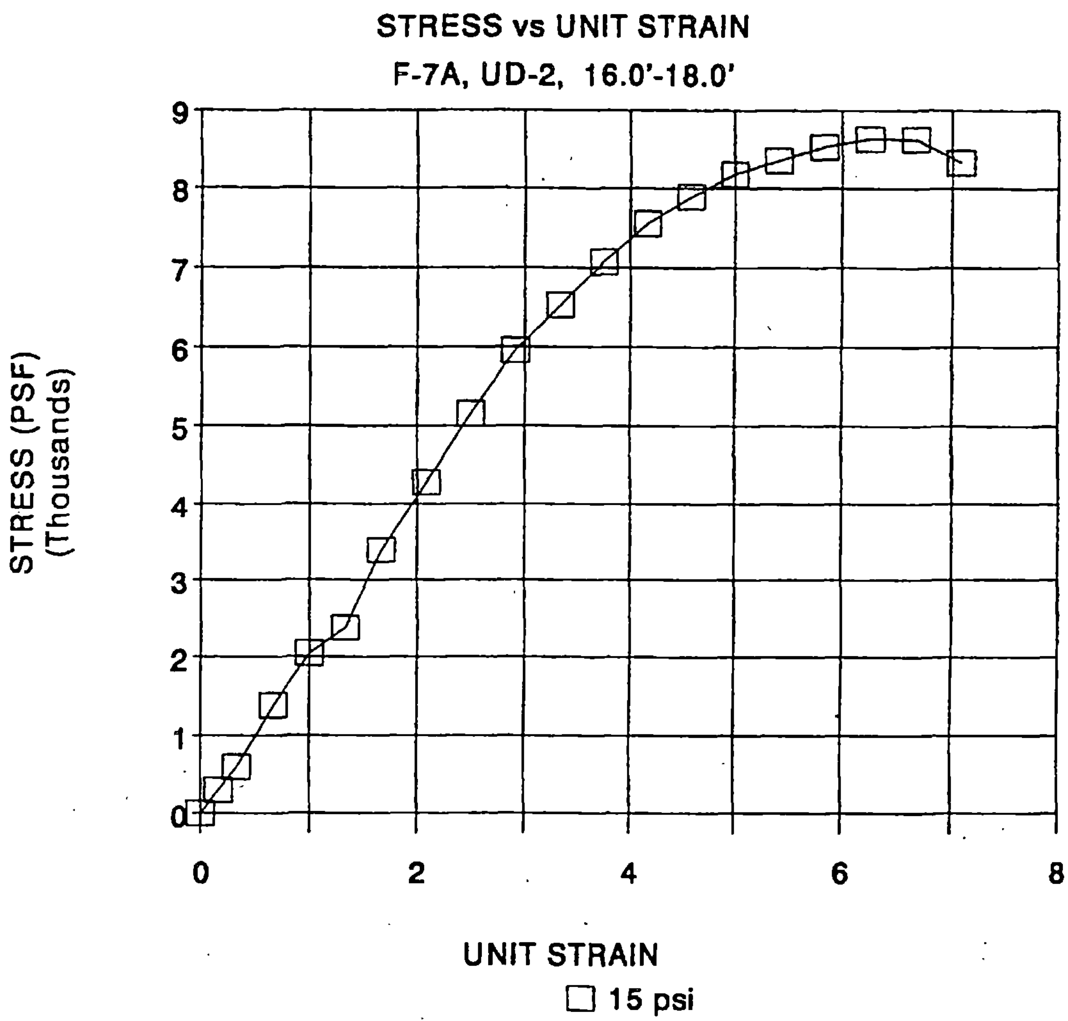
UNCONSOLIDATED UNDRAINED

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Soil Description: Red and Brown Clayey Silt
Boring: F-7A
Sample No.: UD-2
Sample Depth (ft): 16.0-18.0

Sample Data:
Confining Pressure: 15.0 psi
Diameter 2.81 inches
Length: 6.0 inches

READING NUMBER	LOAD DIAL READING	DEFORM. DIAL READING	LOAD	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
0	0	0.000	0.00	0.000	6.20	0.00
1	35	0.010	12.74	0.167	6.21	295.33
2	70	0.020	25.48	0.333	6.22	589.67
3	165	0.040	60.06	0.667	6.24	1385.29
4	245	0.060	89.18	1.000	6.26	2050.04
5	285	0.080	103.74	1.333	6.29	2376.71
6	323	0.100	148.40	1.667	6.31	3388.39
7	373	0.125	188.40	2.083	6.33	4283.48
8	422	0.150	227.60	2.500	6.36	5152.71
9	468	0.175	264.40	2.917	6.39	5960.26
10	501	0.200	290.80	3.333	6.42	6527.25
11	533	0.225	316.40	3.750	6.44	7071.25
12	562	0.250	339.60	4.167	6.47	7556.89
13	583	0.275	356.40	4.583	6.50	7896.25
14	601	0.300	370.80	5.000	6.53	8179.42
15	613	0.325	380.40	5.417	6.56	8354.38
16	625	0.350	390.00	5.833	6.59	8527.48
17	633	0.375	396.40	6.250	6.62	8629.07
18	635	0.400	398.00	6.667	6.64	8625.39
19	620	0.425	386.00	7.083	6.67	8327.98

MAX AXIAL STRESS: 8629.07


STRESS vs UNIT STRAIN
F-7A, UD-2, 16.0'-18.0'
STRESS (PSF)
(Thousands)
0
1
2
3
4
5
6
7
8
9
0
2
4
6
8
UNIT STRAIN
15 psi

TRIAXIAL COMPRESSION TEST

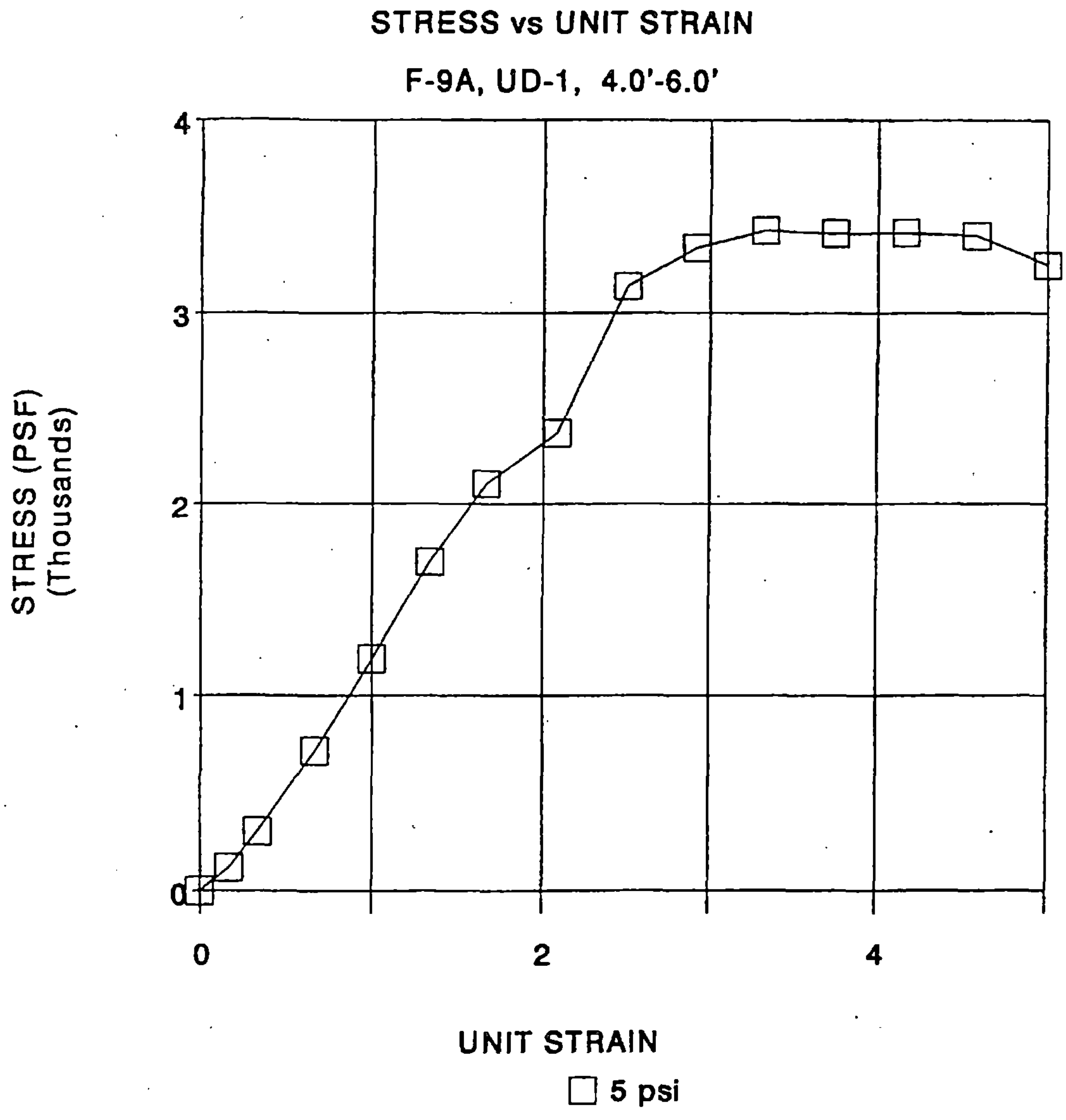
UNCONSOLIDATED UNDRAINED

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Soil Description: Reddish Brown Silty Sand
Boring: F-9A
Sample No.: UD-1
Sample Depth (ft): 4.0-6.0

Sample Data: Confining Pressure: 5.0 psi
Diameter 2.810 inches
Length: 6.0 inches

READING NUMBER	LOAD DIAL READING	DEFORM. DIAL READING	LOAD	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
0	0	0.000	0.00	0.000	6.20	0.00
1	14	0.010	5.10	0.167	6.21	118.13
2	36	0.020	13.10	0.333	6.22	303.26
3	85	0.040	30.94	0.667	6.24	713.63
4	142	0.060	51.69	1.000	6.26	1188.18
5	203	0.080	73.89	1.333	6.29	1692.88
6	254	0.100	92.46	1.667	6.31	2111.03
7	287	0.125	104.47	2.083	6.33	2375.19
8	311	0.150	138.80	2.500	6.36	3142.34
9	323	0.175	148.40	2.917	6.39	3345.32
10	329	0.200	153.20	3.333	6.42	3438.70
11	329	0.225	153.20	3.750	6.44	3423.88
12	330	0.250	154.00	4.167	6.47	3426.86
13	330	0.275	154.00	4.583	6.50	3411.96
14	322	0.300	147.60	5.000	6.53	3255.88

MAX AXIAL STRESS: 3438.70


STRESS vs UNIT STRAIN
F-9A, UD-1, 4.0'-6.0'
STRESS (PSF)
(Thousands)
4
3
2
1
0
0
2
4
UNIT STRAIN
5 psi

TRIAXIAL COMPRESSION TEST

UNCONSOLIDATED UNDRAINED

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Soil Description: Reddish Brown Silty Sand
Boring: F-9A
Sample No.: UD-1
Sample Depth (ft): 4.0-6.0

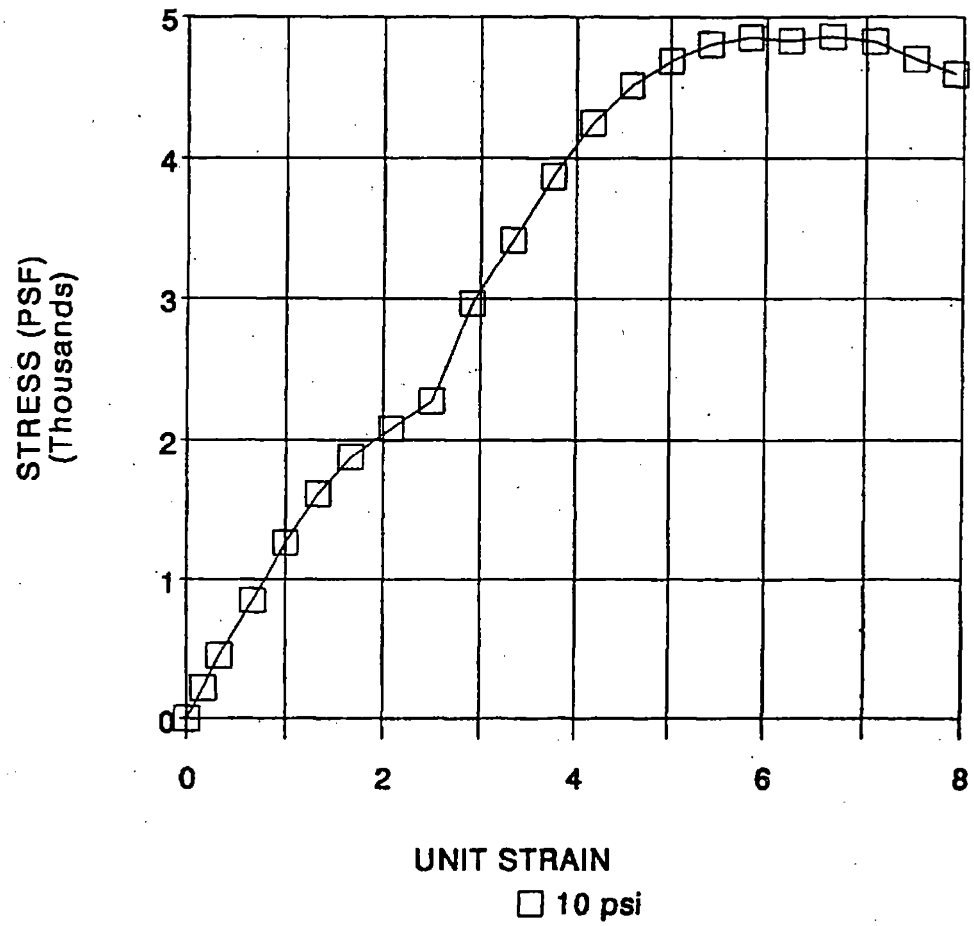
Sample Data: Confining Pressure: 10.0 psi
Diameter 2.810 inches
Length: 6.0 inches

READING NUMBER	LOAD DIAL READING	DEFORM. DIAL READING	LOAD	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
0	0	0.000	0.00	0.000	6.20	0.00
1	26	0.010	9.46	0.167	6.21	219.39
2	53	0.020	19.29	0.333	6.22	446.46
3	101	0.040	36.76	0.667	6.24	847.96
4	151	0.060	54.96	1.000	6.26	1263.49
5	194	0.080	70.62	1.333	6.29	1617.63
6	226	0.100	82.26	1.667	6.31	1878.32
7	251	0.125	91.36	2.083	6.33	2077.26
8	276	0.150	100.46	2.500	6.36	2274.44
9	302	0.175	131.60	2.917	6.39	2966.60
10	328	0.200	152.40	3.333	6.42	3420.74
11	354	0.225	173.20	3.750	6.44	3870.86
12	376	0.250	190.80	4.167	6.47	4245.75
13	392	0.275	203.60	4.583	6.50	4510.88
14	403	0.300	212.40	5.000	6.53	4685.30
15	411	0.325	218.80	5.417	6.56	4805.30
16	415	0.350	222.00	5.833	6.59	4854.10
17	415	0.375	222.00	6.250	6.62	4832.63
18	418	0.400	224.40	6.667	6.64	4863.16
19	417	0.425	223.60	7.083	6.67	4824.19
20	411	0.450	218.80	7.500	6.70	4699.46
21	406	0.475	214.80	7.917	6.73	4592.77

MAX AXIAL STRESS: 4863.16

STRESS vs UNIT STRAIN

F-9A, UD-1, 4.0'-6.0'



UNCONFINED COMPRESSION TEST

Objective: To estimate the load per unit area (compressive strength) that an unconfined, cohesive soil will fail in a simple compression test. The compressive strength is taken as the maximum load (e.g. load at failure) per unit area or the load per unit area at 20% axial strain, whichever occurs first.

Procedure: A cylinder of soil having a height of 1.5 to 2 times the average diameter is loaded to failure, in simple compression, quickly enough that the water content of the soil does not change. The test load is applied using a strain-controlled method. Simultaneous observations are made of the applied load and of the axial strain. The failure load or the load required to produce 20 percent axial strain is expressed as the load per unit of cross-sectional area, in KIPS per square foot.

References: ASTM SPECIFICATION D-2166, "Standard Methods of Test for Unconfined Compressive Strength of Cohesive Soil".

Laboratory Soils Testing, EM 1110-2-1906 by The Department of the Army, Appendix XI.

UNCONFINED COMPRESSION TEST

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: 6B3
Sample: UD-1
Sample Depth (ft): 2.0-3.5
Soil Description: Reddish Brown Clayey Silt

Sample Data:

Height (in):	6.0	Wet Density (pcf):	111.4
Diameter (in):	2.84	Dry Density (pcf):	84.8
Weight (g):	1110.7	Moisture %:	31.4

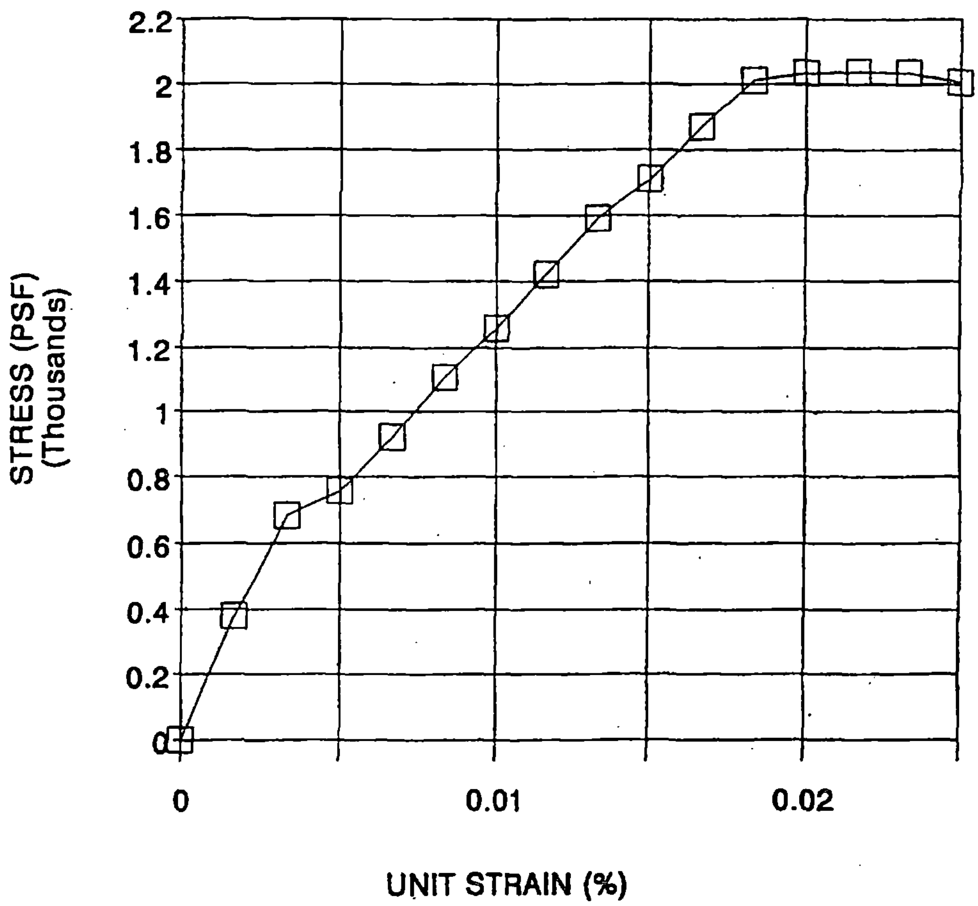
READING NUMBER	DEFORM DIAL READING	LOAD DIAL READING	LOAD (lbs)	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
1	0.000	0.0	0.00	0.000	6.33	0.00
2	0.010	46.0	16.73	0.002	6.34	379.76
3	0.020	83.0	30.18	0.003	6.35	684.08
4	0.030	92.0	33.45	0.005	6.36	756.99
5	0.040	112.0	40.72	0.007	6.37	920.01
6	0.050	135.0	49.09	0.008	6.38	1107.08
7	0.060	154.0	55.99	0.010	6.40	1260.77
8	0.070	174.0	63.27	0.012	6.41	1422.11
9	0.080	195.0	70.90	0.013	6.42	1591.05
10	0.090	210.0	76.36	0.015	6.43	1710.55
11	0.100	230.0	83.63	0.017	6.44	1870.29
12	0.110	248.0	90.17	0.018	6.45	2013.24
13	0.120	251.0	91.26	0.020	6.46	2034.14
14	0.130	252.0	91.63	0.022	6.47	2038.77
15	0.140	252.0	91.63	0.023	6.48	2035.29
16	0.150	249.0	90.54	0.025	6.49	2007.63

MAX. AXIAL STRESS (psf) 2038.77

* Shelby tube secured with backhoe

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: 6B3
Sample No.: UD - 1
Sample Depth (ft): 2.0-3.5

UNCONFINED COMPRESSION TEST



UNCONFINED COMPRESSION TEST

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: 7B1
Sample: UD-1
Sample Depth (ft): 1.5-3.0
Soil Description: Reddish Brown Clayey Silt

Sample Data:

Height (in):	6.0	Wet Density (pcf):	114.7
Diameter (in):	2.84	Dry Density (pcf):	82.6
Weight (g):	1143.6	Moisture %:	38.9

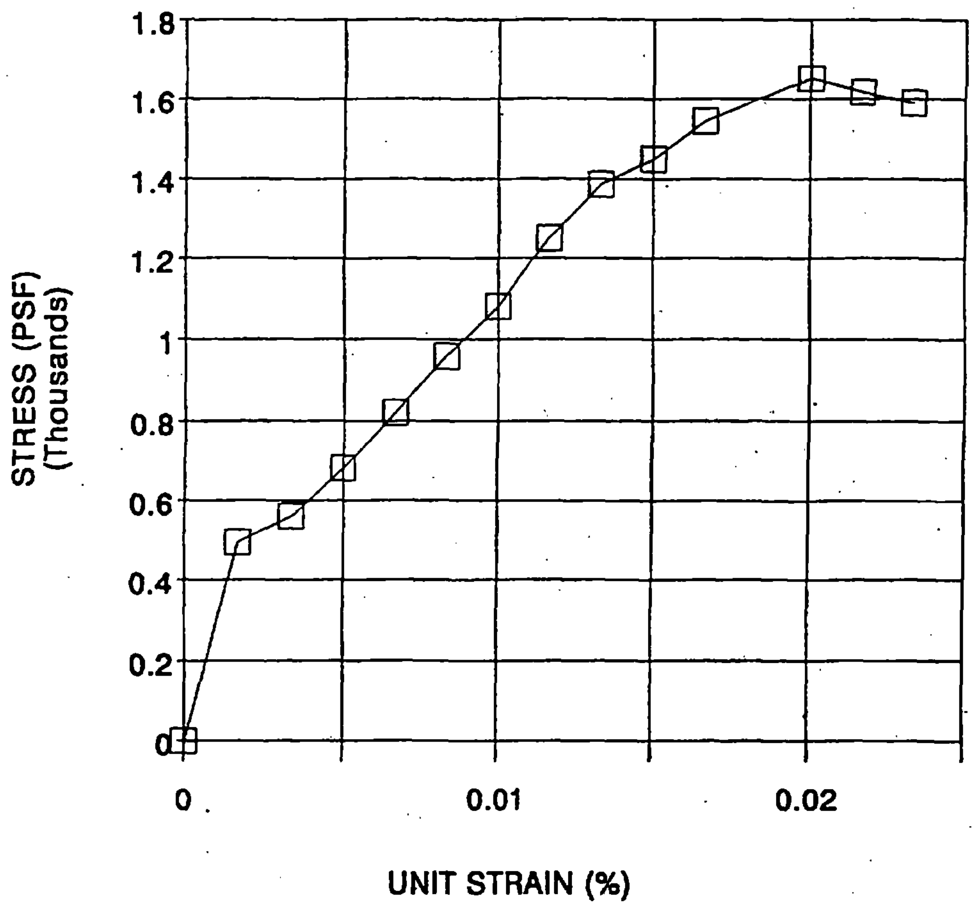
READING NUMBER	DEFORM DIAL READING	LOAD DIAL READING	LOAD (lbs)	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
1	0.000	0.0	0.00	0.000	6.33	0.00
2	0.010	60.0	21.82	0.002	6.34	495.34
3	0.020	68.0	24.72	0.003	6.35	560.45
4	0.030	83.0	30.18	0.005	6.36	682.94
5	0.040	100.0	36.36	0.007	6.37	821.44
6	0.050	117.0	42.54	0.008	6.38	959.47
7	0.060	132.0	48.00	0.010	6.40	1080.66
8	0.070	153.0	55.63	0.012	6.41	1250.47
9	0.080	170.0	61.81	0.013	6.42	1387.07
10	0.090	178.0	64.72	0.015	6.43	1449.89
11	0.100	190.0	69.08	0.017	6.44	1545.02
12	0.120	204.0	74.17	0.020	6.46	1653.24
13	0.130	200.0	72.72	0.022	6.47	1618.07
14	0.140	197.0	71.63	0.023	6.48	1591.08

MAX. AXIAL STRESS (psf) 1653.24

* Organics were observed along the sheer plane after termination of the test
** Shelby tube secured with backhoe

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: 7B1
Sample No.: UD - 1
Sample Depth (ft): 1.5-3.0

UNCONFINED COMPRESSION TEST



SINCE F&R 1961

UNCONFINED COMPRESSION TEST

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: F-7A
Sample: UD-1
Sample Depth (ft): 4.0-6.0
Soil Description: Reddish Brown Clayey Silt

Sample Data:

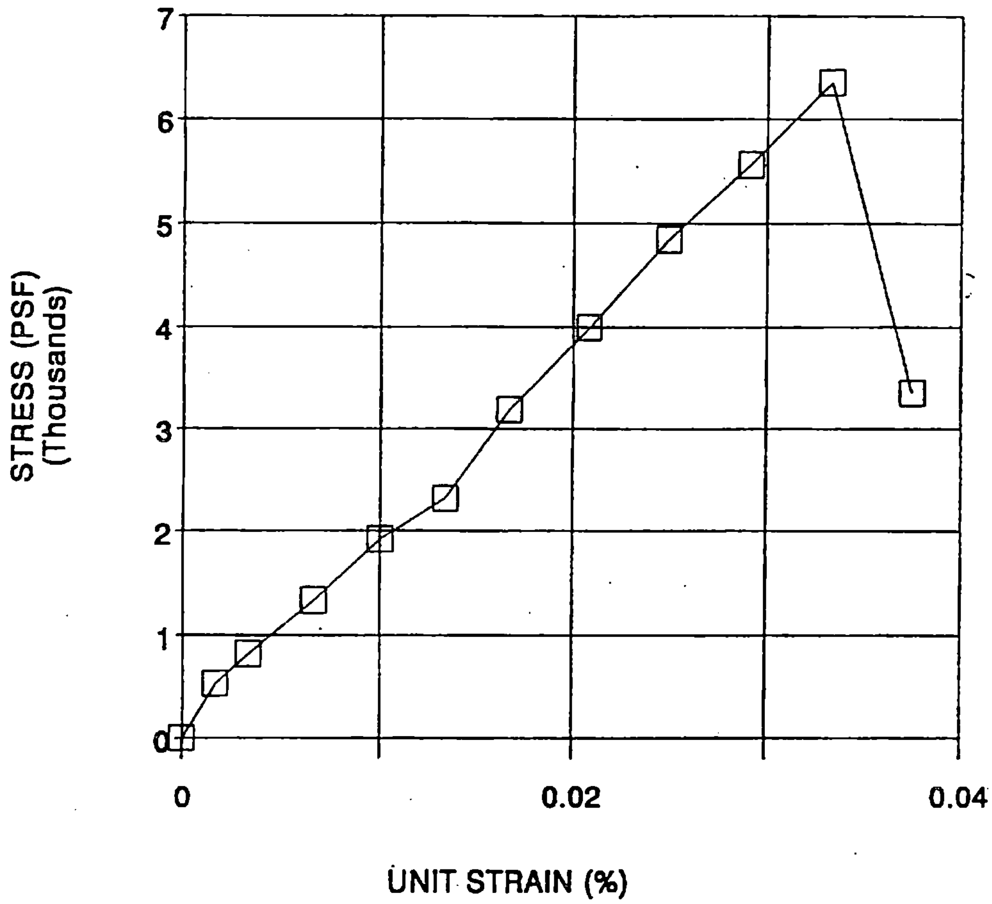
Height (in):	6.0	Wet Density (pcf):	109.3
Diameter (in):	2.81	Dry Density (pcf):	80.9
Weight (g):	1067.5	Moisture %:	35.2

READING NUMBER	DEFORM DIAL READING	LOAD DIAL READING	LOAD (lbs)	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
1	0.000	0.0	0.00	0.000	6.20	0.00
2	0.010	64.0	23.27	0.002	6.21	539.71
3	0.020	98.0	35.63	0.003	6.22	825.05
4	0.040	159.0	57.81	0.007	6.24	1334.12
5	0.060	230.0	83.63	0.010	6.26	1923.39
6	0.080	278.0	101.08	0.013	6.28	2316.96
7	0.100	312.0	139.60	0.017	6.30	3189.09
8	0.125	357.0	175.60	0.021	6.33	3994.49
9	0.150	405.0	214.00	0.025	6.36	4847.29
10	0.175	446.0	246.80	0.029	6.38	5566.34
11	0.200	491.0	282.80	0.033	6.41	6350.92
12	0.225	325.0	150.00	0.038	6.44	3354.07

MAX. AXIAL STRESS (psf) 6350.92

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: F-7A
Sample No.: UD - 1
Sample Depth (ft): 4.0-6.0

UNCONFINED COMPRESSION TEST



UNCONFINED COMPRESSION TEST

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: F-7A
Sample: UD-2
Sample Depth (ft): 16.0-18.0
Soil Description: Red and Brown Silty Sand

Sample Data:

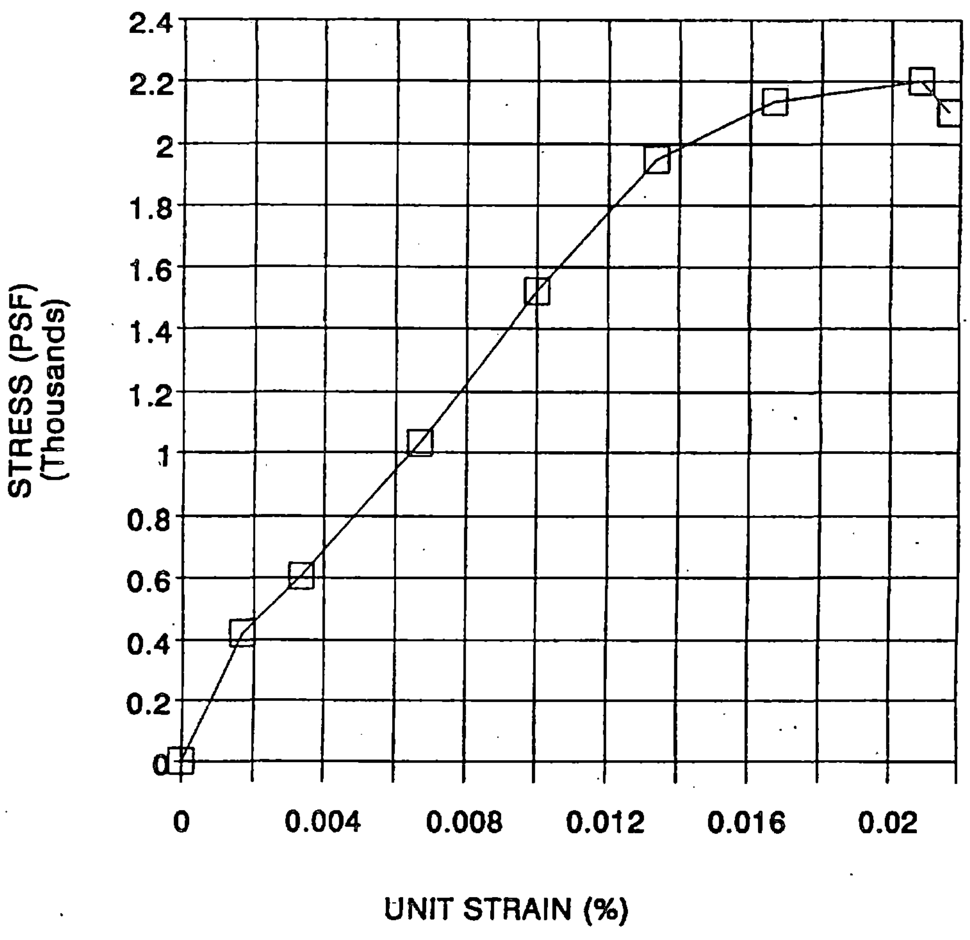
Height (in):	6.0	Wet Density (pcf):	98.0
Diameter (in):	2.81	Dry Density (pcf):	72.1
Weight (g):	957.2	Moisture %:	36.1

READING NUMBER	DEFORM DIAL READING	LOAD DIAL READING	LOAD (lbs)	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
1	0.000	0.0	0.00	0.000	6.20	0.00
2	0.010	50.0	18.18	0.002	6.21	421.65
3	0.020	72.0	26.18	0.003	6.22	606.16
4	0.040	123.0	44.72	0.007	6.24	1032.06
5	0.060	182.0	66.18	0.010	6.26	1521.99
6	0.080	234.0	85.08	0.013	6.28	1950.25
7	0.100	257.0	93.45	0.017	6.30	2134.71
8	0.125	266.0	96.72	0.021	6.33	2200.10
8	0.130	254.0	92.35	0.022	6.34	2099.06

MAX. AXIAL STRESS (psf) 2200.10

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: F-7A
Sample No.: UD-2
Sample Depth (ft): 16.0-18.0

UNCONFINED COMPRESSION TEST



UNCONFINED COMPRESSION TEST

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: F-9A
Sample No.: UD - 1
Sample Depth (ft): 4.0-6.0
Soil Description: Reddish Brown Silty Sand

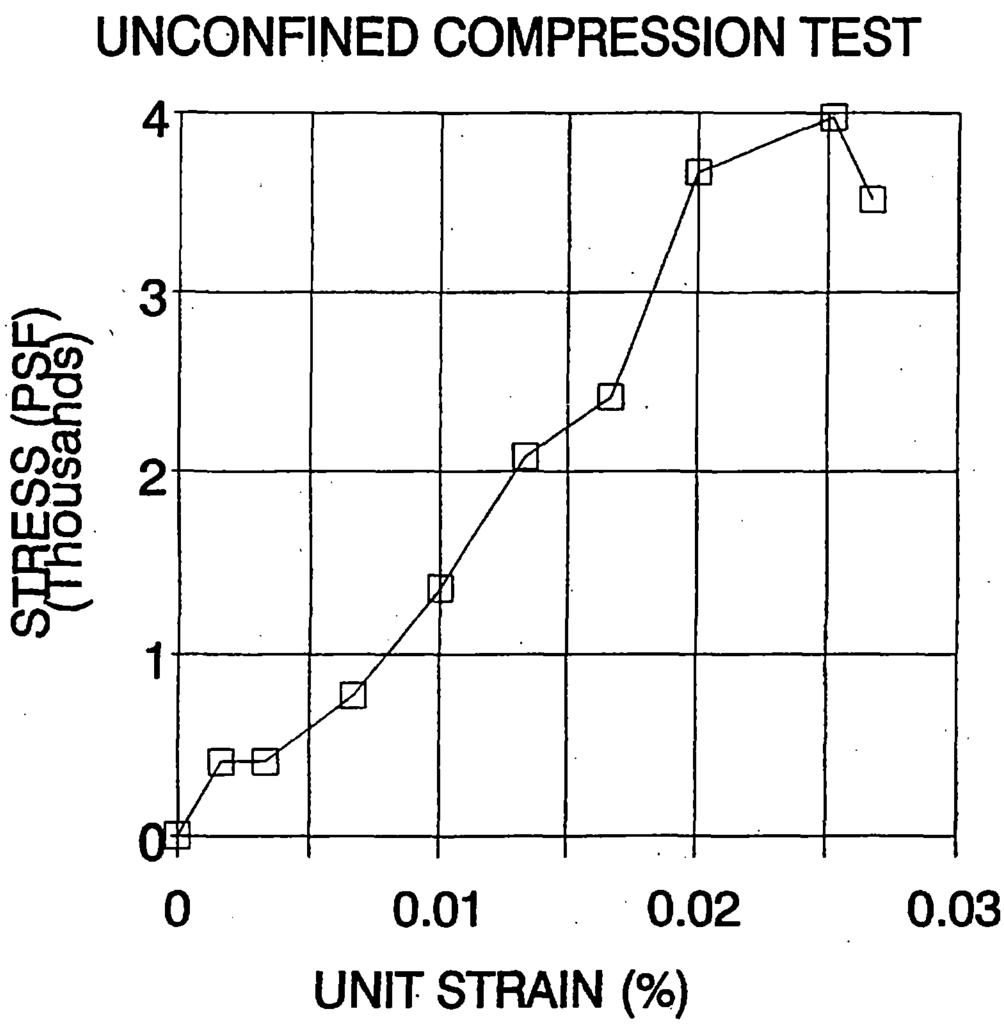
Sample Data:

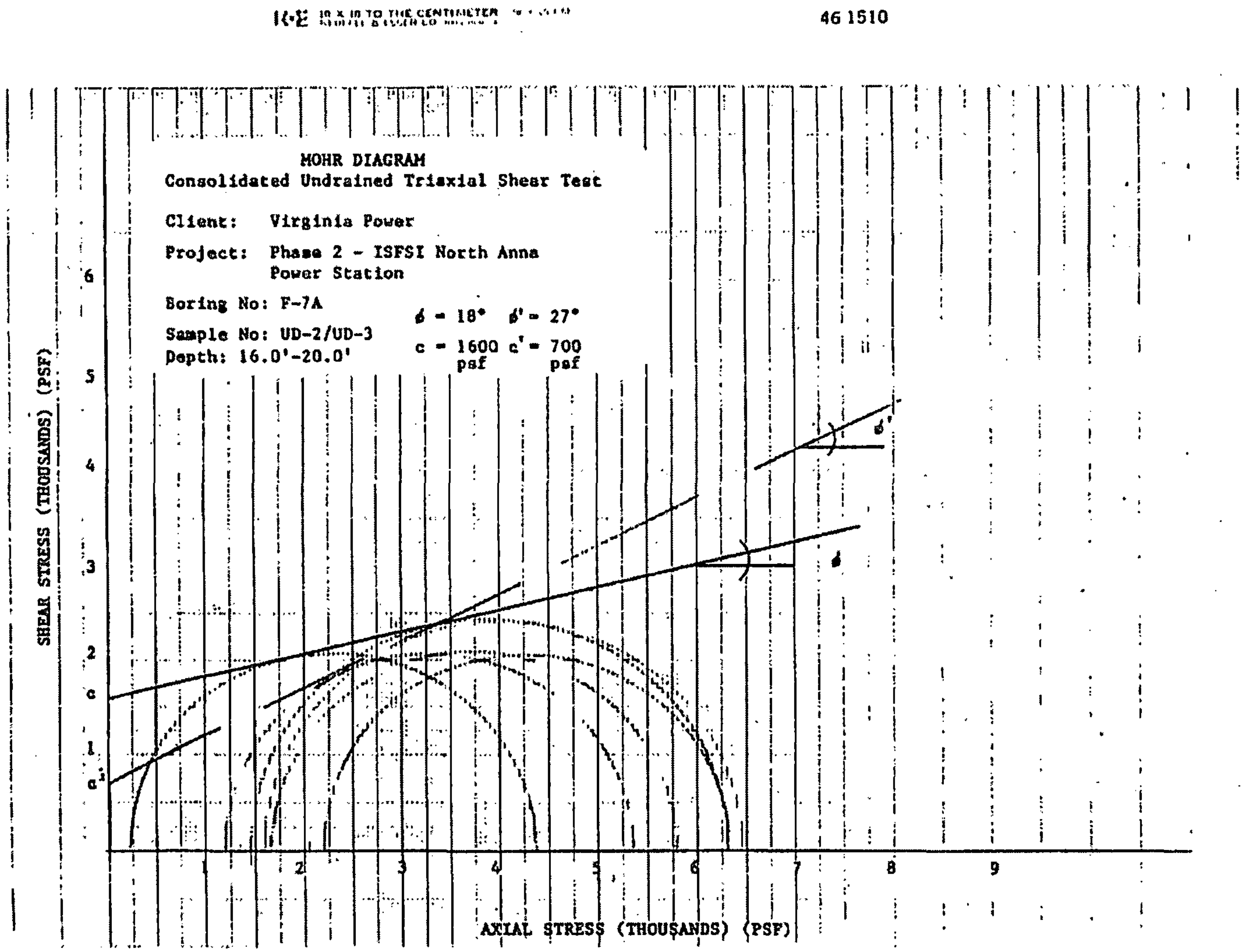
Height (in):	6.0	Wet Density (pcf):	110.5
Diameter (in):	2.81	Dry Density (pcf):	85.0
Weight (g):	1079.1	Moisture %:	30.1

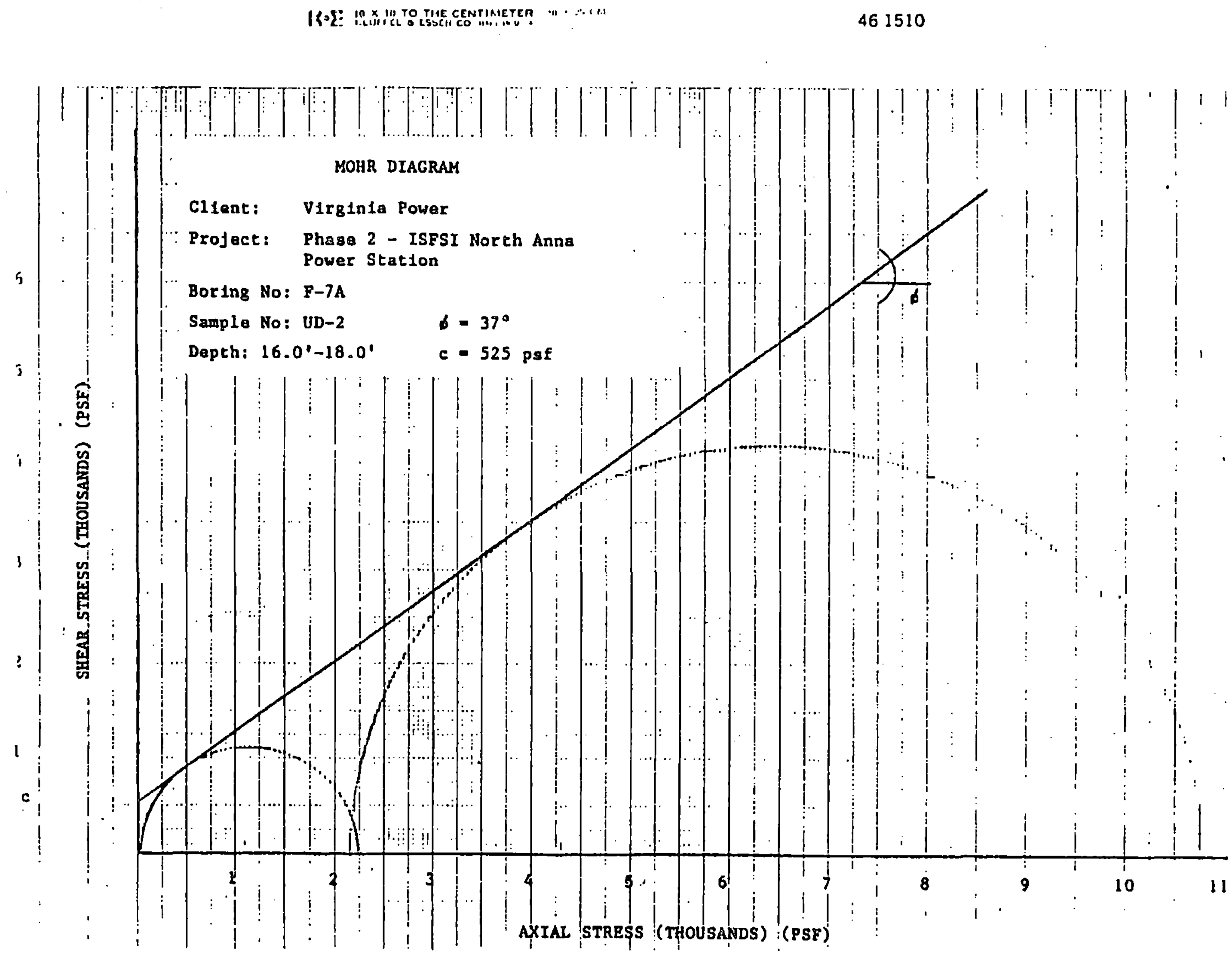
READING NUMBER	DEFORM DIAL READING	LOAD DIAL READING	LOAD (lbs)	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
1	0.000	0.0	0.00	0.000	6.20	0.00
2	0.010	48.0	17.45	0.002	6.21	404.78
3	0.020	48.0	17.45	0.003	6.22	404.11
4	0.040	92.0	33.45	0.007	6.24	771.95
5	0.060	163.0	59.27	0.010	6.26	1363.10
6	0.080	250.0	90.90	0.013	6.28	2083.60
7	0.100	291.0	105.81	0.017	6.30	2417.12
8	0.120	339.0	161.20	0.020	6.32	3670.04
9	0.151	357.0	175.60	0.025	6.36	3976.81
10	0.160	332.0	155.60	0.027	6.37	3518.45

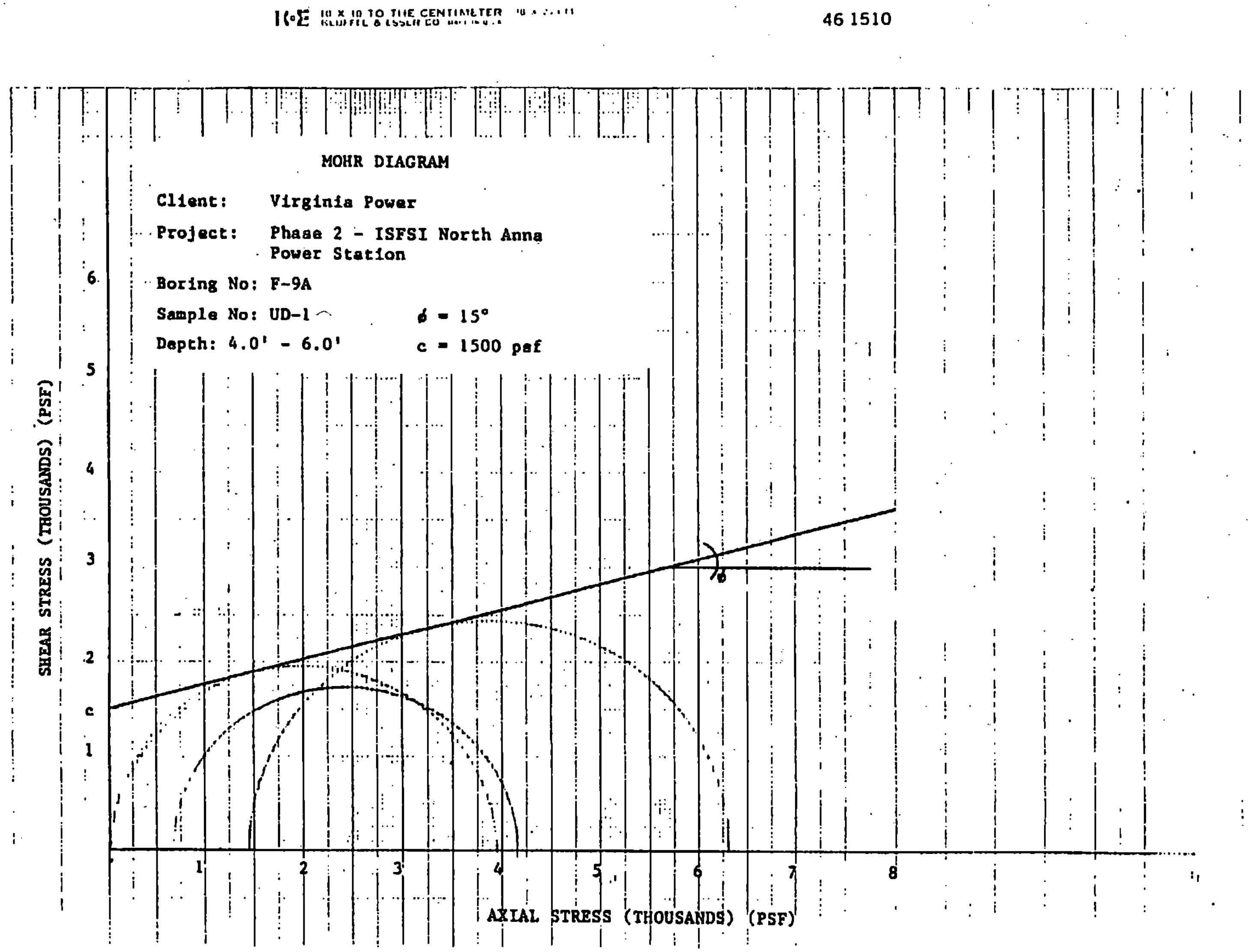
MAX. AXIAL STRESS (psf) 3976.81

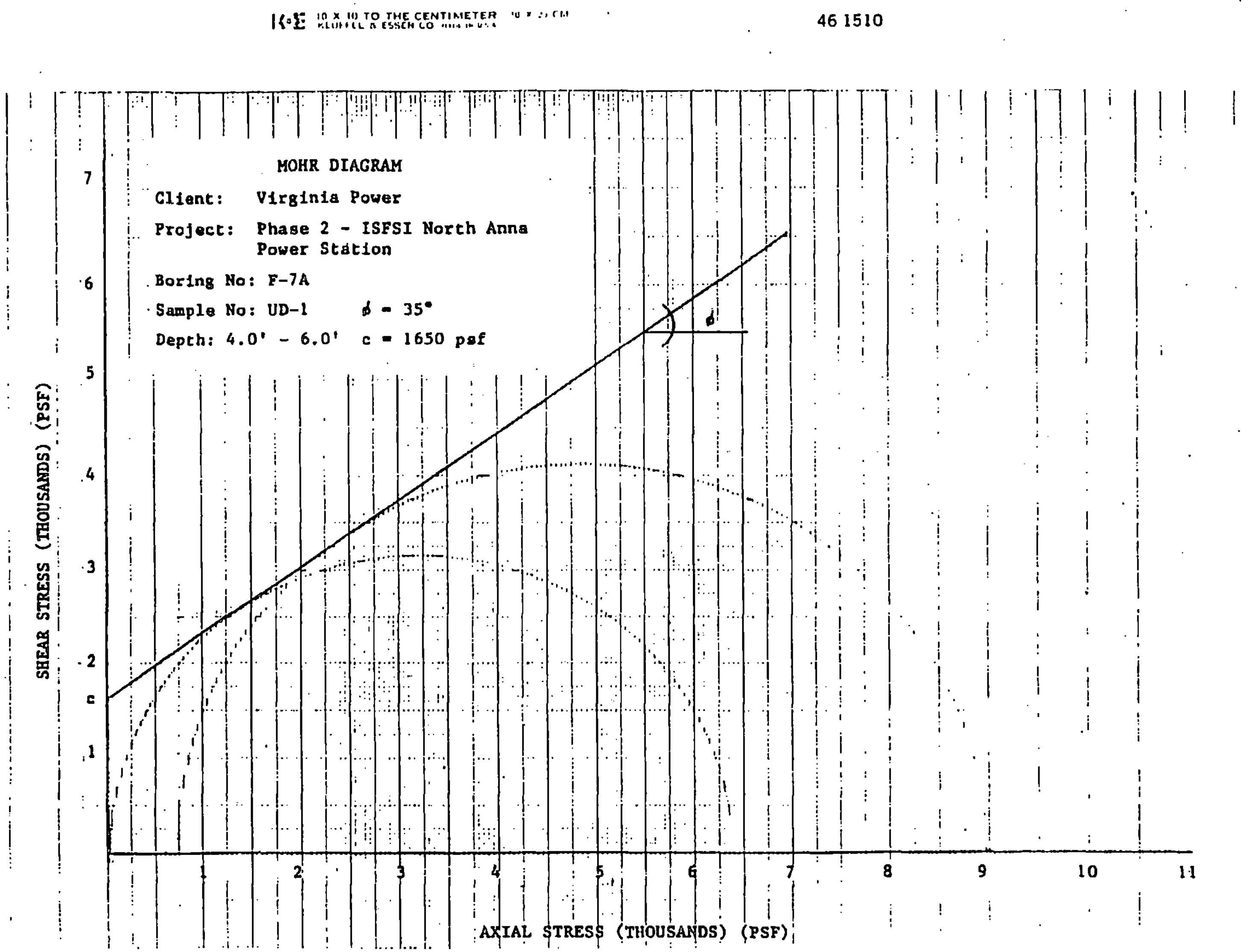
Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: F-9A
Sample No.: UD - 1
Sample Depth (ft): 4.0-6.0




46 1510
MOHR DIAGRAM
Consolidated Undrained Triaxial Shear Test
Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Boring No: F-7A
Sample No: UD-2/UD-3
Depth: 16.0'-20.0'
ϕ = 18° ϕ' = 27°
c = 1600 psf c' = 700 psf
SHEAR STRESS (THOUSANDS) (PSF)
AXIAL STRESS (THOUSANDS) (PSF)
1
2
3
4
5
6
7
8
9
c
c'
ϕ
ϕ'


46 1510
MOHR DIAGRAM
Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Boring No: F-7A
Sample No: UD-2
Depth: 16.0'-18.0'
ϕ = 37°
c = 525 psf
ϕ
c
SHEAR STRESS (THOUSANDS) (PSF)
AXIAL STRESS (THOUSANDS) (PSF)
1
2
3
4
5
6
7
8
9
10
11


46 1510
MOHR DIAGRAM
Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Boring No: F-9A
Sample No: UD-1
Depth: 4.0' - 6.0'
ϕ = 15°
c = 1500 psf
SHEAR STRESS (THOUSANDS) (PSF)
AXIAL STRESS (THOUSANDS) (PSF)
c
ϕ
1
2
3
4
5
6
7
8


46 1510
MOHR DIAGRAM
Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Boring No: F-7A
Sample No: UD-1
ϕ = 35°
Depth: 4.0' - 6.0'
c = 1650 psf
SHEAR STRESS (THOUSANDS) (PSF)
AXIAL STRESS (THOUSANDS) (PSF)
c
1
2
3
4
5
6
7
8
9
10
11

Froehling & Robertson, Inc

PERMEABILITY TEST

ASTM 5084

CLIENT: Virginial Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V60-073

Date: August 24, 1994

Boring: F-7A Sample: UD-2 Depth: 16.0-18.0
Sample Description: Red and Brown Silty Sand

SAMPLE DATA	
LENGTH (in.)	6.00
DIAMETER (in.)	2.81
AREA (cm^2)	40.01
VOLUME (cm^3)	609.75
WEIGHT (g)	1039.90
% MOISTURE	38.80
Dry Density (pcf)	76.70

PRESURE DATA (psi)	
CHAMBER PRESSURE	35
BACK PRESSUE, bottom	30
BACK PRESSUE, top	25
HEAD ACROSS SAMPLE	5

DATE	TIME	t (sec)	h_1 (in)	v_1 (cm^3)	h_2 (in)	v_2 (cm^3)	delta v_1	delta v_2	I	Q (cm^3/sec)	k (cm/sec)
August 16, 1994	08:15	0	21.8	7.3	13.0	44.5	0.0	0.0	24.53		
	12:25	15000	20.4	13.4	14.4	38.7	6.1	5.8	24.07	3.97E-04	4.12E-07
	14:02	5820	19.8	15.6	14.9	36.5	2.2	2.2	23.89	3.78E-04	3.95E-07
	15:02	3600	19.5	16.9	15.2	35.3	1.3	1.2	23.80	3.47E-04	3.65E-07
	16:26	5040	19.1	18.8	15.6	33.5	1.9	1.8	23.65	3.67E-04	3.88E-07
	16:43	1020	19.0	19.1	15.7	33.2	0.3	0.3	23.63	2.94E-04	3.11E-07

Avgerage k: 3.74E-07

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Chapter 3 PRINCIPAL SSSC DESIGN CRITERIA

This chapter describes the design criteria to be met by the SSSCs to be used in the North Anna ISFSI. Compliance with these criteria ensures that the North Anna ISFSI complies with the requirements of 10 CFR 72.

3.1 PURPOSES OF SSSC

A summary description of each SSSC approved for use at the North Anna ISFSI is provided in Appendix A. A detailed description of the approved SSSCs is provided in the Topical Safety Analysis Reports (TSAR) listed in Table A-1 of Appendix A.

3.1.1 Spent Fuel to Be Stored

The ISFSI is designed to accommodate a total of 84 SSSCs. However, the licensed spent fuel storage design capacity of the facility is 839.04 MTU. At approximately 0.46 metric tons of uranium (MTU) per fuel assembly, the facility can accommodate 1824 fuel assemblies under the current license.

The physical characteristics of the fuel to be stored in the ISFSI are described in detail in Section 4.2 of the North Anna Power Station UFSAR and are summarized in Table 3-1. An evaluation of the storage of burnable poison rod assemblies (BPRAs) and/or thimble plug devices (TPDs) with the fuel assemblies placed in SSSCs is provided in Appendix A for each cask design.

The fuel used during the first years of North Anna Power Station Units 1 and 2 operation had initial enrichments not exceeding 3.5 weight percent U^{235} and discharge burnup not exceeding 35,800 MWD/MTU. The North Anna Power Station has been authorized to operate with fuel with higher initial enrichment and higher burnup. The design basis fuel characteristics used in the analyses included in Chapters 7 and 8 include initial enrichment of 4.3 weight percent U^{235}, burnup of 45,000 MWD/MTU and a cooling time of 7 years. The radioactive characteristics of the design basis fuel are discussed in Section 7.2.

3.1.1.1 **Spent Fuel Characteristics**

The following fuel assembly characteristics constitute limiting parameters for storage of fuel assemblies at the ISFSI:

- Initial Fuel Enrichment
- Fuel Burnup
- Heat Generation
- Decay time
- Spent Fuel Physical Configuration/Condition

3.1.1.1.1 Allowable Limits

The allowable limits for each of these characteristics are discussed below.

1. Initial Fuel Enrichment

   The initial fuel enrichment of any fuel that is stored in a SSSC will be limited to the maximum enrichment specified in the ISFSI Technical Specifications.

2. Fuel Burnup

   The burnup of any fuel that is stored in a SSSC will be limited to that specified in the ISFSI Technical Specifications.

3. Heat Generation

   The heat generation rate by an individual fuel assembly is dependent on three factors: the initial fuel enrichment, the fuel burnup, and the amount of decay time after discharge. The maximum allowable heat generation rate for a particular SSSC is specified in the ISFSI Technical Specifications.

4. Decay Time

   The decay time of any fuel that is stored in a SSSC will be at least greater than that specified in the ISFSI Technical Specifications.

5. Spent Fuel Physical Configuration/Condition

   Only spent fuel irradiated at North Anna Power Station Units 1 and 2 with the physical configuration as listed in items 1, 2, and 3 of Table 3-1 will be stored in the ISFSI. The fuel stored shall be intact, shall not have gross cladding defects, and shall not have visible physical damage which would inhibit insertion or removal from the SSSC basket.

3.1.1.1.2 Verification

The method of verification for each of these characteristics is discussed below:

1. Initial Fuel Enrichment, Fuel Burnup and Decay Time

   Fuel management records shall be utilized to verify that the initial fuel enrichment, fuel burnup and decay time meet the specified limits. Each fuel assembly is engraved with a unique identification number (based on ANSI/ANS 57.8) and a vendor identification, which is unique to the site for which the fuel assemblies were fabricated. This will allow visual confirmation of the identity of the fuel assemblies placed in the SSSC.

2. Heat Generation

   The heat generation rate of a fuel assembly is based primarily on the fuel enrichment, burnup, operating history, and cooling time after discharge. Fuel management records will be used to obtain the parameters. A decay heat analysis using a computer code such as ORIGEN or the method described in NUREG/CR-5625 will be used to ensure that the heat generation per fuel assembly is less than that specified in the ISFSI Technical Specifications.

3. Spent Fuel Physical Configuration/Condition

   Fuel management records will be reviewed to ensure that the assemblies to be put in the SSSC have not been previously identified as having gross cladding defects. The fuel assemblies shall also be visually inspected (e.g., using closed-circuit television cameras) for physical damage which could potentially cause problems during insertion and/or removal from the SSSC.

3.1.2 General Operating Functions

The fuel assemblies will be stored unconsolidated and dry in SSSCs. The SSSCs will rest on a reinforced concrete storage pad, and provide safe storage by ensuring a reliable decay heat path from the spent fuel to the environment and by providing appropriate shielding and containment of the fission product inventory.

Storage of spent fuel in SSSCs is a totally passive function, with no active systems required to function. Cooling of the SSSCs is accomplished by convective cooling.

The SSSCs are to be handled with a lifting yoke, the Fuel Building cask handling crane, a transporter, or other appropriate equipment. The Fuel Building crane places the loaded SSSC on the ground outside the Decontamination Building. The SSSC is then lifted by the transporter which is moved to the ISFSI by a tow vehicle. After the transporter has been maneuvered to locate the SSSC in its storage position, the SSSC is set down by the transporter.

The equipment in the Fuel and Decontamination Buildings is capable of handling SSSCs weighing up to 125 tons fully loaded and measuring approximately 16 feet in length with the top cover removed.

All the handling equipment to be used will be sized to handle SSSCs measuring up to the above specifications, as needed. This equipment will be designed according to appropriate commercial codes and standards, and will be operated, maintained, and inspected in accordance with the supplier's recommendations. Documentation will be maintained to substantiate conformance with all applicable standards.

3.2 DESIGN CRITERIA FOR ENVIRONMENTAL CONDITIONS AND NATURAL PHENOMENA

The SSSCs are designed with the objectives of ensuring that fuel criticality is prevented, SSSC integrity is maintained, and fuel is not damaged so as to preclude its removal from the SSSC. The conditions under which these objectives must be met are described below.

The safe storage of the spent fuel assemblies depends on the capability of the SSSCs to fulfill their design functions. The SSSCs are self-contained, independent, passive systems, which do not rely on any other systems or components for their operation. Therefore, the SSSCs are the only components at the North Anna ISFSI which are safety-related. The criteria used in the design of the SSSCs ensure that exposure of the SSSCs to credible site hazards will not impair their safety functions. Because the North Anna ISFSI is located on the North Anna site, all ISFSI design criteria for environmental conditions and natural phenomena are the same as the plant design bases, as found in Chapter 3 of the North Anna Power Station UFSAR.

The design criteria satisfy the requirements of 10 CFR 72. They consider the effects of normal operation, natural phenomena and postulated man-made accidents. The criteria are defined in terms of loading conditions imposed on the SSSCs. The loading conditions are evaluated to determine the type and magnitude of loads induced on the SSSC. The combination of these loads are then established based on the number of conditions that can be superimposed.

3.2.1 Tornado and Wind Loadings

The SSSC manufacturers will be required to meet either the design basis tornado and extreme wind used for the Class 1 (safe shutdown) systems and structures of the North Anna Power Station, as described in Sections 3.3.1 and 3.3.2 of the North Anna Power Station UFSAR or alternately, those prescribed by Regulatory Guide 1.76, *Design Basis Tornado for Nuclear Power Plants,* April 1976.

3.2.1.1 Applicable Design Parameters

The design basis tornado for the North Anna Power Station has a rotational wind velocity of 300 mph, a translational velocity of 60 mph, and a pressure drop of 3 psi in 3 seconds, as described in Section 3.3.2 of the North Anna Power Station UFSAR.

The design basis extreme wind is 80 mph as described in Section 2.3.1 of this SAR.

The design basis tornado and wind loadings for the SSSCs are provided in the SSSC Topical Safety Analysis Reports.

3.2.1.2 Determination of Forces on Structures

The description of the methods used to convert the tornado and wind loading into forces on the SSSCs is addressed in the SSSC Topical Safety Analysis Reports.

The safety function of the SSSCs is not dependent on any other structures or systems. In addition, there are no structures in the vicinity of the ISFSI, which, if failed under tornado loads, could damage the SSSCs.

3.2.1.3 Tornado Missiles

The design basis tornado missiles listed in Section 3.3.2 of the North Anna Power Station UFSAR are the following:

- A wooden utility pole 40 feet long, 12 inches in diameter, with a density of 50 lb/ft^3, and traveling in a vertical or horizontal direction at 150 mph
- A 1-ton automobile traveling at 150 mph not more than 25 feet above ground and with a contact area of 30 ft^2

- A 1-inch solid steel rod, three feet long, with a density of 490 lb/ft^3
- A 6-inch Schedule 40 pipe, 15 feet long, with a density of 490 lb/ft^3
- A 12-inch Schedule 40 pipe, 15 feet long, with a density of 490 lb/ft^3

Analysis of the potential effects of tornado missiles on the SSSCs is addressed in the SSSC Topical Safety Analysis Reports and in Appendix A.

3.2.2 Water Level (Flood) Design

The design finished grade elevation of the ISFSI is approximately 311 feet msl, leaving a margin of approximately 45 feet above the maximum flood. Therefore, the ISFSI site is flood-free. See Section 2.4.2 for additional details.

3.2.3 Seismic Design

Section 2.5.2 describes the vibratory ground motions experienced in the region of the North Anna site and defines design earthquake ground acceleration values of 0.18g horizontal and 0.12g vertical for the ISFSI, which are also the values used for the design basis earthquake (DBE) for North Anna Units 1 and 2 for Seismic Class I structures founded on saprolite more than 15 feet thick.

3.2.4 Snow and Ice Loadings

The rain and snow falls experienced at the North Anna site are described in Section 2.3.1 of this SAR.

Snow and ice would melt soon after contacting the surface of the SSSC due to the decay heat generated by the stored fuel. These phenomena are not considered credible challenges to the SSSCs. Therefore, snow and ice loadings are not identified among the design criteria for the SSSCs.

3.2.5 Combined Load Criteria

The loads postulated as design criteria for the SSSCs have been described in this chapter.

The methods and assumptions made in analyzing the mechanical and structural behavior of the SSSCs are described in the SSSC Topical Safety Analysis Reports and in Appendix A.

3.3 SAFETY PROTECTION SYSTEMS

3.3.1 General

The handling of the SSSCs while they are being placed in the ISFSI requires that they be lifted by a transporter. Technical Specifications for the North Anna ISFSI limit the height the SSSCs may be lifted while being transported and while being emplaced at the ISFSI. The SSSCs are able to withstand drops onto the storage pad without compromising their integrity and without resulting in physical damage to the fuel.

Because of the passive nature of the North Anna ISFSI and the absence of support systems, no other items requiring special design consideration have been identified.

3.3.2 Protection By Multiple Confinement Barriers and Systems

3.3.2.1 Confinement Barriers and Systems

Confinement of radioactivity during the storage of spent fuel is achieved by (1) the uranium dioxide fuel pellet matrix, (2) the metallic tubes (cladding) in which the pellets are contained, and (3) the SSSC in which the assemblies are stored.

The confinement function of the SSSCs is achieved by totally enclosing the spent fuel assemblies within a double-seal rigid metal vessel. The SSSCs are fabricated, delivered to the North Anna site, loaded, sealed, and emplaced at the ISFSI in a manner that ensures their integrity, the capability to perform their safety functions, and compliance with all applicable rules and regulations.

Once the SSSCs are sealed, there are no credible events which could result in a release of radioactive material to the environment. Similarly, there are no credible scenarios which could result in contamination of the outside surface of the SSSCs or in the generation of radioactive waste products.

More detailed information on SSSC confinement barriers is provided in the SSSC Topical Safety Analysis Reports.

3.3.2.2 SSSC Cooling

Natural air flow around the SSSCs provides sufficient cooling. No forced ventilation is required.

3.3.3 Protection By Equipment and Instrumentation Selection

3.3.3.1 Equipment

As discussed in Section 3.2, the SSSCs represent the only components of the ISFSI which are important to safety. Design criteria for the SSSCs are described in this section and summarized in Table 3-2.

3.3.3.2 Instrumentation

Due to the totally passive and inherently safe nature of the SSSCs, safety-related instrumentation is not necessary.

High quality commercial grade instrumentation will be provided to monitor the SSSC's functional performance. Instrumentation to monitor SSSC parameters such as pressure will be furnished as recommended by the specific SSSC designs. The appropriate capabilities to check these monitors will also be provided. The SSSCs are provided with pressure monitoring systems as described in the SSSC Topical Safety Analysis Reports.

3.3.4 Nuclear Criticality Safety

The criterion for ensuring that the fuel remains subcritical at all times is that the effective neutron multiplication factor k_{eff} be less than 0.95 (including two standard deviations), assuming a single active or passive failure, and that an infinite number of SSSCs can be stored in close proximity.

3.3.4.1 Control Methods for Prevention of Criticality

Methods to be used to ensure that subcriticality is maintained at all times in the SSSCs are addressed in the SSSC Topical Safety Analysis Reports or Appendix A.

3.3.4.2 Error Contingency Criteria

Error contingency criteria for the SSSCs are presented in the SSSC Topical Safety Analysis Reports or Appendix A.

3.3.4.3 Verification Analyses

The criteria for establishing verification of the models and programs used in the criticality calculations for the SSSCs are presented in the SSSC Topical Safety Analysis Reports or Appendix A.

3.3.5 Radiological Protection

Provisions for radiological protection by confinement barriers and systems are described in Section 3.3.2.1. No additional radiological protection design criteria are considered to be necessary.

The North Anna ISFSI does not require the continuous presence of operators or maintenance personnel. Access to the ISFSI perimeter fence is limited to personnel needed during operations at the ISFSI, e.g., periodic inspection of the facility, emplacement of SSSCs, and security checks. These activities will be defined and controlled by the Health Physics and Security procedures covering the North Anna ISFSI. Because personnel are seldom at the ISFSI and only for short periods of time, further reduction of collective occupational doses is not practical.

Estimates of the collective occupational doses (in person-rem) per year for SSSC operation, maintenance and repair are included in Section 7.4. No occupational dose is expected for decommissioning of the ISFSI facility, since the facility will not be contaminated. The occupational dose to unload SSSCs will be similar to that for SSSC loading shown in Table 7-2. The occupational dose to dispose of SSSC components as radioactive waste is expected to be very small, as discussed in Section 4.6. Occupational exposures will be kept as-low-as-reasonably-achievable as discussed in Sections 7.1 and 7.3.

3.3.6 Fire and Explosion Protection

A backup diesel generator and its associated fuel tank are located within the ISFSI security fence. To prevent a postulated fire associated with a leaking fuel tank a monitored, double-walled diesel fuel tank with a maximum capacity of 200 gallons is provided. There are no other significant combustible sources within the ISFSI security fence.

As indicated in Section 2.2.2, overpressure of much less than 1 psi can be conservatively postulated to occur at the North Anna ISFSI as a result of accidents involving explosive materials which are transported near the site. The SSSCs are designed to withstand a 1 psi external overpressure without any impairment of their safety functions.

3.3.7 Materials Handling and Storage

The handling of spent fuel within the North Anna Power Station will be conducted in accordance with existing fuel handling procedures. Spent fuel that may be damaged to the extent of losing its cooling geometry or reasonable cladding integrity will be kept at the spent fuel pool and not considered for storage at the ISFSI.

The design criteria for SSSCs related to cooling requirements, criticality and contamination control are provided in the SSSC Topical Safety Analysis Reports or Appendix A. The detection and handling of breached fuel rods is discussed in Section 3.1.1.1.2.

3.4 SUMMARY OF SSSC DESIGN CRITERIA

The principal design criteria for SSSCs used at the North Anna ISFSI are presented in Table 3-2.

Table 3-1

CHARACTERISTICS OF FUEL USED AT THE NORTH ANNA POWER STATION[a]

1. Fuel Assemblies	
a. Manufacturer	Westinghouse
b. Type	PWR
c. Rod array	17 x 17
d. Rods per assembly	264 (25 fuel rods are omitted to provide passage for control rods and in-core instrumentation)
e. Assembly length	161.80 in.
f. Rod pitch	0.496 in.
g. Overall assembly dimensions	8.426 in. x 8.426 in.
h. Total assembly weight	1533 lb (with heaviest insert component)
i. Active fuel length	144 in.
2. Fuel Rods	
a. Outside diameter	0.374 in.
b. Clad thickness	0.0225 in.
c. Clad material	Zircaloy-4 and Zirlo
3. Fuel Pellets	
a. Material	UO_2 Sintered
b. Length	0.530 or 0.387 in. [c]
4. Fuel Condition for Storage in SSSCs	
a. Maximum initial enrichment	b
b. Maximum burnup	b
c. Maximum heat generation for each fuel assembly at the time of storage	b
d. Minimum decay time	b

a. From North Anna Power Station UFSAR. All dimensions are for cold conditions.
b. Specified in the North Anna ISFSI Technical Specifications.
c. Reload batches starting with North Anna Unit 1, Batch 9 and North Anna 2, Batch 8 changed fuel pellet length from 0.530 in. to 0.387 in.

Table 3-2

DESIGN CRITERIA FOR DRY SEALED SURFACE STORAGE CASKS

The SSSCs must meet the following criteria, assuming that they are loaded with the fuel described in Table 3-1.

1. Maximum weight with yoke	125 tons
2. Criticality with single active or credible passive failure	$k_{eff} < 0.95$
3. Ambient temperature	-20°F to 115°F
4. Direct exposure to sunlight	800 gm-cal/cm^2 for flat surfaces[a] 400 gm-cal/cm^2 for curved surfaces[a]
5. Tornado winds	300 mph rotational velocity, 60 mph translational velocity
6. Tornado pressure drop	3 psi in 3 seconds
7. Maximum winds (V)	80 mph
8. Explosive peak overpressure	1 psi
9. Design Earthquake peak acceleration	0.18g horizontal 0.12g vertical

10. Adequate provisions to monitor performance of SSSC leak tightness
11. 15-inch drop onto concrete pad without compromising SSSC integrity and without physical damage to fuel or loss of subcriticality
12. Capable of tipping over and rolling without compromising SSSC integrity and without physical damage to fuel or loss of subcriticality
13. Leak tightness to be maintained under all operating conditions and credible events

a. These values are adapted from 10 CFR 71.71(c) and apply to a 12-hour daylight period. These values may be averaged over a 24-hour period for long-term thermal analyses.

Chapter 4 STORAGE SYSTEM

This chapter provides descriptive information on the North Anna ISFSI structures, systems and components. It also provides the bases for the design criteria presented in Chapter 3.

4.1 LOCATION AND LAYOUT

The location of the North Anna ISFSI and the main and alternate transport route of the SSSCs from the Decontamination Building to the ISFSI are shown in Figure 4-4. In addition, this figure shows other facilities in the vicinity of the ISFSI site, such as roadways and buildings. However, none of these other facilities are related to the ISFSI. The ISFSI and both transport routes are within the North Anna Power Station exclusion area.

The only components with a safety function are the SSSCs. The SSSCs are stored on three nonsafety-related concrete storage pads, 224-by-32-feet, to be built one at a time, as needed, within the ISFSI perimeter fence. Each storage pad is designed to accommodate 28 SSSCs. Each SSSC is approximately 8 feet in diameter and weighs no more than 125 tons. For SSSCs spaced 16 feet minimum center-to-center, there is approximately 8 feet surface-to-surface distance between SSSCs when they are stored in the vertical position. For SSSCs spaced 14 feet minimum center-to-center, there is approximately 6 feet surface-to-surface distance between SSSCs when they are stored in the vertical position.

The North Anna ISFSI perimeter fence is approximately 750-by-660 feet with a vehicle entrance on the northwest side and seven personnel entrances spaced around the perimeter. A security fence and a nuisance fence are also provided around the storage pads. The layout of the ISFSI site is shown on Figure 4-1.

The only utility associated with the North Anna ISFSI is electrical power for lights, communications, and monitoring instrumentation as shown on Figures 4-2 and 4-3. The source of this power is described in Section 4.4.4.

Loading and unloading of the SSSCs takes place in the Fuel and Decontamination Buildings of the North Anna Power Station. These facilities are described in Sections 9.1 and 9.5, respectively, of the North Anna Power Station UFSAR. Figure 4-4 shows the route for transport of the SSSCs from the Decontamination Building to the ISFSI.

4.2 STORAGE SITE

The North Anna ISFSI is designed in accordance with the General Design Criteria set forth in 10 CFR 72, Subpart F. Table 4-1 summarizes compliance with these criteria, and additional details are provided below.

The North Anna ISFSI will consist of three concrete storage pads on which the loaded SSSCs are placed. The storage pads will be constructed one at a time as the need for storage space arises. The storage pads will be surrounded by a security fence and a nuisance fence which are surrounded by an ISFSI perimeter fence. In addition, the ISFSI storage area will include lighting, monitors, alarms, and a diesel generator. The ISFSI site plan is shown on Figure 4-1.

The SSSCs are self-contained, independent, passive systems, which do not rely on any other systems or components for their operation, and are classified as safety-related. The storage pads and other systems and components at the storage site are classified as nonsafety-related.

4.2.1 Structures

The operational areas of the North Anna ISFSI are the three storage pads and the areas immediately around them. The storage pads provide a uniform level surface for storing the SSSCs. The compacted gravel areas around the storage pads allow movement and positioning of SSSC handling equipment.

These storage pads will be built in accordance with the BOCA Basic Building Code (Reference 1) and applicable American Concrete Institute codes and standards. The area surrounding the storage pads will be compacted to properly support the tow vehicle and transporter needed for the handling of the SSSCs.

The primary function of the concrete storage pads is to provide a uniform level surface for storing the SSSCs. Each pad will be a reinforced concrete slab on grade with nominal dimensions of 32 feet by 224 feet by 2 feet thick. Nominal forty-foot long concrete ramps are required on each end of the storage pads to enable the SSSC transporter to gain access to the storage pad. The nominal overall length of the storage pad will be 304 feet. Each storage pad is designed to support a total of 28 SSSCs arranged in fourteen rows of two SSSCs with a minimum center-to-center spacing of 16 feet in both directions for SSSCs with heat loads greater than 27.1 kW. As described in Section 2.5.2.4.1, Pad 1 was analyzed to support a total of 28 SSSCs arranged in fourteen rows of two SSSCs with a minimum center-to-center spacing of 14 feet in both directions for SSSCs with heat loads 27.1 kW or less. SSSCs will be placed on the storage pad starting in the center and moving to the ends in a symmetrical manner. The soil subgrade modulus of elasticity has a nominal value of 30,000 psi. The concrete has a minimum design compressive strength of 3000 psi in 28 days. Reinforcing steel shall be nominally No. 10 bars at 12 inches-on-center, each way, top and bottom, with a minimum yield strength of 60,000 psi. The as-built soil and concrete parameters of the ISFSI storage pad have been verified to ensure that the final storage pad is robust enough to withstand the maximum loads associated with all cask load conditions, yet "soft" enough to limit the deceleration of the cask during design accident cases. The engineering drawing of the plan, sections and details of the storage pads is provided in Figure 4-5. Specifications will be produced so that construction of the storage pads will meet the requirements of ACI 301, *Specifications for Structural Concrete for Buildings* (Reference 2).

The storage pads are designed to support generic SSSCs that are cylindrical in shape and are each approximately 8 feet in diameter by 16 feet high.

Load combinations and design limits for the reinforced concrete structures are in accordance with ANSI/ANS 57.9 (Reference 3). The available strength of the concrete storage pads was calculated in accordance with the requirements and assumptions of ACI 349, *Code Requirements for Nuclear Safety Related Concrete Structures* (Reference 4).

Structural design of the concrete storage pads included the following loads identified in Section 6.17 of ANSI/ANS 57.9. The following loads were evaluated:

D Dead load of the structure and attachments including permanent equipment and piping. The weight of the storage pads at 150 pounds per cubic foot was included for the pad design.

L Live loads include snow, rain, operational loads including impact, and vibratory loads due to operating equipment. For the storage pad design, the SSSC weight of 250 kips was conservatively treated as a live load. The SSSC transporter was also included as live load. The transporter will be moved at very slow speeds and no impact loads need be applied. Also, the SSSC will be lowered from the transporter at a very slow speed and no impact loads will be applied - the SSSC is designed to survive an accidental drop; if the storage pad is damaged it will be repaired. Snow, rain and/or ice loads that could develop are minor in comparison to the weight of the SSSCs. Also, any accumulation of these loads on the storage pad between the SSSCs would reduce the flexural stress in the storage pad and were, therefore, not included.

T Thermal loads during operation. The SSSCs will be stored on the exterior storage pads and will not be enclosed by an additional structure. The storage pad is not restrained except by the foundation soil. No thermal loads need be considered.

H Lateral soil pressure. The storage pad is a slab-on-grade and there are no differential soil pressures to consider.

E Loads generated by the Design Earthquake. The North Anna Power Station design basis earthquake (DBE) described in Section 2.5.2.6 of the UFSAR and Section 2.5.2.3 of this SAR was used as the Design Earthquake.

W Loads generated by the Design Wind. ANSI/ANS-57.9 references ANSI/ANS 2.19 for guidance for determining the Design Wind. ANSI/ANS 2.19 identifies the 100-year recurrence interval wind that shall be used. Design Wind was determined at a 100-year recurrence level in accordance with ASCE 7-88 (Reference 6).

T_a Loads due to a temperature rise resulting from loss of cooling air for an extended period of time or loads resulting from the maximum anticipated heat load. The SSSCs will be stored on the exterior storage pads and will not be enclosed by an additional structure. The storage pads are not restrained except by the foundation soil. Thermal loads need not be considered.

A Loads due to a drop of a heavy load. The SSSCs are designed to survive impact as a result of tornado missile impact (see Section 3.2.1.3) and also survive an accidental drop (see Section 8.2.9). Loads due to a drop of a heavy load need not be considered for the concrete storage pad; if the storage pad is damaged it will be repaired.

Although not identified in ANSI/ANS 57.9, the following extreme environmental loads were also investigated and conservatively included in the design of the concrete storage pad:

W_T Wind loads generated by a tornado. The same maximum tornado wind speed of 360 mph as used for the North Anna Power Station was used to determine loads on the SSSCs, sliding and overturning, and effect on the concrete storage pad.

F Loads resulting from maximum hypothetical flood including buoyancy and dynamic pressure. As stated in Section 2.4.2.3, flood loading need not be considered.

The design of the concrete storage pads included the following load combinations:

$U = 1.4D + 1.7L$
$U = 0.75(1.4D + 1.7L + 1.7W)$
$U = D+L+W_T$
$U = D+L+E$

where U = required concrete strength.

The factor of safety against overturning and sliding is based on Section 6.17.4.1 of ANSI/ANS 57.9 as modified below and is conservatively applied to each SSSC:

	Minimum Safety Factors	
Load Combinations	Overturning	Sliding
$D + L + E$	1.1	1.1
$D + L + W$	1.1	1.1
$D + L + W_T$	1.1	1.1

4.2.1.1 **Static Analysis**

The concrete storage pad design was analyzed using the IMAGES-3D finite element computer program (Reference 7). The analysis was performed to verify that the strength of the storage pad was adequate. Since the ramps are connected to the main portion of the storage pad, they were included in the storage pad model. A 9 x 77 array of 693 nodes and 608 plate elements was used for the model. Nodes were spaced at 4 feet spacing in both directions (See Figure 4-6).

Vertical translational springs were used to model the soil stiffness. These springs were placed at each node of the model based on the tributary area of the node. A conservative modulus of subgrade reaction of 200 kips per cubic foot (115 pci) was used to calculate the spring stiffness (see Section 2.5.1.11 for discussion on soil parameters). The model was restrained at the corners from lateral and rotational displacements for stability but these restraints received no loads from vertical static loading.

The weight of each 250-kip SSSC was modeled as a 50 kip load at the node directly beneath the centerline of the SSSC and 50 kips each at the four adjacent nodes (one on either side of the center node, in both directions). The SSSCs were conservatively treated as a live load and a 1.7 load factor was applied for the ultimate strength evaluation. The five nodal loads were therefore:

50 kips × 1.7 = 85 kips

The storage pad was analyzed for several SSSC loading patterns to determine the maximum stress in the concrete pad. Since the SSSCs will be located starting at the center of the storage pad and will proceed towards both ends in a symmetrical pattern, the following loading cases were considered:

- One center SSSC
- Two center SSSCs
- Four center SSSCs
- Eight center SSSCs
- All 28 SSSCs

The weight of the concrete storage pad was included as dead load in all cases.

As expected, the bending stresses in the storage pad are less with a more uniform loading of all SSSCs and are higher with the less uniform loads of the other cases. The maximum concrete bending stress for the above loading pattern occurs with two center SSSCs.

Also, the effect of the SSSC transporter was evaluated. The transporter was assumed to have a total loaded weight of 310 kips and a wheel load at each of the eight wheels of 38.75 kips per wheel. With the 1.7 load factor, the wheel load becomes 65.88 kips. Several transporter locations with and without other SSSCs were checked. The following cases were evaluated:

- Transporter at edge of storage pad
- Transporter over one center SSSC
- Transporter over one center SSSC plus one additional center SSSC
- Transporter over one center SSSC plus three additional center SSSCs

For these cases, the maximum storage pad stress occurred with the transporter at the edge of the storage pad.

4.2.1.2 **Design Wind**

Design Wind loads on the SSSCs were determined using ASCE 7-88 for a 100-year recurrence interval. From Table 4, design wind forces, F, for structures other than buildings:

$F = q_z G_h C_f A_f$ or $p = F/A_f$, where:

q_z = velocity pressure evaluated at height z above ground

G_h = gust response factor evaluated at height z = h

C_f = force coefficient

A_f = area of structure projected on a plane normal to wind direction

h = height of structure above ground

ASCE 7-88 takes into account characteristics of ground surface irregularities for a particular site and establishes four exposure categories. For the North Anna site, Exposure C was conservatively chosen which describes the site area as open terrain with scattered obstructions having heights generally less than 30 feet and includes flat open country and grasslands. With a SSSC height of 16 feet and storage pad thickness of 2 feet, z and h were conservatively selected as 20 feet.

From Equation 3, $q_z = 0.00256K_z(IV)^2$, where:

K_z = velocity pressure exposure coefficient at height z

I = Importance factor

V= basic wind speed

From the map on Figure 1, V = 70 mph.

From Table 5, with essential structure classification Category III, and location 100 miles from hurricane oceanline and other areas, I = 1.07. This adjusts the design wind speed to a mean recurrence interval of 100 years, therefore:

IV = 1.07(70) = 74.9 mph

In Section 2.3.1, a 100-year design wind speed of 80 mph was identified and will be used in this analysis, as it bounds 74.9 mph calculated above.

From Table 6, with z = 20 feet and Exposure C, K_z = 0.87.

Therefore, $q_z = 0.00256(0.87)(80)^2 = 14.25$ psf.

From Table 8, with z = 20 feet and Exposure C, G_h = 1.29.

From Table 12, with round shape and $D(q_z)^{0.5} > 2.5$, moderately smooth surface, and interpolating for h/d = 2, C_f = 0.52.

Therefore, p = 14.25(1.29)(0.52) = 9.6 psf < 10 psf minimum.

A_f = 8.0(16.0) = 128 sf

Therefore, $F = 10(128) = 1280$ lb, or 1.3 kips.

This lateral force will tend to cause the SSSC to slide or tip over. Sliding is resisted by the static friction force between the SSSC and the concrete storage pad surface. In order to slide, the lateral force must overcome a friction force equal to the SSSC weight times the coefficient of friction of the surface:

$F_f = uW$

The coefficient of static friction for metal on concrete is approximately 0.30 to 0.70 (Reference 8). With a 250-kip SSSC, the minimum resistance would be:

$F_f = 0.30(250) = 75$ kips

which is over 57 times greater than the calculated Design Wind load, therefore, the SSSC will not slide.

The SSSC will start to tip if the overturning moment about the outside edge of the base is greater than the resisting moment about that same point.

$M_O = F(h/2) = 1.3(8) = 10.4$ ft-kips

$M_R = \text{Weight}(7.0/2) = 250(3.5) = 875$ ft-kips

The factor of safety against the start of tipping is:

$F_S = M_R/M_O = 875/10.4 = 84.1$

The effect of the Design Wind loads was included in the static analysis of the storage pad by modifying the SSSC nodal vertical loads by a resultant couple equal to the overturning moment caused by the wind.

$R = M_O/(\text{diameter of base}) = 10.4/7.0 = \pm 1.5$ kips

$R_U = 1.7R = 1.7(1.5) = \pm 2.55$ kips

Therefore, the outside two vertical nodal ultimate loads are:

$P_U = 0.75(85.0 \pm 2.55) = 61.8$ kips to 65.6 kips

4.2.1.3 **Tornado Wind Loads**

Wind loads due to a tornado were similarly determined using ASCE 7-88, except gust and velocity pressure coefficients need not be applied. Using the same maximum tornado wind velocity as used for the North Anna Power Station, V = 360 mph.

$q = 0.00256V^2 = 0.00256(360)^2 = 332 \text{ psf} = 0.332 \text{ ksf}$

$F = qC_fA_f = 0.332(0.52)(128) = 22.1$ kips

As demonstrated with the Design Wind, a lateral force of 75 kips would be necessary to overcome the static frictional resistance, therefore, the SSSCs will not slide under the tornado wind. The Factor of Safety against sliding is 75.0/22.1 = 3.4.

Checking tipping under tornado wind conditions,

$M_O = 22.1(8.0) = 176.8$ ft-kips

$M_R = 250(3.5) = 875$ ft-kips

$F_S = 875/176.8 = 4.95$

Therefore, the SSSCs will not start to tip due to tornado winds.

The effect of the tornado wind loads was included in the static analysis of the storage pad by modifying the SSSC nodal vertical loads by a resultant couple equal to the overturning moment caused by the wind.

$R = M_O/(\text{diameter of base}) = 176.8/7.0 = \pm 25.3$ kips

With tornado winds, the load factors are 1.0, and the outside two vertical nodal ultimate loads are:

$P_U = p = 50.0 \pm 25.3 = 24.7$ kips to 75.3 kips

4.2.1.4 **Dynamic Analysis**

A dynamic analysis was performed to determine the effect of the Design Earthquake on the SSSCs and concrete storage pad. A finite element model was developed using the computer code SASSI (Reference 9). For the dynamic analysis a weight of 230 kips was used for each SSSC. The SSSCs were modeled as a rigid beam 8 feet long connected to the mid elevation of the pad by an ensemble of rigid elements. The translational and rotary weights of the SSSC were lumped at the top of the 8-foot rigid beam.

Due to the symmetry of the pad, a quarter of the pad was modeled. The pad was modeled by 4-foot x 4-foot plate elements, 2-foot thick, and a unit weight of 0.15 kcf. The elastic properties for reinforced concrete were used based on a design compressive strength, f'c = 3000 psi. The slab geometry and elements for the SSSCs and pad plate elements are shown on Figures 4-7, 4-8 and 4-9.

The analysis for the soil-structure interaction was based on the soil boring logs shown in Appendix 2A for the Design Earthquake.

Input motion acceleration time histories for soil conditions were used which envelop the design basis earthquake (DBE) Response Spectra for the Seismic Class I structures for the North Anna Power Station.

Accelerations were calculated at the SSSCs in order to determine the factor of safety for sliding and overturning and the global forces and moments at the base of the SSSCs. These results consider the three components of the input applied simultaneously. For calculating the factor of safety for sliding, a friction coefficient of 0.3 was assumed between the SSSCs and the supporting concrete slab.

When combining responses as identified in Regulatory Guide 1.92 (Reference 10), the lowest factor of safety for sliding is slightly higher than one. The lowest factor of safety for overturning is about 1.6. Figures 4-10 and 4-11 show the time plot of the inverse of the sliding and overturning factors of safety (1/FS), respectively. However, it should be noted that the ground motions in the x and y directions (two horizontal directions) have an extreme peak occurring at the same time at 3.71 seconds even though these motions are statistically independent. This situation is very unrealistic and overly conservative due to the coincidence of two extreme peaks in the horizontal input motions. It is due to the fact that these motions correspond to artificially generated time histories. At any other time, the next lowest factor of safety for sliding during the duration of the earthquake is about 1.25 and for overturning it is approximately 2.0.

The analysis confirmed that the responses due to the 3 components of the input are uncoupled. A better estimate of the factors of safety for sliding and overturning can be obtained by calculating them using the maximum responses for each direction and then combining them using the 100%, 40%, 40% combination rule recommended in ASCE Standard 4-86, Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety-Related Nuclear Structures (Reference 11). Using 100% of the maximum response due to the X input, 40% of the maximum response due to the Y input, and 40% of the maximum response due to the Z input, the factor of safety for sliding is approximately 1.17. The same value results if 40% of X and 100% of Y are used. For the case when 40% of the horizontal cases and 100% of the vertical case are used, then the sliding factor of safety is approximately 2.04.

Also performed was a verification of the personal computer version of the computer code SASSI. A model formed by plates and beams was analyzed using the personal computer version of SASSI and EQE International's QA-verified version of the computer code CLASSI (Reference 12). For comparison purposes, in-structure acceleration response spectra at various elevations and plate stress time histories were calculated using both programs and then plotted together. It was concluded that the personal computer version of SASSI gives results similar to CLASSI for soil-structure interaction analysis.

4.2.1.5 **Storage Pad Design**

Several SSSC loading patterns were investigated during the static analysis to determine the maximum stress in the concrete storage pad:

- One center SSSC
- Two center SSSCs
- Four center SSSCs
- Eight center SSSCs
- All 28 SSSCs

It was determined that the maximum stress occurred with two center SSSCs. Wind and seismic loads were then applied to the two center SSSCs using the load factors previously described to determine the critical condition for the concrete storage pad.

The storage pad was also analyzed using the SAFE (Reference 13) finite element computer program and designed using the SAFERC reinforced concrete design computer program which is a post processor for SAFE. The model for the SAFE runs was similar to the IMAGES run except a finer 2.0-foot x 2.0-foot mesh and a shorter model was used for the SAFE runs concentrating on the critical condition of two center SSSCs. Several runs were made with varying design strip widths. A 48-inch design strip was conservatively selected which resulted in number 10 rebar with 12-inch spacing. This provides an area of 1.27 square inches per linear foot. The number 10 rebar will be placed at 12-inch spacing in both directions, and in both the top and bottom of the storage pad and used for the entire pad area. This exceeds the minimum spacing requirements for primary flexural reinforcement and exceeds the minimum reinforcement requirement of AC1 349. The minimum concrete cover will be three inches on the bottom and two inches on the top in accordance with the concrete protection requirements of AC1 349.

4.2.2 Storage Site Layout

The overall layout of the North Anna ISFSI is described in Section 4.1, and is shown in Figure 1-2.

The SSSCs are the only component of the North Anna ISFSI vital to the fulfillment of its safety function. All other structures and components are of a support nature and do not perform safety functions.

The most important of these support systems are the concrete storage pads, which provide a uniform level surface, slightly above grade elevation, for the SSSCs. These are described in Section 4.2.1. Engineering drawings showing section and details of the storage pads are provided in Figure 4-5.

4.2.3 SSSC Description

The bases and engineering design specifications for the SSSCs are described in the SSSC Topical Safety Analysis Reports. These reports also provide assurance that the applicable design criteria described in Chapter 3 are met.

Compliance with the design criteria ensures that the General Design Criteria in 10 CFR 72, Subpart F are satisfied. This is illustrated in Table 4-1 which shows a correspondence between each of the General Design Criteria and the design criteria of specifications that the SSSCs must meet as identified in Chapter 3.

The specific codes and standards to which the SSSCs are fabricated, delivered to the site, and sealed are addressed in the SSSC Topical Safety Analysis Reports. Compliance with applicable current nationally recognized codes and standards is expected. Codes and standards representing an acceptable level of design are:

- American Welding Society (AWS) *The Structural Welding Code* (AWS Dl.l-1980)
- American Iron and Steel Institute (AISI) *Steel Products Manual*
- American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code*
- American Society of Testing and Materials (ASTM) Standards

As described in Chapter 11, the SSSC manufacturers will be required to maintain the necessary documentation to substantiate conformance with the specified codes and standards.

Construction materials are compatible with each other and with the expected radiation levels. In addition, the baskets holding the fuel assemblies within the SSSCs are typical of those currently used in spent fuel pools throughout the industry, and are designed to protect the spent fuel assemblies from mechanical damage during insertion and removal operations and as a result of all credible events. Damage resulting from postulated accidents is limited to the extent that normal removal of the fuel assemblies is not precluded.

4.2.3.1 **Function**

Descriptions of the fuel loading, SSSC preparation, and SSSC placement operations are provided in Chapter 5.

The performance objectives during fuel loading are to transfer the selected fuel assemblies from their storage location in the spent fuel pool to the SSSC without damaging the fuel. All operations within and outside the Fuel Building will be conducted in a manner that does not jeopardize the safe operation of the North Anna Power Station, does not present a hazard to the stored fuel, and does not result in releases of radioactive gases in excess of the guidelines in 10 CFR 100.

The performance objectives for the post-loading activities are to ensure that the SSSCs can fulfill all of their design functions, and in particular that the SSSCs will confine the radioactive products under all credible conditions.

The performance objectives for SSSC transfer and emplacement operations are to ensure that the design criteria are not exceeded, and that the safety of the North Anna Power Station is not impaired.

The performance objectives for SSSC unloading operations are to ensure that all operations within and outside the Fuel Building will be conducted in a manner that does not jeopardize the safe operation of the North Anna Power Station, that there is no hazard to the stored fuel, and that there are no releases of radioactive gases in excess of the guidelines in 10 CFR 100.

4.2.3.2 Description

A description of the SSSC components is provided in the SSSC Topical Safety Analysis Reports.

4.2.3.3 Design Bases and Safety Assurance

The ability of the SSSCs to perform their design function is demonstrated in the SSSC Topical Safety Analysis Reports and in Appendix A.

Loading and handling of the SSSCs will be done according to the applicable procedures.

As described in Chapter 8, the design and operation of the North Anna ISFSI ensures that a single failure does not result in the release of significant radioactive material.

The only interactions between the ISFSI and the North Anna Power Station are those concerning the loading and handling of the SSSCs in the Fuel and Decontamination Buildings. These are discussed in Chapter 5.

Radiation protection of operating personnel is addressed in Chapter 7.

Nuclear criticality safety for the SSSCs is addressed in the SSSC Topical Safety Analysis Reports or Appendix A.

4.2.4 Instrumentation System Description

Due to the passive nature of the SSSCs, no safety-related instrumentation is required. A description of the nonsafety-related SSSC pressure monitoring system is provided in Section 4.4.5.3.

4.2.5 References

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2. American Concrete Institute, ACI 301, *Specifications for Structural Concrete for Buildings,* 1989.
3. American Nuclear Society, ANSI/ANS 57.9, *Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type),* 1984.
4. American Concrete Institute, ACI 349, *Code Requirements for Nuclear Safety Related Concrete Structures,* 1985.
5. American Nuclear Society, ANSI/ANS 2.19, *Guidelines for Establishing Site-Related Parameters for Site Selection and Design of an Independent Spent Fuel Storage Installation (Water Pool Type),* 1981.

6. American Society of Civil Engineers, ASCE 7-88, *Minimum Design Loads for Buildings and other Structures,* 1988.
7. Celestial Software, *IMAGES-3D,* Version 3.0, 1993.
8. Beer, F. P., Johnston, E. R. Jr., *Vector Mechanics for Engineers: Statics and Dynamics,* McGraw-Hill Book Company, 1962.
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10. Regulatory Guide 1.92, Combining Modal Responses and Spatial Components In Seismic Response Analysis, Revision 1, dated February 1976.
11. ASCE Standard 4-86, Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety-Related Nuclear Structures, September 1986.
12. H. L. Wong and J. E. Luco, Soil-Structure Interaction: A Continuum Mechanics Approach (CLASSI), Report No. CE 79-03, Department of Civil Engineering, University of Southern California, in publication.
13. Computers and Structures, Inc., *SAFE, Slab Analysis by the Finite Element Method,* 1988.

4.3 TRANSPORT SYSTEM

4.3.1 Function

The function of the transporter is to move the loaded SSSCs between the Decontamination Building and the ISFSI storage pads. The transporter shall be capable of being towed over several different types of ground surfaces, including compacted gravel, and concrete and asphalt paving. The performance objectives of the transporter are to move the loaded SSSC in a vertical position in a manner that will preclude damage to the SSSC body and its internal components, and to any other safety or security related system or component which could be affected by SSSC transport.

4.3.2 Components

The transporter is a gantry lift system on a "U" shaped trailer which carries the SSSC in a vertical position. It is approximately 16 feet wide, 21 feet long, 20 feet high and weighs approximately 30 tons. It has a tow bar pivot and four steerable wheels as well as four fixed wheels with solid tires to ensure maximum stability, maneuverability, and even-load distribution. A tow vehicle will be used to move the transporter. Side and plan views of the transporter are provided in Figure 4-12.

The hydraulic cylinders used for SSSC lifting are a heavy duty design and made of steel. No load bearing member of the hydraulic unit is made of cast iron or any other brittle material. There are flow control valves at the downside of the cylinders in order to restrict the flow of hydraulic fluid from the cylinders, thus preventing the load from dropping too fast. There are lift cylinder locking valves to assure that the SSSC will not be accidently lowered.

The power unit used for SSSC lifting is diesel powered and is placed at the front of the transporter. The backup power unit is a 480V, three phase motor coupled to a heavy duty pump. The pumping unit contains suction and return line filters, pressure relief valves, pressure gauges, and check valves.

The transporter is equipped with disc brakes designed for normal, park, and emergency functions. Normal and park brake operations are controlled by a lever mounted on the side of the transporter, easily accessible to an operator walking alongside.

The emergency brake has a separate control and will control brake application to minimize dynamic braking effects and yet bring the transporter to a stop quickly.

The transporter tires are designed to distribute the load and provide adequate mobility. Solid tires are used to assure reliability. The transporter, loaded with a SSSC, is designed for a nominal towing speed of 5 miles per hour.

None of the features or components of the transporter are important to the safety function of the SSSCs and will not be covered by the Quality Assurance program described in Chapter 11.

The location of the transfer routes from the Decontamination Building to the ISFSI is shown in Figure 4-4. The main route runs west from the Decontamination Building toward the West End Security Access Facility and south to the ISFSI, while an alternate transfer route runs east from the Decontamination Facility, south to the South East Security Access Facility and then west to the ISFSI. Both routes consist of asphalt roadways. The portions of the routes within the North Anna Power Station are asphalt and lines for several safety-related systems for North Anna Power Station Units 1 and 2 are located beneath the transfer routes. The portion of the transfer route in and to the west of the Station has also been used for the transport of replacement steam generators, otherwise, only personnel and maintenance vehicles use portions of the transfer route.

Safety-related and nonsafety related with special quality regulatory requirements utilities located beneath the main transfer route include an electrical ductbank, service water lines, fuel oil lines and fire protection lines. All of these utilities are located within the protected area for North Anna Units 1 and 2. Based on a combined transporter and cask weight of 315,000 lb and a load of 39,400 lb/wheel, none of these utilities will be affected by movement of the loaded transporter over them.

The electrical ductbank is approximately 5.5 feet below grade and would be subject to approximately 1000 psf surcharge loading. This ductbank is founded on rock and requires no protection due to the depth of burial and its reinforcement design. The service water lines are approximately 6.7 feet below grade and would be subject to a surcharge loading of approximately 900 psf, which is negligible. The ten 1-1/2-inch diameter fuel oil lines are encased in concrete on top of the electrical ductbank discussed above, and, for the same reasons, they require no protection. There are two fire lines crossing under the transport path that are 6.0 feet below grade. These pipes are not encased, however, they are not overstressed by the additional 1000 psf surcharge pressure.

Nonsafety-related utilities passing under the main transport route in the protected area include domestic water lines, a well water line, a 42-inch diameter storm drain and a security duct bank. The water lines do not lie directly under the transport route, are relatively deep and have a small diameter. The storm drain is protected by a 2.5-foot thick concrete slab that will distribute loads evenly, and is approximately 5.0 feet below grade.

A 24-inch diameter surface drain culvert passes beneath the main transport route approximately 900 feet west of the protected area gate. The top of this culvert is approximately three feet below surface grade, and steel plates or concrete will be used to protect this culvert from damage.

There are no portions of safety-related systems located beneath the alternate transfer route. Within the protected area, there is a single buried section of fire protection pipe beneath this route. This pipe is located a minimum of 6 feet below grade. Based on a combined transporter and cask weight of 315,000 lb, this results in a load of 39,400 lb/wheel and a corresponding surcharge loading of 1000 psf at 6 feet below grade. The pipe is not overstressed by the loaded transporter movement.

The portions of nonsafety-related systems located beneath the alternate transfer route and within the protected area include duct banks, a domestic water pipe, storm drain pipes, a waterline, a well waterline, mat sump pump lines, a pipe tunnel, manholes, and a diesel fuel pipe. These nonsafety-related systems, with the exception of a 12 foot wide security ductbank and a 9 foot wide pipe tunnel, are either located at acceptable depth or constructed of materials able to withstand the stresses generated from loaded transporter movement.

An East-West running security duct bank and a North-South running reinforced concrete pipe tunnel each have top-of-concrete elevations located at 2.3 feet and 2 feet below grade, respectively. Both the duct bank and tunnel are located directly beneath the alternate transport route. Reinforced concrete protective slabs are installed over the duct bank and tunnel to bridge each structure and divert transporter surcharge loads so that the duct bank and tunnel are not adversely impacted by stresses generated by loaded transporter movement

4.3.3 Design Bases and Safety Assurance

The transporter is designed to limit SSSC lift height to less than 15 inches by the use of internal mechanical stops. Lifting system integrity is maintained during transport by means of a hydraulic lock valve. The transporter is equipped with a SSSC restraint system which prevents SSSC sway during road movement.

The transporter design includes static and dynamic evaluations for strength, fatigue resistance, buckling resistance, joint design and the use of stiffeners. These evaluations included a minimum factor of safety of 1.67 in accordance with CMAA (Reference 1) and the AISC *Manual of Steel Construction* (Reference 2).

In order to minimize the weight of the transporter, no radiation shielding is provided in the transporter design. However, operation of the transporter can be done by one person, thereby minimizing radiation dose to operating personnel. Other personnel accompanying transport of SSSCs may do so at a distance from the transporter that minimizes their exposure to radiation. Section 7.4 includes an evaluation of the occupational exposure during transport.

The transporter is designed for independent operation, however, the electrical system may be powered from an external source. The transporter has no other backup provisions and no interfaces with SSSC or ISFSI systems. The codes and standards used in the design and fabrication of the transporter are listed in Table 4-2.

4.3.4 References

1. Crane Manufacturer's Association of America, Specification No. 70, *Specification for Electric Overhead Traveling Cranes.*
2. American Institute of Steel Construction, *Manual of Steel Construction*, Ninth Edition.

4.4 OPERATING SYSTEMS

4.4.1 Loading and Unloading System

4.4.1.1 **Function**

The functions of the loading systems are to transfer the spent fuel from the spent fuel pool to the SSSC and move the SSSC from the spent fuel pool to the transporter outside the Decontamination Building. The same systems would be used to unload the SSSCs.

The performance objectives are to load the spent fuel into the SSSCs in such a manner as to preclude damage to the fuel and ensure that subcriticality is maintained, and to move the loaded SSSC in a manner which will preclude damage to the SSSC and to any other safety-related system or component in the load path. The same objectives apply to unloading the SSSCs.

The ISFSI, SSSCs and related support equipment will be designed to interface with existing and planned equipment and systems at the North Anna Power Station. An amendment to the North Anna Power Station UFSAR will provide a description of the systems and equipment.

4.4.1.2 **Major Components and Operating Characteristics**

The fuel storage area at the North Anna Power Station is located in the Fuel Building between the two reactor containments, and consists of a new fuel storage area, a pool for storing spent fuel, a cask loading area, and two canals for transfer of fuel assemblies between the reactors and the pool. The spent fuel pool is 72 feet 6 inches long, 26 feet 9 inches wide at the east end, 21 feet 4 inches wide at the west end and normal water depth is approximately 40 feet. The cask loading area at the west end of the spent fuel pool is separated from the spent fuel storage racks by a concrete wall that is 3 feet 6 inches thick and has a gate to allow spent fuel assemblies to be moved from the rack area. The cask loading area has two locations for casks, one that is 12 feet by 12 feet with a floor elevation 2 ft. 6 in. lower than the spent fuel storage area, and a second that is 12 feet by 9 feet 4 inches with a floor elevation 19 ft. 8 in. above the spent fuel storage area. A 32-inch high pedestal has been placed in the deep end of the cask loading area to allow the fuel assemblies in the spent fuel cask to be at approximately the same elevation as the assemblies in the spent fuel racks.

The Fuel Building walls consist of blow-off siding attached to the steel superstructure. Access to the Fuel Building for the 125-ton cask crane and SSSCs is provided by a roll-up door. Movement of the cask crane in the Fuel Building is limited to the cask loading area and adjacent areas north and south, so that casks cannot pass over the fuel storage area. Figure 4-13 shows the layout of the Fuel and Decontamination Buildings and the load path for the SSSCs. Figure 4-14 is a section view of the load path in the Fuel and Decontamination Buildings.

The Decontamination Building is used for preparation of empty SSSCs and for vacuum drying, helium backfill, leak testing and decontamination of loaded SSSCs. Preparation of loaded SSSCs for unloading also takes place in the Decontamination Building, including testing of the helium backfill for indications of fuel failure. The north bay of the Decontamination Building will be used specifically for SSSCs, and is equipped with a platform to allow easy access to all areas of the SSSC surface, vacuum pumps, helium leak detector equipment and a system control panel. Helium bottles are placed outside the Decontamination Building, for easy access during bottle replenishment, and are connected by piping to the north bay.

Station systems and other components used during the loading and unloading of SSSCs include the 125-ton cask handling crane and 10-ton auxiliary crane that service the Fuel and Decontamination Buildings. Other components include a cask lift beam and special tools for lifting SSSC lids and covers. A vacuum drying system (vacuum pumps, water collection bottle, piping and hoses) is used in the Decontamination Building to remove any water remaining in the cask cavity after pumping water from the cavity back to the spent fuel pool. Specialized leak detection equipment is used for seal testing.

Fuel assembly crud is controlled during unloading of the SSSCs through the slow addition of water to the SSSC cavity. Once the SSSC cavity is filled with water and the SSSC has been placed in the spent fuel pool, slow removal of the lid will also help prevent the spread of crud into the spent fuel pool.

4.4.1.3 Safety Considerations and Controls

Fuel handling activities in the spent fuel pool are subject to limiting conditions for operations as set forth in Section 3.9, Refueling Operations, of the North Anna Units 1 and 2

Technical Specifications. A 125-ton trolley crane with a 10-ton auxiliary crane serve the Decontamination Building and Fuel Building. This crane and the fuel loading and SSSC handling will be subject to conditions as set forth in the North Anna Units 1 and 2 Technical Specifications and Operating License.

A lift beam designed to ANSI N14.6 (Reference 1) is used for SSSC handling. The lift beam and the SSSC lifting trunnions are designed such that stresses from lifting three times the weight of the SSSC will not exceed the yield strength of the lift beam materials and five times the weight will not exceed the ultimate strength. The arms of the lift beam open as the lift beam is attached to the SSSC. The arms are hydraulically locked in the closed position for lifting the SSSC.

4.4.2 Decontamination System

Standard decontamination methods will be used to remove surface contamination from the SSSCs resulting from their submersion in the spent fuel pool during loading. Decontamination of the SSSCs will be performed in the north bay of the Decontamination Building. Decontamination will typically be done manually, using water detergents and wiping cloths.

4.4.3 SSSC Repair and Maintenance

Incidental mechanical operations involving the SSSCs include receiving the new SSSCs from the supplier, their temporary (empty) storage, and transfer to the Fuel Building. During these operations, the SSSCs will be inspected in detail and corrections made as needed. The facilities and machine shops of the North Anna Power Station will be available in the event repair operations become necessary. Repairs made to SSSCs must be done in or outside the Decontamination Building where the crane capacity exists for lifting the SSSC. Occupational exposures during repair operations will be kept as-low-as-reasonably-achievable (ALARA) under the North Anna Power Station ALARA program.

No significant maintenance or repair operations are anticipated once the SSSCs are placed into storage. Periodic maintenance is not required beyond instrument adjustment and other similar evolutions of a minor nature, such as touching up defects in the outer SSSC coating. Recoating of the SSSCs can also be performed over the life of the ISFSI. Recoating can be performed within the ISFSI area, without need to move the SSSCs.

Degradation of a SSSC primary seal is considered extremely unlikely. Nevertheless, in the event that this were to occur, the pressure sensor would activate an alarm. Upon identification of the affected SSSC, a series of actions identified in the ISFSI procedures will be taken. Depending on the exact circumstances, these may include monitoring the SSSC pressure with a time recorder in order to ascertain whether the malfunction is a progressing one, and checking for possible instrumentation failure. If a failure of a seal is ascertained, arrangements will be made to repair the SSSC in place, to transfer the SSSC to the Decontamination Building for repair work, if necessary, or any other action recommended by the manufacturer and included in the North Anna ISFSI operating procedures.

Because SSSCs have double seals, seal failure hypothesized in this section would not result in release of radioactive material.

The ISFSI operating procedures will be prepared to provide step-by-step actions to be taken for all alarms. These will be prepared according to the specific SSSC manufacturers' designs and recommendations.

4.4.4 Utility Supplies and Systems

The SSSCs are passive devices and no utility services are necessary for their operation.

4.4.4.1 Electrical Systems

Electric power is not required to support functions of the North Anna ISFSI important to safety. Power for ISFSI security equipment is provided by normal station power. A discussion of emergency power for security equipment is provided in the Physical Security Program.

Nonsafety-related electric power is supplied to the ISFSI for purposes of lighting, general utility, and instrumentation with which SSSC seal integrity is monitored. These support systems are not needed for effective SSSC function.

The source of electric power is obtained from three new pole-mounted transformers inside the ISFSI perimeter fence. The 34.5 kV line providing service to these transformers comes from the plant's electrical switchyard. The transformers provide power to ISFSI loads through a separate feeder and disconnect and distribution panel which are located at the diesel generator pad. This distribution panel will provide normal power to loads for all three storage pads. Service power for lighting and welding receptacles is 480V, 60 Hz, single or three phase. A 120V circuit is also provided.

Since the SSSCs are the only components important to safety and since they do not require electric power to perform their functions, loss of electricity will not jeopardize the safety of the facility. A backup diesel generator will be provided to power security-related and SSSC monitoring equipment on the loss of normal power.

The ISFSI is a passive installation. There are no motorized fans, dampers, louvers, or valves, and no electrically operated cranes or lifts. Electricity is required only for monitoring equipment, lighting and security-related equipment.

4.4.5 Other Systems

4.4.5.1 Fire Protection System

As described in Section 8.2.5.1, no fires other than small electrical fires are considered credible at the North Anna ISFSI.

Therefore, the North Anna ISFSI does not include a fire protection system, other than portable fire extinguishers which will be available within the ISFSI perimeter fence. In addition, the fire fighting equipment and personnel present at the North Anna Power Station would be available if needed.

4.4.5.2 Sewage Treatment System

Neither sanitary nor chemical sewage is produced at the North Anna ISFSI. During the infrequent periods of manning for SSSC transfer operations or construction of the second and third storage pads, portable sanitary facilities may be provided in the vicinity of, but not directly within, the ISFSI. Chemical wastes, such as small amounts of ethylene glycol (antifreeze) or drips of lubricating fluid from transport vehicles could be cleaned up manually and disposed of at appropriate facilities of the North Anna Power Station. No permanent sewage treatment system is required or provided.

4.4.5.3 Alarm Systems

The ISFSI is not manned on a continuous basis. All of the SSSCs will be provided with a pressure sensing device to monitor their seal tightness.

The monitoring devices will actuate a pressure switch at a preset alarm level. Specific recommendations for monitoring the SSSCs are provided in the SSSC Topical Safety Analysis Reports. Each of the SSSC alarms (maximum of two per SSSC) will initiate an annunciator alarm in the local annunciator panel at the ISFSI. The alarm panel will indicate the specific SSSC and will remain lit until reset. Actuation of the pressure monitoring alarm will also cause an alarm in the Station Security Central Alarm Station (CAS) and the Secondary Alarm Station (SAS). Security personnel continuously monitor these stations and they will notify the Shift Manager. This instrumentation is not required for safe operation of the ISFSI and therefore will not be safety-related.

4.4.5.4 Seismic Recording Instrumentation

On August 23, 2011, an earthquake occurred approximately 5 miles from Mineral, Virginia. In response to this event, Dominion committed to install seismic recording instrumentation at the ISFSI (Reference 2). This instrumentation consists of a triaxial time-history accelerograph and a motion recorder, and is located in the north-west section of the ISFSI adjacent to the alarm panel pad. The motion recorder is equipped with seismically qualified battery backup that permits continuous operation of the instrumentation upon loss of external power. The instrumentation is designed to detect the occurrence of an earthquake and provide records on intensity and duration. The data collected can be used to evaluate the potential degradation of equipment and structures at the ISFSI due to an earthquake. This instrumentation is not required for safe operation of the ISFSI and therefore is not classified safety-related.

4.4.6 References

1. ANSI N14.6-1993, *Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 kg) or More for Nuclear Materials,* American National Standards Institute.

2. Grecheck, E. S., Virginia Electric and Power Company (Dominion), Letter to U.S. Nuclear Regulatory Commission, *Virginia Electric and Power Company (Dominion), North Anna Power Station Units 1 and 2, Independent Spent Fuel Storage Installation, Revised Long-Term Actions Commitment List,* Serial No. 11-520D, dated November 7, 2011.

4.5 CLASSIFICATION OF STRUCTURES, SYSTEMS AND COMPONENTS

The SSSCs are the only components of the North Anna ISFSI which are important to safety. None of the other systems and structures comprising the North Anna ISFSI (storage pads, fence, monitors, wiring, and lights) perform a safety function. The SSSC transporter is not considered important to safety because the SSSCs are designed to withstand its failure without jeopardizing the health and safety of the public. The SSSC handling equipment (cask lift beam and cask lid lifting tools) used during loading and unloading operations is also considered important to safety because the SSSCs are not designed to withstand their failure. The cask handling and auxiliary cranes are included in the Station NUREG-0612 Heavy Loads program in order to provide programmatic control. A cask drop analysis has been conducted which evaluated potential Station structural damage and offsite dose consequences. This analysis is included in Appendix 15A of the North Anna Power Station UFSAR.

The specific portions of the SSSCs that are important to safety and a definition of the specific safety function are provided in the SSSC Topical Safety Analysis Reports.

4.6 DECOMMISSIONING PLAN

The SSSC design concept utilized at the North Anna ISFSI features inherent ease and simplicity for decommissioning. At the end of its service lifetime, SSSC decommissioning could be accomplished by one of the options described below.

The SSSC, including the spent fuel stored inside, could be shipped to a fuel repository for permanent disposal. Depending on licensing requirements existing at the time of shipment offsite, placement of the entire SSSC inside a supplemental shipping container or overpack would be considered.

Alternately, the spent fuel could be removed from the SSSC and shipped in a licensed shipping container to a fuel repository. If needed, SSSC decontamination could be accomplished through the use of conventional high pressure water sprays to reduce contamination on the SSSC interior. The sources of contamination on the interior of the SSSC would be crud from the outside of the fuel rods and the crud left by the spent fuel pool water. The expected low levels of contamination from these sources could be easily removed with a high pressure water spray. After decontamination, the SSSC could either be cut-up for scrap or partially scrapped and any remaining contaminated or activated portions shipped as low-level radioactive waste to a disposal facility.

The volume of waste material produced incidental to ISFSI decommissioning will be limited to that necessary to accomplish surface decontamination of the SSSCs once the spent fuel assemblies are removed.

SSSC activation analyses have been performed to quantify specific activity levels of SSSC materials after years of storing spent fuel. These activation calculations and the assumptions under which they were performed are described in the SSSC Topical Safety Analysis Reports. Based on the results of the analyses, the SSSC materials will be only slightly activated by the low level neutron flux emanating from the stored spent fuel. Consequently, after application of the surface decontamination process described above, the radiation level due to activation products will be negligible, and the SSSCs may be able to be scrapped. A detailed evaluation will be performed at the time of decommissioning to determine the appropriate mode of disposal.

Due to the leak tight design of the SSSCs, no residual contamination is expected to be left behind on the storage pads. The storage pad, fence, and peripheral utility structures require no decontamination or special handling after the last SSSC has been removed.

The spent fuel pool at the North Anna Power Station will remain functional until the ISFSI is decommissioned. This will allow the pool to be utilized to transfer fuel from the SSSCs to licensed shipping containers for shipment offsite if the SSSCs cannot be utilized for transport.

Virginia Power presently owns and operates four nuclear power generating units. The cost to decommission the ISFSI is expected to be a small fraction of the total decommissioning costs for the North Anna Power Station. Nuclear decommissioning trusts have been established to accumulate the funds needed to cover the costs of decommissioning.

Table 4-1

COMPLIANCE WITH GENERAL DESIGN CRITERIA (SUBPART F, 10 CFR 72)

72.122(a)	Quality standards The design criteria require that the SSSCs be designed, fabricated, delivered to the site, and sealed according to recognized commercial codes and standards and in accordance with Virginia Power's quality assurance (QA) program for safety-related equipment.
72.122(b)	Protection against environmental conditions and natural phenomena Extreme environmental conditions are defined in Chapter 2. The design criteria require that the SSSCs be designed to withstand the Design Earthquake, high ambient temperature, exposure to sunlight, and extreme winds.
72.122(c)	Protection against fire and explosions No large fire within the North Anna ISFSI is considered credible. The design criteria require that SSSCs be designed to withstand extreme ambient temperatures and peak overpressure resulting from postulated nearby explosions.
72.122(d)	Sharing of structures, systems, and components The ISFSI activities will be done without jeopardizing the safe shutdown capability of the North Anna Power Station Units 1 and 2.
72.122(e)	Proximity of sites The design and operation of the North Anna ISFSI result in minimal additions of risk to the health and safety of the public.
72.122(f)	Testing and maintenance of systems and components The SSSCs require minimum maintenance. The design criteria require that the SSSCs be capable of being inspected and monitored.
72.122(g)	Emergency Capability All emergency facilities at the North Anna Power Station will be available if needed.
72.122(h)	Confinement barriers and systems The design of the SSSCs will ensure that the stored fuel is maintained in a safe condition. No paths for the release of radioactive material are considered credible. No ventilation or off gas systems are needed. Continuous monitoring of SSSC confinement barriers is provided.
72.122(i)	Instrumentation and control systems No instrumentation or control systems are needed for the SSSCs to perform their safety functions, however, continuous monitoring of SSSC confinement barriers is provided.
72.122(j)	Control room or control areas The North Anna ISFSI is a passive installation, with no need for operator actions. No control room or control area is needed.
72.122(k)	Utility services The SSSCs are the only safety-related components at the North Anna ISFSI. There are no utility or emergency systems required to perform any safety functions or to meet emergency conditions at the North Anna ISFSI.

Table 4-1 (CONTINUED)
COMPLIANCE WITH GENERAL DESIGN CRITERIA
(SUBPART F, 10 CFR 72)

72.122(l)	Retrievability	The design of the SSSCs will enable subsequent removal of the stored fuel in the North Anna spent fuel pool and repackaging of the spent fuel into shipping casks. The spent fuel pool will remain operational as needed for spent fuel transfer.
72.124(a)	Design for criticality safety	The design criteria require that the SSSCs be designed to maintain subcriticality at all times, assuming a single active or credible passive failure.
72.124(b)	Methods of criticality control	Different SSSC designs may use different methods of criticality control. All designs use conservative analyses and specified error contingency criteria. Since criticality control is provided entirely within the SSSC design, additional design features for criticality control at the ISFSI are not needed.
72.124(c)	Criticality monitoring	Not required
72.126(a)	Exposure control	Operations at the North Anna ISFSI will be done according to ALARA procedures. Minimal maintenance operations are needed following SSSC emplacement at the ISFSI. SSSC loading, transport and unloading are done in accordance with health physics procedures in effect for the North Anna Power Station.
72.126(b)	Radiological alarm systems	No radioactive releases are considered credible at the North Anna ISFSI. No safety-related alarm systems are needed at the ISFSI. Radiological alarm systems are provided for operations in the Fuel Building at the North Anna Power Station.
72.126(c)	Effluent and direct radiation monitoring	Operation of the North Anna ISFSI does not result in any radioactive effluents. No safety-related monitors are needed. Direct radiation monitors will be installed around the ISFSI.
72.126(d)	Effluent control	No radioactive releases are considered credible at the North Anna ISFSI.
72.128(a)	Spent fuel and radioactive waste storage and handling systems	The design criteria require that the SSSCs have adequate provisions to monitor the SSSC performance, provide sufficient shielding to restrict surface dose rates to below prescribed levels, maintain leak tightness under all operating and credible accident conditions, and maintain the spent fuel in a safe condition. Only minimal amounts of radioactive waste are generated in the decontamination of the SSSCs.
72.128(b)	Waste treatment	Radioactive wastes generated in the decontamination of the SSSCs are processed by the North Anna Power Station waste processing systems.
72.130	Decommissioning	Operation of the North Anna ISFSI does not result in contamination of the outside surface of the SSSCs or any other ISFSI components. Therefore, there is no need for additional provisions to facilitate decommissioning.

Table 4-2

CODES AND STANDARDS FOR TRANSPORTER DESIGN AND FABRICATION

1. American National Standards Institute (ANSI)
   a. B30.2, *Overhead and Gantry Cranes (Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist)*
   b. B30.9, *Slings*
   c. B30.10, *Hooks*
2. American Institute of Steel Construction (AISC) - *Manual of Steel Construction*, Ninth Edition, 1989
3. American Welding Society (AWS)
   a. D1.1, *Structural Welding Code*
   b. D14.1, *Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment*
4. Crane Manufacturer's Association of America, Specification No. 70, *Specification for Electric Overhead Traveling Cranes*
5. American Society of Non-Destructive Testing - SNT-TC-1A (1980), *Recommended Practice for Non-Destructive Testing, Personnel Qualification and Certification*
6. American Society for Testing and Materials (ASTM)
   a. A36, *Specification for Carbon Structural Steel*
   b. A48, *Standard Specification for Gray Iron Castings*
   c. A108, *Specification for Steel Bars, Carbon, Cold-Finished, Standard Quality*
   d. A148, *Specification for Steel Castings, High-Strength for Structural Purposes*
   e. A325, *Specification for Structural Bolts, Steel, Heat Treated for Structural Steel Joints*
   f. A434, *Specification for Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered*
   g. A490, *Specification for Heat Treated Steel Structural Bolts*
   h. A514, *Specification for High Yield Strength Quench and Tempered Alloy Steel Plate Suitable for Welding*
   i. A576, *Specification for Steel Bars, Carbon, Hot-Wrought Special Quality*
   j. A668, *Specification for Steel Forgings, Carbon and Alloy for General Industrial Use*
   k. A730, *Specification for Forgings, Carbon and Alloy, for Railway Use*
   l. E709, *Standard Guide for Magnetic Particle Examination*
7. Code of Federal Regulations, Title 29, Part 1910, *Occupational Safety and Health Standards*

Figure 4-1
ISFSI SITE PLAN

Security-Related Information Figure Withheld Under 10 CFR 2.390.

Security-Related Information
Figure Withheld Under 10 CFR 2.390

Figure 4-2
ISFSI ELECTRICAL DETAILS

Security-Related Information
Figure Withheld Under 10 CFR 2.390

Figure 4-3
ISFSI ELECTRICAL DETAILS

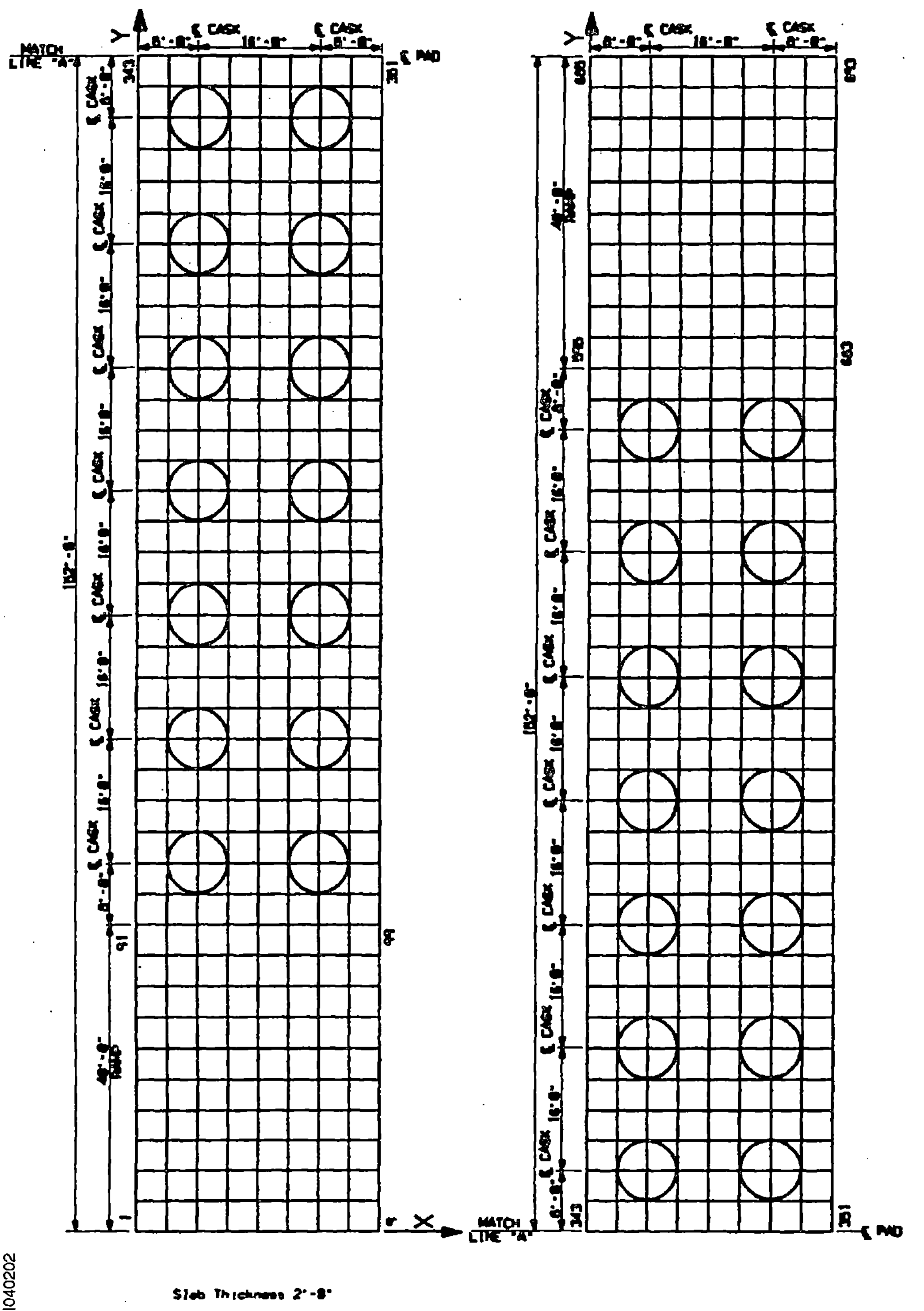
Security-Related Information
Figure Withheld Under 10 CFR 2.390

Figure 4-4
TRANSPORT ROUTE

Figure 4-5
ISFSI STORAGE PAD DETAILS

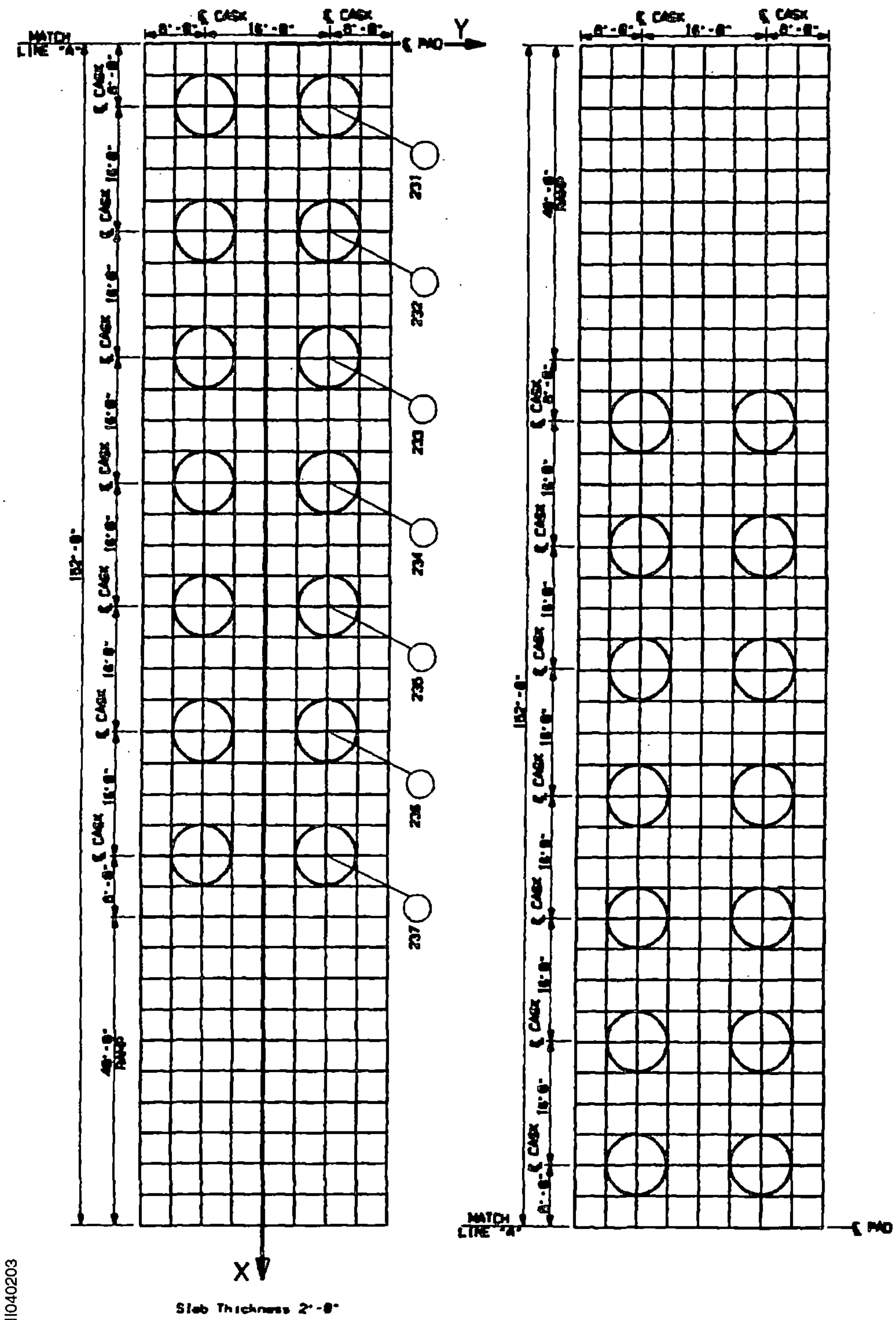
Security-Related Information Figure Withheld Under 10 CFR 2.390.

Figure 4-6
IMAGES-3D MODEL OF STORAGE PAD GEOMETRY



NI040202

Figure 4-7
SASSI MODEL OF STORAGE PAD GEOMETRY



NI040203

Figure 4-8
SASSI CASK MODEL

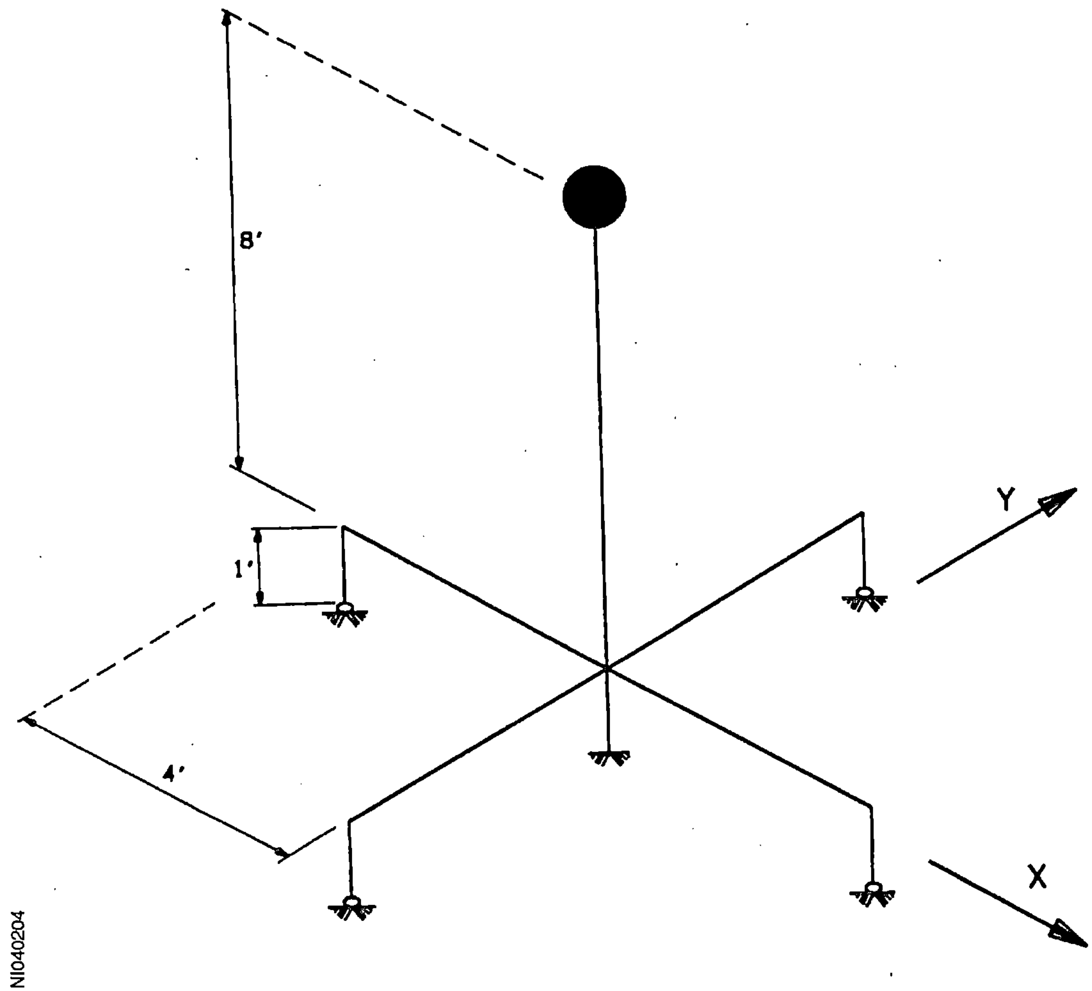
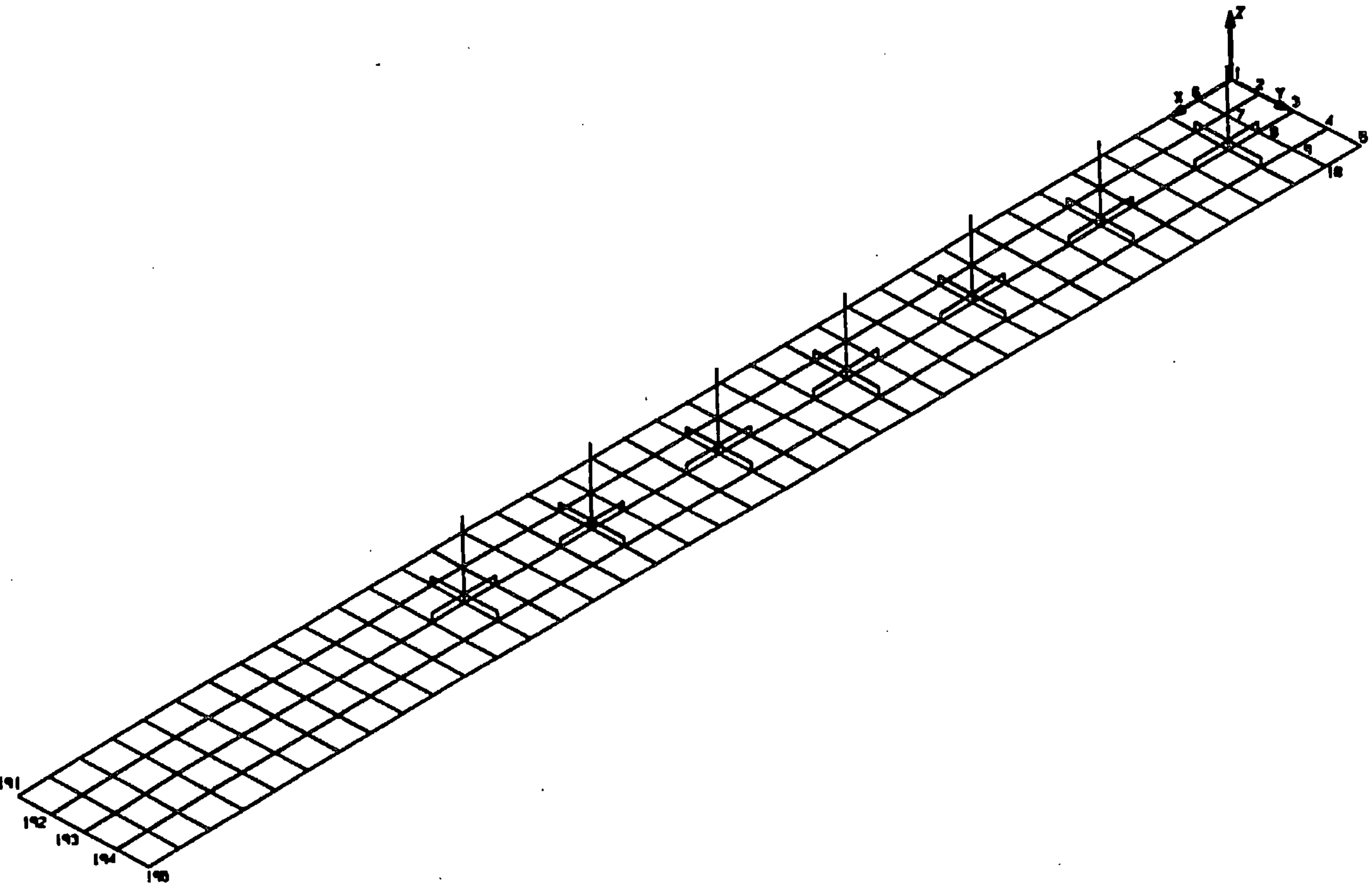
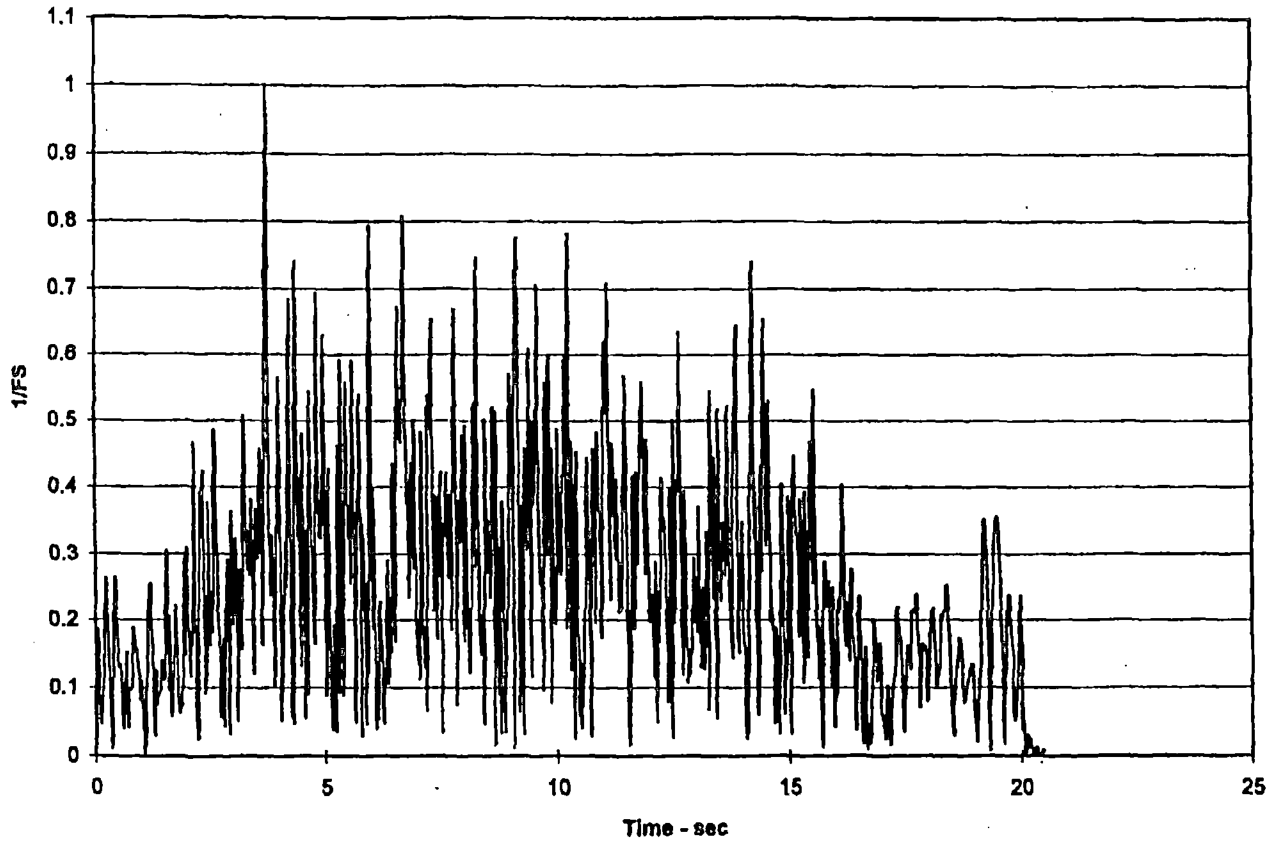


Figure 4-9
SASSI PAD PLATE ELEMENTS



NI040205

Figure 4-10
SLIDING FACTORS OF SAFETY



NI040206

Figure 4-11
OVERTURNING FACTORS OF SAFETY

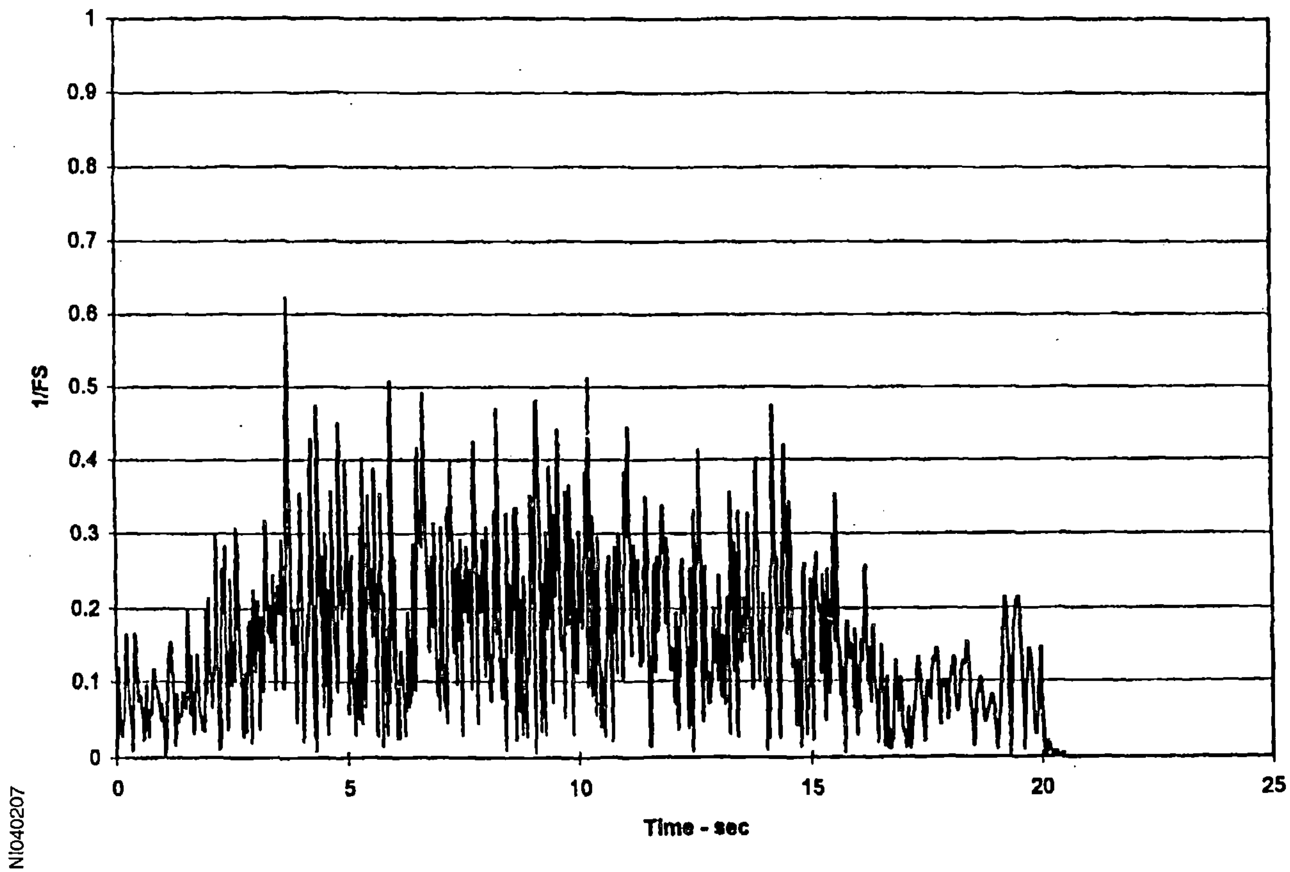
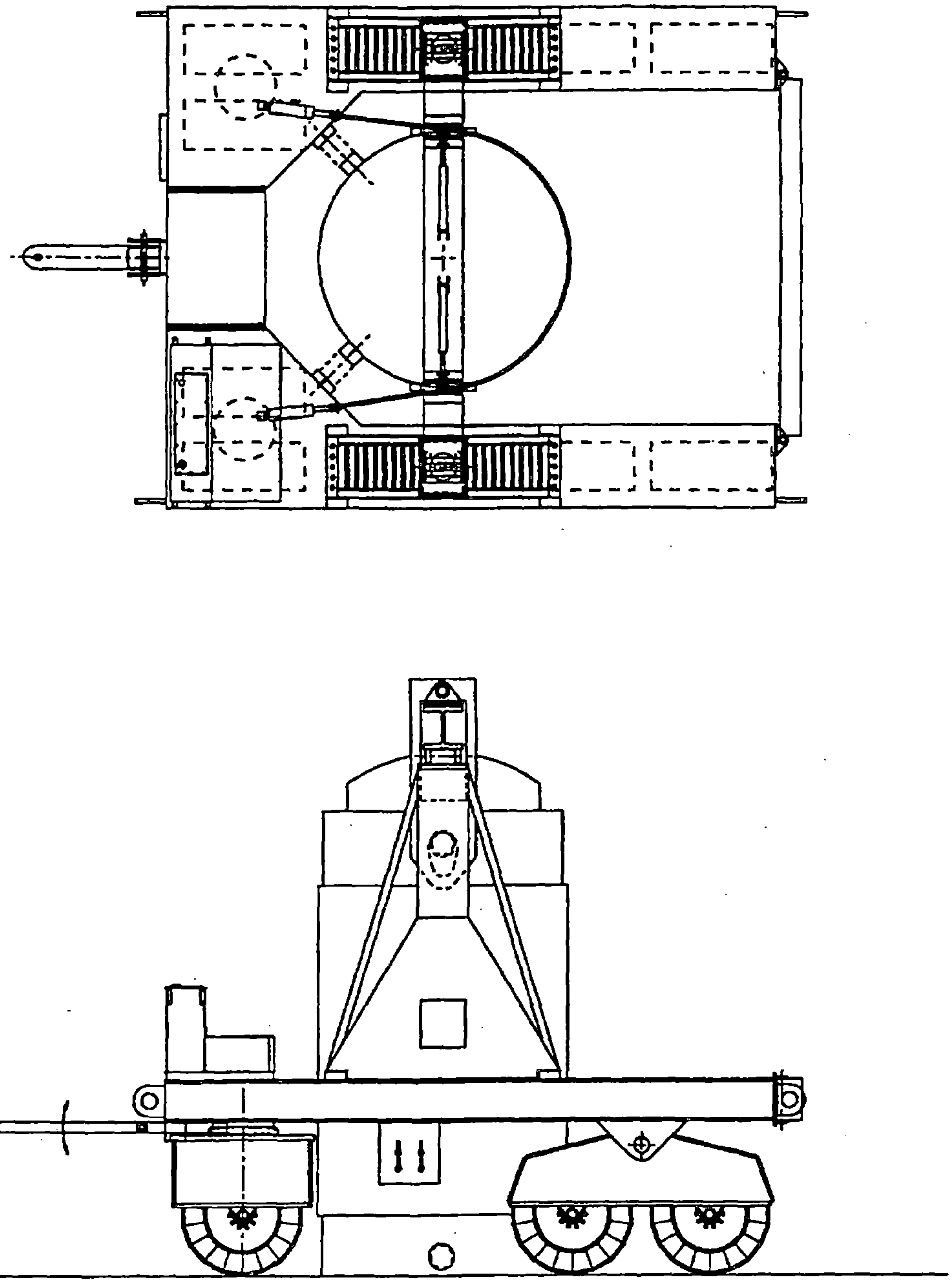


Figure 4-12
TRANSPORTER DESIGN



NI040301

Security-Related Information
Figure Withheld Under 10 CFR 2.390

Figure 4-13
FUEL AND DECONTAMINATION BUILDINGS PLAN VIEW

Figure 4-14
FUEL AND DECONTAMINATION BUILDINGS SIDE VIEW

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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Chapter 5 STORAGE SYSTEM OPERATIONS

This chapter describes the operations associated with the North Anna ISFSI. As indicated in previous chapters, the North Anna ISFSI is a totally passive installation, requiring no actions or maintenance for its proper functioning. The operations described in this chapter relate to the loading and preparation of the SSSCs and their transfer to the ISFSI. Also described is the transfer of the SSSCs from the ISFSI and unloading operations.

5.1 OPERATION DESCRIPTION

5.1.1 Narrative Description

5.1.1.1 Loading Operations

The loading of the SSSCs takes place within the North Anna Power Station Fuel and Decontamination Buildings. These operations are similar to the loading of transport casks, as described in Section 9.1 of the North Anna Power Station Updated Final Safety Analysis Report (UFSAR). An update to the North Anna Power Station UFSAR will address the loading and unloading of the SSSCs in the Fuel and Decontamination Buildings. These operations are conducted in a manner that ensures that the capability to safely operate Units 1 and 2 is not jeopardized. Handling of the SSSCs inside the Fuel and Decontamination Building is performed in accordance with the operating license for the North Anna Power Station under 10 CFR 50.

The cask loading operation begins with the receipt and inspection of an empty SSSC outside the Decontamination Building. A two-point lift beam is attached to the 125-ton crane and placed on the upper trunnions of the SSSC. The SSSC is rotated to a vertical position, lifted from the shipping frame, moved over the Decontamination Building and through a roll-up door, and lowered into the preparation area in the north bay of the Decontamination Building. The SSSC lid is removed and inspected. The fuel basket is also visually inspected for foreign material. The lid is attached to the 10-ton auxiliary crane and all seals are replaced.

Once prepared, the SSSC is lifted from the north bay and moved to the cask loading area, with the lid still attached to the 10-ton crane. The SSSC is lowered into the deep end of the cask loading area and the lift beam detached. Fuel assemblies are loaded into the SSSC using a long handling tool suspended from the spent fuel bridge crane hoist. An underwater camera is used to verify the proper placement of the fuel assemblies in the SSSC. After the SSSC is loaded with spent fuel, the lid is placed on the SSSC with the aid of guide pins. The SSSC is lifted to the pool surface, the lid bolts are installed and water is pumped from the fuel cavity.

The SSSC is lifted from the cask loading area, moved to the north bay, and is lowered into the bay.

In the north bay, the lid bolts are tightened according to vendor specifications. Vacuum drying of the fuel cavity is completed and tested. The cavity is backfilled with helium to design pressure, and the lid seals are tested. All exterior surfaces of the SSSC are decontaminated.

Additional lids, if any, are installed and the pressure monitoring system is installed and tested. If appropriate, the weather cover is installed. Surface radiation dose measurements are then completed. When all preparations have been completed, the SSSC is lifted from the north bay and placed on the concrete surface outside of the Decontamination Building.

The SSSC is lifted by the transporter for transfer to the ISFSI. The routes followed by the transporter from the Decontamination Building to the ISFSI are shown on Figure 4-4. This figure also shows the location of all nearby systems and structures needed for the safe shutdown of Units 1 and 2. Drop of an SSSC while in transit to the ISFSI will not result in damage to any of these systems and structures, nor in radioactive releases in excess of the guidelines in 10 CFR 100. As indicated in Section 3.3.1, the design criteria require that the SSSC maintain its integrity, preclude physical damage to the fuel, and ensure sub-criticality following a 15-inch drop. Operating procedures will limit the lifting heights to less than 15 inches once the SSSC is lifted by the transporter.

The pressure monitoring device on the SSSC must be connected to the monitoring panel after the SSSC is placed on the ISFSI pad.

5.1.1.2 **Unloading Operations**

Unloading of an SSSC begins with disconnecting the pressure monitoring device on the SSSC from the monitoring panel and transporting the SSSC along the same route used for its placement at the ISFSI. Once the transporter and SSSC are outside the Decontamination Building, the SSSC is lowered to the concrete surface beneath the 125-ton crane. The SSSC is lifted using the lift beam and moved to the north bay of the Decontamination Building. A sample of the helium in the fuel cavity is tested for indications of fuel failure (Kr^{85}). If this test indicates that failed fuel is present in the SSSC, the fuel cavity is evacuated to the Decontamination Building ventilation system described in Chapter 6, and refilled with helium. This process of sampling, evacuating and refilling is continued until helium sample tests are acceptable.

The lid bolts are then loosened and the SSSC is lifted from the north bay and moved to the cask loading area. The SSSC is lowered into the deep end of the cask loading area until the top of the cask is level with the spent fuel bridge crane platform. A water supply, with flow indicator, is attached to the SSSC reflood valve and water is slowly added to the fuel cavity. Flooding of the cask cavity takes at least 3 hours. When the cavity is full, the lid bolts are removed, the SSSC is lowered to the bottom of the cask loading area, and the lift beam is detached. The lid is slowly removed from the SSSC, lifted from the pool and placed at its designated laydown area. Fuel assemblies are then removed from the SSSC using a long handling tool suspended from the spent fuel bridge crane hoist. After the SSSC is unloaded, the lid is placed back on the SSSC with the aid of guide pins. The SSSC is lifted to the pool surface and water is pumped from the fuel cavity. The SSSC is then returned to the north bay for decontamination of the inner and outer surfaces.

None of the operations needed to load or unload the SSSCs at the North Anna ISFSI will result in unacceptable damage to the North Anna Power Station Units 1 and 2, or to the stored spent fuel.

5.1.2 Flowsheets

Table 5-1 shows a general sequence of operations to load and transport an SSSC to the ISFSI. Table 5-2 shows the general sequence of operations for unloading an SSSC. Operations more specific to a particular vendor's SSSCs are outlined in the vendor's SSSC Topical Safety Analysis Report.

These operations are performed in accordance with procedures addressing health physics and handling of the SSSCs. They also fulfill the surveillance requirements specified in Chapter 10.

5.1.3 Identification of Subjects for Safety and Reliability Analysis

5.1.3.1 Criticality Prevention

The design criteria specified in Section 3.3.4 require that spent fuel stored at the North Anna ISFSI be maintained subcritical at all times. The specific means by which the SSSCs comply with this criterion are described in the SSSC Topical Safety Analysis Reports or Appendix A.

5.1.3.2 Instrumentation

Due to the totally passive and inherently safe nature of the SSSCs, there is no need for any instrumentation to perform safety functions. It is desirable, however, to monitor the performance of some or all of the SSSCs. Accordingly, the design criteria described in Section 3.3.3 require that the SSSCs have adequate provisions for the installation and testing of monitors.

The parameters to be monitored will be selected based on recommendations made by the SSSC manufacturers, experience gained with specific SSSC designs, and other engineering and health physics considerations. Instrumentation provisions for the SSSCs are described in the SSSC Topical Safety Analysis Reports.

Although these instruments are not safety related, commitments for their installation, inspection, and replacement (if needed) are proposed in Section 10.2.

Actions to be taken when monitored parameters exceed preset levels are described in Section 4.4.5.3.

5.1.3.3 Maintenance Techniques

Because of their passive nature, the SSSCs require little, if any, maintenance over the lifetime of the ISFSI. No major maintenance tasks are required. Typical maintenance tasks would involve occasional replacement of monitoring instrumentation, recoating of some SSSCs with corrosion-inhibiting coatings, minor road and drainage ditch repairs, and minor maintenance of security systems. Cask re-coating involves enclosing a SSSC within a temporary building. The building is lowered over top of a SSSC and ventilation is supplied along with appropriate health physics ventilation controls. The building is used to ensure that the removed coating is not dispersed to the environment and to provide a controlled environment during the re-coating process. A specific evaluation was performed for this evolution to ensure the original thermal evaluation remained valid. Additional details of this evaluation are contained in Appendix A.1.4.

Specific maintenance recommendations for the SSSCs are provided in the SSSC Topical Safety Analysis Reports.

In addition to ISFSI maintenance and SSSC maintenance, a visual surveillance of the ISFSI will be performed on a periodic basis to determine that no significant accumulation of debris on or near SSSC surfaces has occurred.

5.2 CONTROL ROOM AND CONTROL AREAS

The North Anna ISFSI does not require continuous surveillance by the operations staff or operator actions, even during postulated accidents. Therefore, a control room or control area is not considered necessary.

Local panels at the ISFSI site provide an annunciator alarm if the value of a monitored parameter exceeds an alarm setpoint. The local panels indicate the SSSC that requires operator attention. Provisions have been made to allow for two alarms per SSSC at the local panels.

If an alarm signal is received at the alarm panel, an alarm is also transmitted to the Station Security Central Alarm and Secondary Alarm Stations. Security personnel continuously monitor these stations and they would notify the Shift Manager for a response. Personnel first determine that an electronic fault at the alarm panel is not causing the alarm. If no electronic fault is found and an alarm signal is being received from an SSSC, the pressure switch for this SSSC is checked for proper function. If the pressure switch has failed, it is replaced. If the pressure switch is functioning properly, a seal leak is occurring, and the SSSC is returned to the Decontamination Building for repairs.

5.3 SPENT FUEL ACCOUNTABILITY PROGRAM

Accountability and control of special nuclear materials will be maintained at all times during the loading, transport, and storage of spent fuel assemblies. Accountability records for all fuel assemblies transferred to, stored in or removed from the ISFSI will be maintained for as long as the fuel assemblies are stored on the North Anna site.

Material status reports shall be completed and submitted to the NRC, as specified in 10 CFR 72.76. Nuclear material stored at the ISFSI will not be transferred from Virginia Power to other ownership, therefore, Nuclear Material Transaction Reports (DOE/NRC Form-741) required by 10 CFR 72.78 will not be needed. The North Anna ISFSI will be treated as a separate material balance area of the North Anna Power Station.

Records showing the transfer of spent fuel between the spent fuel storage pool and the ISFSI shall be maintained in accordance with the administrative procedure that provides for control of nuclear material.

5.4 SPENT FUEL TRANSPORT

The transporter to be used to move the SSSCs between the Decontamination Building and the ISFSI is described in Section 4.3. A tow vehicle, such as a diesel tractor, will be used to move the transporter.

Each SSSC will be lifted by the transporter outside the Decontamination Building. The transporter will then be towed to either the west gate or the south east gate of the protected area fence. Beyond each gate, an asphalt road is used to the ISFSI site.

The plan and profile of the ISFSI site access road is shown in Figure 5-1.

Table 5-1

GENERAL SEQUENCE OF LOADING OPERATIONS[a]

1. Unload empty SSSC from rail car.
2. Move SSSC inside Decontamination Building.
3. Remove weather cover and inspect for shipping damage.
4. Remove lid(s) and inspect the following for damage: exterior surfaces, sealing surfaces, trunnions, accessible interior surfaces and basket assembly, bolts, and bolt holes and threads.
5. Replace lid seals.
6. Move SSSC to cask loading area.
7. Lower SSSC into cask loading area.
8. Load SSSC with preselected spent fuel assemblies using spent fuel handling crane.
9. Verify inventory of fuel assemblies loaded into SSSC.
10. Place lid on SSSC.
11. Lift SSSC to surface and install lid bolts.
12. Pump water from the SSSC fuel cavity into cask loading area.
13. Raise SSSC from cask loading area and spray exterior with water.
14. Return SSSC to Decontamination Building.
15. Begin to decontaminate exterior surfaces of SSSC.
16. Secure lid with bolts.
17. Vacuum dry SSSC cavity and test.
18. Fill SSSC cavity with helium and test seals.
19. Install pressure monitoring device and test.
20. Perform SSSC surface radiation measurements.
21. Lift SSSC from Decontamination Building and place on concrete surface.
22. Lift SSSC with transporter.
23. Transport SSSC to ISFSI.
24. Connect pressure monitoring device to monitoring panel.

a. Some steps indicated on this flowsheet may be performed in parallel with other steps.

Table 5-2

GENERAL SEQUENCE OF UNLOADING OPERATIONS[a]

1. Disconnect pressure monitoring device.
2. Transport SSSC to Decontamination Building.
3. Release SSSC from transporter.
4. Lift SSSC to Decontamination Building.
5. Sample and test helium in fuel cavity.
6. Purge helium in fuel cavity, if necessary.
7. Loosen lid bolts.
8. Lift SSSC from north bay and move to fuel loading area in Fuel Building.
9. Lower SSSC into cask loading area and install reflood water supply.
10. Reflood fuel cavity with water and remove lid bolts.
11. Lower SSSC into cask loading area.
12. Remove lid from SSSC and store.
13. Remove fuel assemblies from SSSC.
14. Place lid on SSSC.
15. Lift SSSC to surface of cask loading area.
16. Pump water from the SSSC fuel cavity into the cask loading area.
17. Raise SSSC from cask loading area and spray exterior with water.
18. Return SSSC to Decontamination Building.
19. Decontaminate interior and exterior surfaces of SSSC.

a. Some steps indicated on this flowsheet may be performed in parallel with other steps.

Figure 5-1
PLAN AND PROFILE OF ISFSI SITE ACCESS ROAD

Security-Related Information
Figure Withheld Under 10 CFR 2.390

Chapter 6 WASTE MANAGEMENT

No radioactive wastes will be generated during storage of the SSSCs at the ISFSI or during transport to/from the ISFSI. Radioactive wastes generated during loading operations in the Fuel and Decontamination Buildings will be treated using existing North Anna Power Station radioactive waste control systems as described in Chapter 11 of the North Anna Power Station Updated Final Safety Analysis Report (UFSAR).

Contaminated water from loaded SSSCs will normally be drained back into the spent fuel pool with no additional processing. A small amount of liquid waste will result from SSSC decontamination. The decontamination procedure may result in a small amount of detergent/demineralized water mixture being collected in the Decontamination Building. Liquid wastes in this building are directed to the Fluid Waste Treatment Tank for transfer to the liquid waste disposal system.

Potentially contaminated air and helium purged from the SSSCs during loading and unloading will be handled by the Fuel and Decontamination Building ventilation systems, as described in Sections 9.4.3 and 9.4.4 of the North Anna Power Station UFSAR. Ventilation air from these buildings may be exhausted through filter banks consisting of roughing, particulate and charcoal filters in series.

A small quantity of low-level solid waste may be generated during SSSC loading operations. This solid waste may include disposable anti-contamination garments and plastic sheeting, tape, and rags, and will be processed as described in Section 11.5 of the North Anna Power Station UFSAR.

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Chapter 7 RADIATION PROTECTION

7.1 ENSURING THAT OCCUPATIONAL RADIATION EXPOSURES ARE AS LOW AS REASONABLY ACHIEVABLE (ALARA)

7.1.1 Policy Considerations and Organization

A radiological protection program will be implemented at the North Anna ISFSI in accordance with the requirements of 10 CFR 72.126. The program will be based on policies in existence at the North Anna Power Station, which are described below.

The management policies, organizational structure and program criteria for maintaining exposures ALARA at the North Anna ISFSI are the same as for the North Anna Power Station, and are collectively referred to as the Virginia Power ALARA Program. The Virginia Power ALARA Program is an important part of the North Anna Power Station radiation protection program. The basic principles of the Virginia Power ALARA Program are described in Virginia Power administrative procedures and are implemented by health physics technical procedures.

The North Anna Power Station ALARA program complies with 10 CFR 20.1101, *Radiation Protection Programs,* and is consistent with the guidance of Regulatory Guide 8.8 (June 1978), *Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Reasonably Achievable.* The station ALARA program includes the following aspects:

- Specific individuals are assigned responsibility for, and authority to implement the station ALARA Program consistent with Virginia Power policy. These individuals include the station ALARA coordinator and department ALARA coordinators.
- A Station ALARA Committee has been established with the responsibility for overall coordination of the station ALARA Program and for advising the Station Management on matters relating to ALARA. A member of station management chairs the Committee.
- Pre-job measures are required to implement the station ALARA philosophy. These include ALARA evaluations of proposed work, pre-job meetings, and tiered levels of review based on projected expended person-rem.
- Monitoring and control of ongoing work is accomplished by the establishment of an exposure tracking system, ALARA hold points, and ALARA Radiation Work Permit (RWP) re-evaluation meetings.
- Completed work is evaluated via post-job reviews, maintenance of job history files and periodic process reviews of selected work evolutions.
- A temporary shielding program has been established.
- An ALARA suggestion system is maintained to solicit, evaluate, and reward employee ideas that save person-rem.

- Engineering design change packages receive an ALARA review prior to implementation.
- A system has been established to actively involve, guide, and monitor the performance of the station and individual departments toward meeting ALARA objectives.

The location of the ISFSI within the North Anna Power Station site allows the health physics facilities, equipment and personnel to be readily available at all times to ensure that ALARA considerations are met. The ISFSI is located a sufficient distance from buildings and occupied spaces to minimize total personnel exposure.

Regulatory Guide 8.10 (May 1977), *Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Reasonably Achievable,* Regulatory Position 1, concerning management commitment to minimizing exposures, is addressed by Virginia Power administrative procedures. Regulatory Position 2, concerning radiation protection staff vigilance in ALARA matters, is addressed and implemented by Virginia Power administrative procedures and health physics technical procedures.

The health physics organization is described in an administrative procedure. The organization to maintain exposures ALARA is also described in Virginia Power administrative procedures. The Station ALARA Committee is a major part of that organization. An administrative procedure also lists North Anna Power Station health physics administrative procedures by functional grouping. These procedures are also applicable to the North Anna ISFSI.

The guidance of Regulatory Position 2 of Regulatory Guide 8.8 (June 1978) is followed as described in Section 7.1.2. The guidance of Regulatory Guide 8.10 (May 1977) is followed as described in this section.

Virginia Power personnel qualifications and experience are considered more than sufficient for operation of the North Anna ISFSI since these personnel have gained considerable experience at the North Anna Power Station. An administrative procedure provides the functional responsibilities and reporting relationships of the members of the health physics organization and the personnel qualification requirements for positions in the station health physics organization.

Health physics equipment, instrumentation, and facilities for the North Anna ISFSI will be those of the North Anna Power Station. Radiation surveys with portable instruments will be performed during surveillance of the SSSCs and other activities at the ISFSI. Portable instruments required for measuring dose rates and radiation characteristics are maintained in accordance with approved health physics procedures.

As indicated in Section 7.2.2, respiratory protection equipment will not be needed at the North Anna ISFSI.

Radiation protection facilities, instrumentation, and equipment available at the North Anna Power Station are similar to that described by Regulatory Position 4 of Regulatory Guide 8.8

(June 1978). These include count room equipment, portable instruments, personnel monitoring instruments, protective equipment, and their associated support facilities.

The guidance for testing, rejection criteria, and use in mixed radiation fields being followed for the dosimeters at the North Anna Power Station will be used at the North Anna ISFSI.

The bioassay program in use for personnel at the North Anna Power Station will also apply to the North Anna ISFSI.

The methods and procedures for conducting radiation surveys at the North Anna ISFSI will comply with the approved health physics procedures in effect at the North Anna Power Station.

This section describes the health physics and ALARA procedures and planning for the North Anna Power Station which will be used at the ISFSI. The complete details are in the applicable Virginia Power station and departmental administrative procedures and health physics technical procedures.

The radiological respiratory protection program is outlined in Virginia Power administrative procedures and implemented by health physics technical procedures.

Access control will be accomplished by means of a perimeter fence with locked gates surrounding the North Anna ISFSI. Control of the keys will be in accordance with security and health physics policies and procedures.

The bases and methods for monitoring and controlling personnel, equipment and surface contamination control, and radiation protection training program content are described in Virginia Power administrative procedures and health physics technical procedures.

The guidance provided by Regulatory Guide 8.10 (May 1977) will be followed as described in this section and Section 7.1.3. The guidance of Regulatory Guide 8.15 (October 1976), *Acceptable Programs for Respiratory Protection,* will be followed as described in this Section. There should be no need for bioassay of personnel after surveillance activities at the North Anna ISFSI. There should also be no need for radiological respiratory protection equipment.

Personnel dosimetry used at the North Anna ISFSI will be controlled by the external dosimetry program approved for the North Anna Power Station. An ALARA feedback mechanism using dosimeter results for preplanning future tasks is included in Virginia Power administrative procedures and their implementing documents.

The criteria for performing routine and non-routine whole-body counting and bioassay are contained in Virginia Power administrative procedures and health physics technical procedures for the North Anna Power Station. Methods and procedures for evaluating and controlling airborne radioactive material are also given in these procedures.

Respiratory protection program requirements, equipment use and maintenance guidance, and fit testing protocol are delineated in Virginia Power administrative procedures and health physics technical procedures. Radiological respiratory protection training is conducted in accordance with Nuclear Training Department procedures.

7.1.2 Design Considerations

The North Anna ISFSI has been located in an area adjacent to the Station main access road. This location was chosen based on several considerations, including ALARA, as follows:

1. The ISFSI is centrally located within the North Anna Power Station site boundary, thus minimizing off-site exposures.
2. The ISFSI is sufficiently distant from buildings and occupied spaces to minimize dose to station personnel.

The layout of the ISFSI is designed to minimize personnel exposures. The SSSCs will be stored with sufficient separation between them to allow adequate personnel access between the SSSCs for surveillance and handling operations.

The equipment design considerations are ALARA since the fuel will be stored dry, inside heavily-shielded SSSCs. The heavy shielding will minimize personnel exposures. The required maintenance and surveillance of the SSSCs will be minimal and therefore ALARA. Additionally, the SSSCs will not be opened nor will fuel be removed from the SSSCs while at the ISFSI. Storage of the fuel in dry SSSCs eliminates the possibility for release of contaminated liquids. Gaseous releases are also not considered credible. The exterior of the SSSCs will be decontaminated before being placed at the ISFSI. There will be no contaminated equipment at the ISFSI, so there will be no potential for personnel contamination at the ISFSI.

Guidance provided by Regulatory Guide 8.8 (June 1978), Regulatory Position 2, which concerns design considerations, is being addressed as follows:

1. Regulatory Position 2.a concerning access control is met by use of a perimeter fence with locked gates that surrounds the ISFSI and prevents unauthorized access.
2. Regulatory Position 2.b concerning radiation shielding is met by the heavy shielding of the SSSCs which minimizes personnel exposures.
3. Regulatory Position 2.c concerning process instrumentation and controls is not applicable since there are no radioactive systems at the ISFSI. No process controls are required at the ISFSI. However, there may be minor exposure attributed to monitoring instrument testing and replacement.
4. Regulatory Position 2.d concerning control of airborne contaminants is not applicable because no gaseous releases are expected. No significant surface contamination is expected because the exterior of the SSSCs will be decontaminated before being placed at the ISFSI.
5. Regulatory Position 2.e concerning crud control is not applicable to the ISFSI because there are no radioactive systems at the ISFSI that could transport crud.

6. Regulatory Position 2.f concerning decontamination is met because the exteriors of the SSSCs are decontaminated before being placed at the ISFSI.

7. Regulatory Position 2.g concerning radiation monitoring is met because the SSSCs are sealed. There is no need for airborne radioactive material monitoring since no airborne radioactive material is anticipated. Area radiation monitors will not be required because the ISFSI will not normally be occupied; however, thermoluminescent devices will be installed along the ISFSI perimeter fence. Portable survey meters will normally be used for work performed near or on the storage pads. Personnel dosimetry will be used at all times. An RWP will be required for any entry into the ISFSI.

8. Regulatory Position 2.h concerning resin and sludge treatment systems is not applicable to the ISFSI because there will not be any radioactive systems containing resins or sludges.

9. Regulatory Position 2.i concerning other miscellaneous ALARA items is not applicable because these items refer to radioactive systems not present at the North Anna ISFSI.

7.1.3 Operational Considerations

The ALARA procedures for the ISFSI will be the same as those used in the health physics program for the North Anna Power Station. Section 7.1.1 describes the policy and procedures that ensure that ALARA occupational exposures and contamination levels are achieved. Section 7.1.2 describes how the design considerations are ALARA.

Storage of spent fuel in SSSCs is expected to involve lower exposures than other methods or designs for onsite storage. For example, storage in a fuel pool would involve the use of contaminated water cooling and cleanup systems, and filtered heating, ventilation and air conditioning. There would be higher operator exposures due to pump, valve, and motor maintenance of these systems, and filter and resin replacement. This alternative would also lead to additional airborne and liquid releases that will not occur at the North Anna ISFSI.

The count room, portable instruments, personnel monitoring instruments, protective equipment, and support facilities similar to those described in Regulatory Position 4 of Regulatory Guide 8.8 (June 1978) will be provided by the health physics facilities and personnel at the North Anna Power Station. Section 7.1.1 provides additional details.

Operational requirements for surveillance are incorporated into the design considerations described in Section 7.1.2 in that the SSSCs are stored with adequate spacing to allow ease of surveillance. The operational requirements are incorporated into the radiation protection design features described in Section 7.3 since the SSSCs are heavily shielded to minimize occupational exposure.

The criteria and conditions under which certain ALARA techniques are implemented to ensure ALARA exposures and contamination levels are described in Section 7.1.1. ALARA techniques will be implemented at all times.

As the potential person-rem per task increases, the ALARA techniques employed become more stringent as described in Virginia Power administrative procedures.

The ISFSI does not contain any systems that process liquids or gases or contain, collect, store, or transport radioactive liquids or solids, other than the SSSCs. Therefore, the ISFSI is ALARA since there are no such systems to be maintained, or repaired, or be a source of leaks.

7.2 RADIATION SOURCES

7.2.1 Characterization of Sources

The physical characteristics of the fuel used at the North Anna Power Station are summarized in Table 3-1. Typical fuel assembly source data for the fuel used at North Anna is provided in the TN-32 Final Safety Analysis Report (Reference 1). Descriptions of the fuel which the SSSCs are designed to store are provided in the SSSC Topical Safety Analysis Reports and Appendix A. The exterior surfaces of the SSSCs will be decontaminated prior to transfer to the ISFSI. The fuel will not be removed from the SSSCs nor will the SSSCs be opened while at the ISFSI. There are no radioactive systems at the ISFSI. Therefore, the only source of radioactivity will be the direct radiation from the fuel stored inside the SSSCs.

7.2.2 Airborne Radioactive Material Sources

Under normal operation, the radioactive material sources are safely confined both within the fuel cladding and within the SSSC containment during storage. Surface contamination from the spent fuel pool will be removed prior to storage at the ISFSI. Therefore, provisions for personnel protection measures against airborne sources are not required. A loss of confinement barrier event and subsequent airborne radiation impact is discussed in Section 8.2.10.

7.2.3 References

1. *TN-32 Dry Storage Cask Final Safety Analysis Report,* Revision 0, Transnuclear, Inc., January 2000.

7.3 RADIATION PROTECTION DESIGN FEATURES

7.3.1 Storage System Design Description

A description of the North Anna ISFSI, including layout and characteristics is provided in Section 4.1. Figure 7-1 depicts the ISFSI showing the storage pads numbered to correspond with the order in which they will be filled.

The ISFSI has a number of design features which ensure that exposures are ALARA:

- There are no radioactive systems in the ISFSI other than the SSSCs
- The SSSCs are loaded, sealed, and decontaminated prior to transfer to the ISFSI
- The fuel is not unloaded nor are the SSSCs opened at the ISFSI

- The fuel is stored dry inside the SSSCs, so that no radioactive liquid is available for leakage
- The SSSCs are sealed airtight
- The SSSCs are heavily shielded to minimize external dose rates
- A perimeter fence with locked gates surrounds the ISFSI to limit access near the SSSCs

Typically, the ISFSI will not be occupied, therefore, no personnel areas, equipment decontamination areas, contamination control areas, or health physics facilities need to be located at the ISFSI. These types of facilities are available at the North Anna Power Station.

7.3.2 Shielding

The SSSC shielding designs are provided in the SSSC Topical Safety Analysis Reports. An earth berm was constructed inside the north and east perimeter fences of the ISFSI to reduce direct radiation. No other shielding is required.

7.3.2.1 SSSC Surface Dose Rates

The gamma and neutron dose rates on the SSSC surface and their associated energy spectra are dependent on the SSSC design. These dose rates are also dependent on the burnup and initial enrichment of the fuel stored in the SSSCs. Therefore, SSSC-specific analyses have been performed for representative North Anna Power Station fuel. The assumptions used in the SSSC-specific analyses for SSSC surface dose rates and energy spectra are provided in the SSSC Topical Safety Analysis Reports.

The TN-32 SSSC loaded with fuel with an enrichment of 3.50 weight percent U-235, burnup of 45,000 MWD/MTU and cooling time of 7 years has been chosen as the base case for analysis purposes. Using an enrichment lower than the 4.30 weight percent U-235 approved for the TN-32 yields a bounding isotope inventory, and is in accordance with NUREG-1536 and NRC Interim Staff Guidance.

Source terms for the fuel were calculated using the SAS2H/ORIGEN-s module of SCALE4.3 as described in Section 5.1 of Reference 1. These source terms are then passed through a SAS2H cask shielding model for a 1-dimensional dose assessment. Section 5.2 (Reference 1) describes the source specification and Section 5.3 (Reference 1) describes the shielding analyses performed for the TN-32 cask.

In addition to the spent fuel, the TN-32 is capable of storing burnable poison rod assemblies (BPRA) and thimble plug assemblies (TPA). BPRAs and TPAs with combinations of cumulative exposures and cooling times are permissible for storage in the TN-32 cask. The source evaluation of the BPRAs and TPAs is described in Section 5.2 (Reference 1).

Dominion conducted an independent analysis of the TN-32 surface dose rate using the MCNP Monte Carlo transport code (Reference 2). This analysis was used to form the basis for the average cask surface dose rate limit in the ISFSI Technical Specifications. The average surface dose rates calculated for the TN-32 base case SSSC were 218 mrem/hr (neutron and gamma) for the side surface and 58 mrem/hr (neutron and gamma) for the top surface.

7.3.2.2 Dose Rate Versus Distance

Analyses have been completed to determine dose rates at the ISFSI perimeter fence, the site boundary and the nearest permanent resident. These analyses were performed using the MCNP Monte Carlo transport code (Reference 2) and the following conservative inputs.

1. Isotope inventories were based on 32 fuel assemblies with enrichment of 3.5 weight percent U-235 and burnup of 45,000 MWD/MTU.
2. The three storage pads are filled with 84 TN-32 SSSCs, each pad having 28 SSSCs. Assuming 84 TN-32 SSSCs results in an amount of fuel stored on the pads which exceeds the current licensed limit of 839.04 TeU (approximately 57 TN-32 SSSCs), providing additional conservatism to the analysis.
3. The inventory of SSSCs stored in the ISFSI will increase by four SSSCs per year. This average rate of inventory change was used to determine the age of the spent fuel (years after discharge) and the subsequent reduction in dose rates.
4. The effects of irradiated insert components are included in the MCNP analyses.

Figure 7-1 shows the layout of the ISFSI. The MCNP analysis of the dose rate at the ISFSI perimeter fence using base case TN-32 SSSCs resulted in peak dose rates that range from 0.3 to 1.9 mrem/hr when all three pads were full. The specific dose rates for the various points on Figure 7-1 are provided in Table 7-1. Dose rate measurements at the ISFSI perimeter fence will be used to ensure that the requirements of 10 CFR 20 are met.

The MCNP analysis for the nearest site boundary indicated that the maximum dose rate at this location was less than 100 mrem/yr, which meets the requirements of 10 CFR 20.1301.

The MCNP analysis for the nearest permanent resident indicated that the contribution to the maximum dose rate from the operation of the ISFSI was 2.1 mrem/yr. When combined with the contributions from the operations of North Anna Power Station Units 1 and 2, the result is well below the 25 mrem/yr imposed by 10 CFR 72.104(a).

7.3.3 Area Radiation and Airborne Radioactivity Monitoring Instrumentation

As indicated in Section 3.3.5, area radiation and airborne radioactivity monitors are not needed at the North Anna ISFSI. However, thermoluminescent devices will be used to record gamma radiation doses at appropriate intervals along the ISFSI perimeter fence. Neutron radiation detection devices may also be used on the ISFSI perimeter fence if they are available and reliable.

7.3.4 References

1. *TN-32 Dry Storage Cask Final Safety Analysis Report,* Revision 0, Transnuclear Inc., January 2000.

2. *Evaluation of the TN-32 Cask with Increased Enrichment and Burnup Fuel for use at the North Anna Power Station Independent Spent Fuel Storage Installation,* Dominion Technical Report NE-1311, Revision 0, January 2002.

3. MCNP4C, *Monte Carlo N-Particle Transport Code System,* CCC-700, J. W. Briesmeister, LANL, December 2000.

7.4 ESTIMATED ONSITE COLLECTIVE DOSE ASSESSMENT

Table 7-2 provides the estimated occupational exposures to ISFSI personnel during the loading, transport, and emplacement of one SSSC. These results are based on the design basis surface dose rates discussed in Section 7.3.2.1. Our experience at the Surry Power Station ISFSI indicates that these estimated occupational exposures are very conservative, and that actual occupational exposures for loading, transport and emplacement activities are approximately 0.250 person-rem (Reference 1).

Table 7-3 provides the estimated annual occupational exposure for ISFSI surveillance and maintenance activities. The design basis surface dose rates were utilized, and it was assumed that all storage pads were filled with SSSCs. To estimate the dose rates for operability tests and calibration, the worker was assumed to be located at the control panel at the perimeter fence vehicle gate entrance. Visual surveillance was based on a walkdown of each of the three storage pads at a distance no closer than 2 meters to the SSSCs. During surface defect repairs, the worker was assumed to be positioned next to an SSSC. The two surrounding SSSCs (all within 16 feet of the worker) are the predominant dose contributors during repair work.

To evaluate the additional dose to station personnel from ISFSI operations, a conservative analysis has been performed using the assumptions given in Section 7.3.2.2, including annual decay. The dose calculation considers all workers at the North Anna Power Station to be in offices, non-shielded buildings, or in the plant yard. This population includes a normal work force of utility and contractor personnel as well as the increased staffing required during outages. As a bounding estimate, the total number of workers assumed was 750 spending a total of 1,560,000 person-hours/year in the North Anna yard area and in offices.

The minimum distance between the North Anna Units 1 and 2 protected area fence and the nearest SSSC is approximately 2000 feet. The dose rate from the fully-loaded ISFSI to a location 2000 feet away is 1.83E-03 mrem/hr. The annual dose for station workers due to the fully-loaded ISFSI is calculated to be 3.66 mrem/person or a total annual dose to Station personnel of 2.75 person-rem. The maximum annual dose of 3.66 mrem/person represents less than 0.1% of the 5 rem annual occupational exposure limit.

The total annual occupational exposure during ISFSI loading operations is 14.39 person-rem (see Table 7-4), and represents the maximum expected. As indicated previously, the actual occupational exposures for loading, transport, and emplacement of an SSSC are approximately 0.25 to 0.5 person-rem per loading. This combined with the North Anna Power Station annual occupational exposure during ISFSI loading operations (Table 7-4) results in a total annual occupational exposure during ISFSI operations of approximately 4 person-rem. This exposure represents approximately 5% of the average annual occupational exposure from all operations at the North Anna Power Station.

7.4.1 References

1. C. J. Hostick, J. C. Lavender and B. H. Wakeman, *Time and Dose Assessment of Barge Shipment and At-Reactor Handling of a CASTOR V/21 Spent Fuel Storage Cask,* Pacific Northwest Laboratory, PNL-7205, April 1992.

7.5 OFFSITE COLLECTIVE DOSE ASSESSMENT

The site plan for the North Anna ISFSI and its relative location to the North Anna Power Station are provided in Figure 2-3. The North Anna site within the boundary is the controlled area as defined in 10 CFR 72.

Based on projections for year 2000, 354 permanent residents are located within a 2-mile radius of the North Anna site boundary. The nearest permanent resident is located at 2860 feet from the ISFSI. The maximum annual dose to the nearest resident is 2.10 mrem. Using the conservative assumption that all of the residents within two miles are located at the same distance from the ISFSI as the nearest resident, their maximum annual collective dose from the ISFSI would be:

$$0.00210 \text{ rem/year} \times 354 \text{ persons} = 0.74 \text{ person-rem/year}$$

The annual dose to the maximally exposed individual from all significant sources at the North Anna Power Station has been estimated in Appendix 11B of the North Anna Power Station Updated Final Safety Analysis Report (UFSAR) as 3 mrem/yr. Therefore, the maximum combined radiation contribution to the nearest permanent resident from the operation of the ISFSI (2.10 mrem/yr) and North Anna Power Station Units 1 and 2 (3.00 mrem/yr) is 5.10 mrem/yr. This is well below the 25 mrem/yr limit imposed by 10 CFR 72.104(a).

The North Anna ISFSI has no gaseous or liquid effluents, therefore, these do not contribute to the dose of nearby residents.

Considering the conservatisms in the above calculation and the rapid attenuation of neutron and gamma dose rates with distance, the dose for the more distant population is negligible.

7.6 HEALTH PHYSICS PROGRAM

The health physics organization and the health physics equipment associated with operation of the North Anna Power Station are considered sufficient for the operation of the ISFSI. The health physics technical procedures directing routine surveys include ISFSI activities. Thermoluminescent devices are in place along the ISFSI fence for routine monitoring of onsite dose.

7.7 ENVIRONMENTAL MONITORING PROGRAM

The North Anna Power Station environmental monitoring program is utilized for the ISFSI. Since there are no effluents from the ISFSI, no changes are required for the environmental monitoring program.

Table 7-1

MAXIMUM DESIGN BASIS DOSE RATES ALONG ISFSI PERIMETER FENCE (MREM/HR)

Years[a]	Status	A	B	C	D	E	F	G	H
14	Pads 1 and 2 Full				0.318[b]	0.556[b]	0.736[b]		
21	Pads 1, 2, and 3 Full	1.933	0.365	0.974	0.302	0.397	0.630	0.974	0.813

a. 14 years corresponds to the first two pads being filled assuming 4 SSSCs stored per year. Fuel stored would have minimum of additional 7 years of decay.

b. Due to location of pad 2, maximum dose rates at these locations occur after pad 2 is filled.

Table 7-2
ESTIMATED OCCUPATIONAL EXPOSURES FOR CASK LOADING, TRANSPORT, AND EMPLACEMENT[a] (ONE TIME EXPOSURE)

Task	Time Required (hr)	No. of Persons	Dose Rate (rem/hr)	Person-Rem
1. Unload empty SSSC from rail car	2.00	5	0.00E+00	0.00E+00
2. Move SSSC inside Decon Bldg	0.25	2	0.00E+00	0.00E+00
3. Remove cover; inspect	2.00	2	0.00E+00	0.00E+00
4. Remove lid(s); inspect	2.00	2	0.00E+00	0.00E+00
5. Replace lid seals	0.50	2	0.00E+00	0.00E+00
6. Move SSSC to loading area	1.00	3	1.70E-03	5.10E-03
7. Lower SSSC into loading area	0.25	3	1.70E-03	1.28E-03
8. Load SSSC with spent fuel	3.00	3	1.70E-03	1.53E-02
9. Verify fuel inventory	0.50	1	1.70E-03	8.50E-04
10. Place lid on SSSC	1.00	2	1.70E-03	3.40E-03
11. Lift SSSC; install lid bolts	0.50	2	2.86E-02	2.86E-02
12. Remove water in fuel cavity	1.00	2	2.86E-02	5.72E-02
13. Raise SSSC from loading area	0.25	2	8.39E-02	4.20E-02
14. Return SSSC to Decon Building	0.33	2	8.39E-02	5.54E-02
15. Decontaminate SSSC	2.00	2	8.39E-02	3.36E-01
16. Secure Lid	1.00	2	8.39E-02	1.68E-02
17. Vacuum dry cavity and test	4.00	2	8.39E-02	6.71E-01
18. Fill cavity with helium and test	3.00	2	8.39E-02	5.04E-01
19. Install pressure device and test	3.00	2	8.39E-02	5.04E-01
20. Perform radiation measurements	0.50	1	8.39E-02	4.20E-02
21. Lift SSSC; place outside of Decon Building	0.50	2	5.88E-02	5.88E-02
22. Lift SSSC with transporter	1.00	2	3.36E-02	6.72E-02
23. Transport SSSC to ISFSI	0.50	3	3.36E-02	5.20E-02
24. Connect pressure monitoring device; install weather cover	1.00	2	8.39E-02	1.68E-01
			Total	2.78E+00

a. Dose rates are from the base TN-32 cask.

Table 7-3

NORTH ANNA ISFSI MAINTENANCE OPERATIONS[a] ANNUAL OCCUPATIONAL EXPOSURES

Task	Time Required (hr)	No. of Persons	Dose Rate (rem/hr)	Person-Rem
Visual Surveillance of Casks [b]	1.00	2	8.39E-02	1.68E-01
Instrumentation				
a. Operability Tests [c]	1.00	2	1.90E-03	3.80E-03
b. Calibration [d]	2.00	2	1.90E-03	7.60E-03
c. Repair [e]	1.00	2	8.39E-02	1.68E-01
Surface defect repairs [f]	1.00	2	8.39E-02	1.68E-01
				5.15E-01

a. Dose rates are from the base case TN-32 cask. Assumes ISFSI is full.
b. Based on four surveys per year, 15 minutes each.
c. Based on two tests per year, 30 minutes each.
d. Based on recalibration of the instruments every two years. Total time required is four hours every two years.
e. Based on repair of one instrument every year, one hour per repair.
f. Based on repair of three SCCCs per year, 20 minutes each.

Table 7-4

TOTAL ANNUAL OCCUPATIONAL EXPOSURES DURING ISFSI LOADING OPERATIONS[a]

	Person-Rem
North Anna Power Station [b]	2.75E+00
ISFSI Operations	
SSSC Preparation and Placement [c]	11.12E+00
Maintenance and Surveillance [b]	5.15E-01
Total	14.39E+00

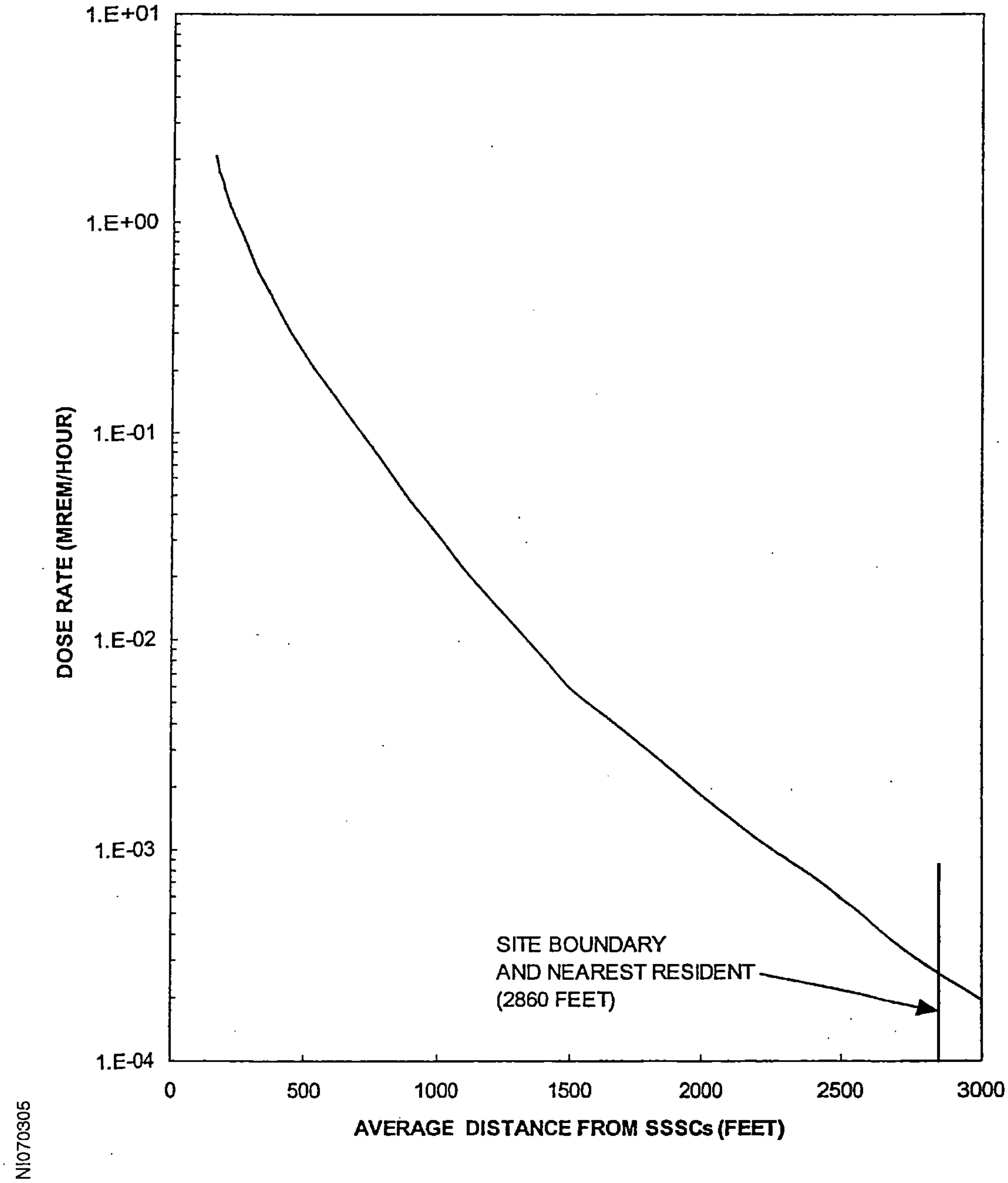
a. Utilizes design basis SSSC surface dose rates.
b. Assumes full ISFSI (84 SSSCs).
c. Assumes four SSSCs every year.

Figure 7-1
ISFSI LAYOUT

Security-Related Information Figure Withheld Under 10 CFR 2.390.

Note: Only the vehicle gate is shown. Personnel gates are not shown but exist at the top right and bottom two corners and in the center of each side.

Figure 7-2
DOSE RATE FOR 84 BASE CASE CASKS VERSUS DISTANCE



Chapter 8 ACCIDENT ANALYSES

An evaluation of the safety of the North Anna ISFSI with respect to postulated accident events is presented in this chapter. The facility response is analyzed in terms of event causes and precursors, recognition and quantification, and consequence mitigation for the spectrum of postulated occurrences.

Four categories of design events have been considered, as defined in ANSI/ANS 57.9-1984. Design event categories are designated as:

- I Events that are expected to occur regularly or frequently in the course of normal operation
- II Events which can be expected to occur with moderate frequency as on the order of once per year
- III Events anticipated to occur infrequently or, at most, once during the lifetime of the installation
- IV Events which are not considered credible, but nevertheless are postulated in order to bound the consequences.

8.1 OFF-NORMAL OPERATIONS

The design and operation of the North Anna ISFSI include features intended to minimize or preclude the compromise of safety functions due to off-normal conditions. These features are described in Chapters 4 and 5. Nevertheless, design events have been postulated and analyzed to demonstrate the inherent safety of the facility.

Design events in Category I (normal operations) have been previously discussed in Chapters 4, 5, and 6 and are not presented further here. A loss of electric power design event has been included as a Category II event and is discussed in the following section. The SSSC Topical Safety Analysis Reports postulate additional off-normal events for the SSSCs. The Topical Safety Analysis Reports analyze the effects of these additional events and identify the corrective actions.

8.1.1 Loss of Electric Power

A total loss of ac power is postulated to occur in the feeder cabling which supplies power to the ISFSI. The failure could be either an open or a short to ground circuit, or any other mechanism capable of producing an interruption of power.

8.1.1.1 Postulated Cause of Event

A loss of power to the ISFSI may occur as a result of natural phenomena, such as lightning or extreme wind, or as a result of undefined disturbances in the nonsafety-related portion of the electric power system of the North Anna Power Station.

If electric power is lost, the following systems would be powered from the ISFSI diesel:

- Area lighting
- Area receptacles
- SSSC pressure monitoring instrumentation
- Microwave
- Camera System

8.1.1.2 Detection of Event

A loss of ac power at the North Anna site would be indicated in the CAS. If the loss of power were localized solely at the ISFSI, this would be indicated at the local annunciator.

8.1.1.3 Analysis of Effects and Consequences

This event has no safety or radiological consequences. None of the systems whose failure could be caused by this event are required for the accomplishment of the safety function of the ISFSI. The lighting system functions merely for convenience and visual monitoring, and the instrumentation monitors the long-term performance of the SSSCs with respect to seal integrity. Seal integrity is not expected to change rapidly and its status is not dependent upon electric power.

8.1.1.4 Corrective Actions

Following a loss of electric power to the ISFSI, plant maintenance personnel will be informed, and will isolate the fault and restore electrical service by conventional means. Such an operation is straightforward and routine for the maintenance crews of an electric utility.

8.1.2 Radiological Impact from Off-Normal Operations

A loss of power will not affect the integrity of the SSSCs, jeopardize the safe storage of the fuel, nor result in radiological releases.

8.2 ACCIDENTS

This section addresses more serious occurrences which are expected to happen on an extremely infrequent basis, if ever, during the lifetime of the facility (Event Category III). In addition, a maximum hypothetical accident, which is not considered credible (Event Category IV), is identified and analyzed.

8.2.1 Earthquake

8.2.1.1 Cause of Accident

The design earthquake (DE) as described in Sections 2.5.2 and 3.2.3, is postulated to occur as a design basis extreme natural phenomenon.

8.2.1.2 **Accident Analysis**

Analyses of the storage pads for the DE is provided in Section 4.2.1.4. The results of these analyses show that the storage pads remain intact and that the SSSCs will not slide or tip over.

The seismic response characteristics of the SSSCs are provided in the SSSC Topical Safety Analysis Reports. The results of these analyses show that SSSC leak-tight integrity is not compromised and that no damage will be sustained by the SSSC or the spent fuel.

8.2.1.3 **Accident Dose Calculations**

As demonstrated in Section 4.2.1.4, the DE is not capable of damaging the storage pads or causing SSSC sliding or tipover. As demonstrated in the SSSC Topical Safety Analysis Reports, the DE is not capable of producing SSSC seal leakage. No radioactive material is released, and there are no dose consequences associated with this event.

8.2.2 Extreme Wind

8.2.2.1 **Cause of Accident**

The extreme winds due to passage of the design basis wind and tornado as defined in Section 3.2.1 are postulated to occur as a design basis extreme natural phenomenon. As described in Section 2.3.1, the design basis tornado is expected to occur less than once in 30,800 years, and the design basis wind is expected to occur less than once in 100 years.

8.2.2.2 **Accident Analysis**

The effect of the design basis wind on the storage pads is provided in Section 4.2.1.2. The effect of the design basis tornado on the storage pads is provided in Section 4.2.1.3. Both analyses demonstrate that the storage pads are not damaged and the SSSCs will not slide or tip over during the design basis extreme wind events.

The effects and consequences of extreme winds on the SSSCs are provided in the SSSC Topical Safety Analysis Reports. The results of these analyses show that minor damage to the SSSC may be sustained from tornado missiles, but SSSC leak-tight integrity is not compromised.

8.2.2.3 **Accident Dose Calculations**

As demonstrated in Sections 4.2.1.2 and 4.2.1.3 and the SSSC Topical Safety Analysis Reports, design basis extreme winds are not capable of damaging the storage pads or tipping over or sliding an SSSC, and that the damage sustained from the tornado missiles will not compromise seal integrity. No radioactive material is released, and there are no dose consequences associated with these events.

8.2.3 Flood

As discussed in Section 3.2.2, the North Anna ISFSI is considered flood-dry. Flooding is not considered as a design basis event.

8.2.4 Explosion

8.2.4.1 Cause of Accident

An explosion is postulated to occur as a result of a vehicular accident at a point approximately 1.5 miles from the ISFSI. The evaluation of this event is described in detail in Section 2.2.2. A pressure wave of less than 1 psi is estimated to reach the ISFSI.

8.2.4.2 Accident Analysis

As described in the SSSC Topical Safety Analysis Reports, a pressure wave of the magnitude associated with this event will not damage the SSSCs or cause tip-over.

8.2.4.3 Accident Dose Calculations

The postulated event will not damage the SSSC exterior nor cause SSSC tip-over. This event is not capable of producing leakage from the SSSC. No radioactive material is released, and there are no dose consequences associated with this event.

8.2.5 Fire

8.2.5.1 Cause of Accident

The only combustible materials at the ISFSI storage pads are in the form of insulation on instrumentation wiring, and coating of the outside surface of the SSSCs. No other combustible or explosive materials are allowed to be stored on the storage pads. As described in Section 2.1.2, the ISFSI area will be cleared of trees and seeded with grass. In addition, other equipment in the area has adequate separation from the storage pads. Therefore, no fires other than small electrical fires are considered credible at the storage pads.

The fire protection capabilities available at the ISFSI are described in Section 4.4.5.1. These include portable fire extinguishers within the ISFSI perimeter fence. In addition, the fire fighting equipment and personnel present at the North Anna Power Station would be available if needed.

8.2.5.2 Accident Analysis

The ability of the SSSCs to withstand postulated fires and the consequence of postulated fires are addressed in the SSSC Topical Safety Analysis Reports. Results of these analyses indicate that the postulated fires are not capable of compromising seal integrity.

8.2.5.3 Accident Dose Calculations

The damage to an SSSC due to fire is not capable of producing SSSC seal leakage. No radioactive material is released, and there are no dose consequences associated with this event.

8.2.6 Storage of an Unauthorized Fuel Assembly

The ISFSI Technical Specifications specify limiting values for the initial enrichment, average burnup, decay heat, and cooling time after reactor discharge for the fuel assemblies to be placed in SSSCs. The Technical Specifications also specify required structural attributes for those fuel assemblies. The possibility of storing a fuel assembly that does not meet the Technical Specification requirements has been considered.

8.2.6.1 Cause of Accident

The cause of this event is postulated to be an error during the loading operations, e.g., the wrong fuel assembly is selected by the fuel handling operator, or a failure in the administrative controls governing the fuel handling operations.

8.2.6.2 Accident Analysis

The loading of an unauthorized fuel assembly has no consequence while the SSSC remains in the spent fuel pool. The borated water in the spent fuel pool provides adequate protection against a criticality event, and also provides shielding and heat removal. Loading of an unirradiated fuel assembly will not cause a criticality event because SSSC criticality analyses must show subcritical conditions assuming all fuel assemblies are unirradiated. Loading of an unauthorized fuel assembly with gross cladding defects will not cause further damage to the cladding or result in the release of radioactive material. Loading of an unauthorized fuel assembly with structural defects will likely be detected during placement of the assembly in the SSSC. In order to preclude this event from going undetected, however, and to ensure that appropriate corrective actions can take place prior to placing the lid on an SSSC, a final verification of the identity and location of the fuel assemblies loaded into the SSSCs is performed with an underwater video camera to ensure that the correct fuel assemblies have been loaded into the SSSC.

These administrative controls and the records associated with them are included in the procedures described in Chapter 9 and in the proposed license requirements described in Chapter 10, and will comply with the applicable requirements of the Quality Assurance Program described in Chapter 11.

Appropriate and sufficient actions will be taken to ensure that a fuel assembly loading error does not remain undetected. In particular, the storage of an unauthorized fuel assembly is not considered credible in view of the multiple administrative controls.

8.2.6.3 Accident Dose Calculations

The storage of an unauthorized fuel assembly is not considered to be a credible event. No radioactive material is released, and there are no dose consequences associated with this event.

8.2.7 Loss of Neutron Shield

The design of the SSSCs includes neutron absorbing material either internal or external to the SSSC body. As applicable to the particular SSSC design, the SSSC Topical Safety Analysis Reports discuss a postulated loss of neutron shield. As concluded in these documents, a total loss of neutron shield is not a credible event for the North Anna ISFSI.

8.2.8 SSSC Seal Leakage

The SSSCs feature redundant seals in conjunction with extremely rugged body designs. Additional barriers to the release of radioactive material are provided by the sintered fuel pellet matrix and the zircaloy cladding. Furthermore, the fuel cavity helium pressure is substantially less than the helium pressure-of the volume monitored by the pressure monitoring device. The pressure monitoring device provides an early warning of a decrease in the pressure of this monitored volume. No credible mechanisms that could result in leakage of radioactive material have been identified.

8.2.9 SSSC Drops

SSSC handling and drop events postulated to occur in the Fuel and Decontamination Buildings are addressed in Appendices 9B and 15A of the North Anna Power Station UFSAR.

The SSSCs are designed to withstand drops of at least 15 inches without compromising SSSC integrity. SSSC drops in excess of these heights at the ISFSI, or during transport, are not considered credible because of procedures that preclude the lifting of the SSSCs any higher. Analyses of SSSC drop events are presented in the SSSC Topical Safety Analysis Reports.

8.2.10 Loss of Confinement Barrier

The following postulated event scenario is not considered to be credible. It is hypothesized solely to demonstrate the inherent safety of the North Anna ISFSI by subjecting it to a set of simultaneous multiple failures, any one of which is far beyond the capability of natural phenomena or man-made hazards to produce.

8.2.10.1 Cause of Accident

A simultaneous failure of all protective layers of radioactive material confinement is postulated to occur by unspecified nonmechanistic means for a single SSSC.

8.2.10.2 Accident Analysis

In this event, the SSSC confinement function is nonmechanistically removed. Heat removal and radiation shielding functions are assumed to continue to operate in the normal passive manner.

This event was analyzed for a TN-32 cask based on the requirements of NUREG-1536 (Reference 1), Interim Staff Guidance-5 (ISG-5), Revision 1 (Reference 2), and the following inputs:

1. Isotope inventories are based on 32 fuel assemblies with an enrichment of 3.30 weight percent U-235, burnup of 45,000 MWD/MTU and seven years decay. This enrichment was selected after reviewing the enrichment and burnup of all North Anna spent fuel to ensure that this enrichment is bounding. Using a lower enrichment yields a bounding isotope inventory, and is in accordance with NRC ISG-6 (Reference 3).

2. The Co-60 source is calculated based on the surface area of a 17 x 17 fuel assembly and a seven year decay time from discharge.
3. The cask seal leak rate calculated in Reference 4 was increased by 50 percent.
4. The maximum boundary dispersion factor (X/Q) calculated for the North Anna site (see Table 2-1).
5. The breathing rate identified in Reference 4.
6. The bounding dose conversion factors in EPA Guidance Report No. 11 (Reference 5) are used to calculate the whole body, critical organ, and thyroid dose from inhalation.
7. The bounding dose conversion factors in EPA Guidance Report No. 12 (Reference 6) are used to calculate the whole body, critical organ, thyroid, and skin dose from immersion.

The isotopes used in the analysis were based on the selection criteria in ISG-5, Revision 1, including Co-60 in the fuel rod crud, iodine-129, tritium, metastable tellurium-125, fission products that contribute greater than 0.1% of activity, and actinides that contribute greater than 0.01% of activity. The isotope concentrations were used with the release fractions, the free volume in the cavity of the TN-32 cask (5.39 cubic meters), and the cask seal leak rate to calculate the isotope release rate (µCi/sec) from the cask. The isotope release rate is used over a 30-day period to calculate a release inventory in curies.

Using this release inventory, the bounding dose conversion factors from EPA Guidance Report No. 11, the maximum dispersion factor (X/Q), and the breathing rate from Reference 3, the site boundary inhalation dose for each isotope was calculated. Similarly, using this release inventory, the bounding dose conversion factors from EPA Guidance Report No. 12, and the maximum bounding dispersion factor (X/Q), the site boundary immersion dose for each isotope was calculated.

8.2.10.3 Accident Dose Calculations

This accident evaluation, performed to determine the radiological consequences of a release of the inventory in an SSSC, resulted in a deep dose plus committed dose equivalent to the worst organ (bone marrow) of 13 mrem at the nearest site boundary. This dose is well within the criteria of 10 CFR 72.106(b).

8.2.11 References

1. NUREG-1536, *Standard Review Plan for Dry Cask Storage Systems,* US NRC, Spent Fuel Project Office.
2. Interim Staff Guidance-5, Revision 1, *Confinement Evaluation,* US NRC Spent Fuel Project Office.
3. Interim Staff Guidance-6, *Minimum Enrichment for Design Basis,* US NRC Spent Fuel Project Office.

4. *TN-32 Final Safety Analysis Report,* Revision 0, Transnuclear Inc., January 2000.

5. U. S. Environmental Protection Agency, Federal Guidance Report No. 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,* EPA 520/1-88-020, 1988.

6. U. S. Environmental Protection Agency, Federal Guidance Report No. 12, *External Exposure to Radionuclides in Air, Water, and Soil,* EPA 402-R-93-081, September 1993.

8.3 SITE CHARACTERISTICS AFFECTING SAFETY ANALYSIS

Site characteristics have been considered in the formation of the bases for these safety analyses. Conditions of meteorology were used in the determination of χ/Q values as well as the characteristics of extreme winds and their contribution to maximum flood level. Regional and site seismology and geology were used to help define the design earthquake acceleration value. Regional population distribution and other demographic data were used to determine radiation doses.

Chapter 9 CONDUCT OF OPERATIONS

9.1 ORGANIZATIONAL STRUCTURE

9.1.1 Corporate Organization

The ISFSI will be operated under the same corporate management organization responsible for operation of the North Anna Power Station. This organization is depicted in the Dominion Nuclear Facility Quality Assurance Program Description, Topical Report DOM-QA-1 (QA Program Topical Report).

9.1.1.1 **Corporate Functions, Responsibilities, and Authorities**

Corporate functions, responsibilities and authorities for the North Anna ISFSI are discussed in the QA Program Topical Report.

9.1.1.2 **Applicant's In-House Organization**

A discussion of Virginia Power's in-house organization is provided in the QA Program Topical Report.

9.1.1.3 **Relationships with Contractors and Suppliers**

The SSSC suppliers are responsible for the fabrication and testing of the SSSCs, and for recommending SSSC handling procedures. The Nuclear Analysis and Fuel Department is the primary interface with the SSSC supplier and other equipment vendors.

Site preparation and construction will be performed by Virginia Power, using specialty subcontractors, as required.

9.1.1.4 **Applicant's Technical Staff**

Virginia Power's technical staff is described in the QA Program Topical Report.

9.1.2 Operation Organization, Management, and Administrative Control System

9.1.2.1 **Onsite Organization**

The North Anna Power Station onsite organization is described in the QA Program Topical Report.

9.1.2.2 **Personnel Functions, Responsibilities, and Authorities**

Personnel functions, responsibilities and authorities are described in the QA Program Topical Report.

9.1.3 Personnel Qualification Requirements

9.1.3.1 Minimum Qualification Requirements

Each member of the North Anna Power Station staff is required to meet or exceed the minimum qualifications specified in the QA Program Topical Report.

9.1.3.2 Qualifications of Personnel

The qualification requirements for the managerial and technical positions are described in the QA Program Topical Report.

9.1.4 Liaison with Outside Organizations

Dames & Moore provided geotechnical expertise initially required to evaluate site conditions and to design the ISFSI structures and foundations. SSSC vendors provide technical expertise in the design, fabrication and use of the SSSCs. Bechtel Power Corporation provided expertise in the development of computer models to initially assess radiation doses.

9.2 STARTUP TESTING AND OPERATION

9.2.1 Administrative Procedures for Conducting Test Program

The administrative procedures and instructions for the North Anna ISFSI are the same as those used for the North Anna Power Station. Any changes to, or deviations from, these procedures and instructions are reviewed and approved in accordance with the QA Program Topical Report.

9.2.2 Test Program Description

The objectives of the pre-operational testing program are to ensure that the SSSCs perform their safety functions as intended and that the means to fulfill the commitments made in Chapter 10 are available.

9.2.2.1 Physical Facilities

Before operation of the ISFSI, the SSSC monitoring instrumentation, the electrical system, the communications system and the security system are tested to ensure their proper functioning. The ISFSI security system is tested after completion of its installation. Details on security system testing are provided in the Security Plan.

The SSSC monitoring instrumentation alarms are tested to ensure that individual alarm signals annunciate at the local annunciator enclosure at the ISFSI location.

The electrical system is tested to ensure that power is available for the SSSC monitoring instrumentation and the local annunciator. The lighting and service receptacles are also tested for proper operation.

The communications system is tested to ensure that the telephone at the local annunciator is properly connected into the station phone system.

9.2.2.2 **Operations**

Testing of SSSC operations, i.e., loading, drying, sealing and unloading, shall be conducted prior to the first use of each SSSC design. This simulation shall include all SSSC loading and unloading operations, with the exception of loading actual fuel assemblies into the SSSC. SSSC loading will instead be tested with a dummy fuel assembly to ensure that fuel assemblies will fit properly into the SSSC. All SSSCs are tested for fuel assembly fit by the vendor at the fabrication facility. The SSSCs are also tested by the vendor to ensure that they seal properly. New seals are installed prior to and tested following fuel loading.

The function of the transporter is tested prior to its first use with each new SSSC design using an empty SSSC for a transport simulation to and from the ISFSI, including placement of the SSSC at a storage location.

9.2.3 Test Discussion

The pre-operational test purposes, responses, acceptance criteria, margins, and corrective actions are discussed in Section 9.2.2. Instrumentation, electrical, and communications equipment shall be functionally tested to confirm operability. Acceptance criteria for SSSC seal testing shall be as specified in Section 3.3.

9.3 TRAINING PROGRAM

The training program has the objective of providing and maintaining a well qualified work force for safe and efficient operation of the ISFSI. All personnel working in the fuel storage area receive radiation and safety training. Those personnel actually performing SSSC and fuel handling functions are given additional training in specific areas as required by the radiological protection program in effect at the North Anna Power Station.

All personnel working at the North Anna ISFSI receive training and indoctrination geared toward providing and maintaining a well-qualified work force for safe and efficient operation of the ISFSI. The existing North Anna training programs are INPO accredited and are directly applicable to the North Anna ISFSI, and provide this training and indoctrination. Additional training requirements specific to the ISFSI will address the following subjects:

- ISFSI Licensing Basis and Technical Specifications
- ISFSI Layout and Function
- ISFSI Security
- ISFSI Communications Systems
- ISFSI Operation, Emergency, Maintenance, and Administrative Procedures

- SSSC Loading and Unloading, Handling and Onsite Transportation
- SSSC Decontamination Techniques

Following completion of the ISFSI training program, trainees are given a written and practical exam to ensure they understand the important aspects of the information described above. Retention of training records and certifications of proficiency is consistent with that for personnel involved in fuel handling operations.

ISFSI retraining is consistent with the retraining requirements in effect at the North Anna Power Station for personnel involved in fuel handling operations.

Training records are maintained for in accordance with the QA Program Topical Report. Such records include dates and hours of training and other documentation on training subjects, information on physical requirements, job performance statements, copies of written examinations, information pertaining to walk-through examinations, and retesting particulars.

9.4 NORMAL OPERATIONS

9.4.1 Procedures

Written procedures for all normal operating, maintenance, and testing at the ISFSI will be prepared and will be in effect prior to operation of the North Anna ISFSI. These procedures are briefly described in Sections 9.4.1.1 through 9.4.1.8.

These procedures, and any subsequent revisions, will be reviewed and approved in accordance with the QA Program Topical Report. All procedure revisions shall be documented.

The Nuclear Oversight Department periodically audits (on a sampling basis) the procedures to ensure revisions are made promptly and that obsolete material is deleted.

9.4.1.1 **Administrative Procedures**

Administrative procedures will provide a clear understanding of operating philosophy and management policies to all ISFSI personnel. These procedures include instructions pertaining to personnel conduct and control, including consideration of job-related factors which influence the effectiveness of operating and maintenance personnel, e.g., work hours, entering and exiting the ISFSI, organization, and responsibility, etc.

9.4.1.2 **Annunciator Procedures**

Annunciator procedures will provide information relative to each alarm annunciator which monitors SSSC parameters. The procedures will provide alarm set points and appropriate corrective action.

9.4.1.3 Health Physics Procedures

Health physics procedures are used to implement the radiation protection plan. The radiation protection plan involves the acquisition of data and provision of equipment to perform necessary radiation surveys, measurements, and evaluations for the assessment and control of radiation hazards associated with the operation of the ISFSI. Procedures have been developed and implemented for monitoring exposures of employees, utilizing accepted techniques, radiation surveys of work areas, radiation monitoring of maintenance activities, and for records maintenance demonstrating the adequacy of measures taken to control radiation exposures of employees and others within prescribed limits and as low as practicable. These procedures will be revised as needed to address ISFSI operations prior to operation of the ISFSI. The revised procedures will ensure the safety of personnel performing loading, transport, and unloading operations, and surveillance and maintenance at the ISFSI. Entrance to the ISFSI and all work performed inside will require a radiation work permit and will be controlled by health physics and security personnel.

9.4.1.4 Maintenance Procedures

Maintenance procedures will be established for performing preventative and corrective maintenance on ISFSI equipment and the SCCSs. Preventative maintenance will be performed on a periodic basis to preclude the degradation of ISFSI systems, equipment, and components. Corrective maintenance will be performed to rectify any unexpected system, equipment, or component malfunction, as the need arises.

9.4.1.5 Operating Procedures

The operating procedures will provide the instructions for handling, loading, sealing, transporting, storing and unloading the SSSCs.

9.4.1.6 Test Procedures

Periodic test procedures will be established to verify operability of the ISFSI systems, equipment, and components on a routine basis.

9.4.1.7 Pre-operational Test Procedures

Pre-operational test procedures will be established to ensure that ISFSI structures, systems, and components satisfactorily perform their required functions. These test procedures will further ensure that the ISFSI has been properly designed and constructed and is ready to operate in a manner that will not endanger the health and safety of the public.

9.4.1.8 Procedures Implementing the QA Program

Procedures will be established to ensure that the operation and maintenance of the ISFSI is performed in accordance with the QA program described in Chapter 11.

9.4.2 Records

In accordance with the requirements of 10 CFR 72.72, records on the identity of each fuel assembly will be maintained with SSSC loading procedures, and shall include the following:

- Fuel manufacturer
- Date of delivery
- Reactor exposure history
- Burnup
- Calculated special nuclear material content
- Inventory control number
- Pertinent data on discharge and storage at the reactor, transfer to the ISFSI and storage at the ISFSI

All records related to the ISFSI, including those for quality assurance, operations, accountability, off-normal occurrences, events associated with radioactive releases and environmental surveys shall be maintained by the North Anna Power Station document management system.

9.5 EMERGENCY PLANNING

The North Anna Emergency Plan (NAEP) describes the organization, assessment actions, conditions for activation of the emergency organization, notification procedures, emergency facilities and equipment, training, provisions for maintaining emergency preparedness, and recovery criteria used at the North Anna Power Station. This emergency plan will also be used for any radiological emergencies that may arise at the North Anna ISFSI.

Portions of Section 4 of the NAEP and applicable implementing procedures reflect the conditions and indications that require entry into the Emergency Plan. Appropriate response actions and notifications have been established in the Emergency Plan. Damage to a loaded SSSC confinement boundary requires declaration of a Notification of Unusual Event.

9.6 PHYSICAL SECURITY PLAN

The purpose of a security program for the ISFSI is to establish and maintain a physical security capability for the protection of the spent fuel stored in the SSSCs. The physical security program for the North Anna ISFSI is provided in the Physical Security Plan, Safeguards Contingency Plan and the Nuclear Security Personnel Training and Qualification Plan for the North Anna Power Station.

Additional information regarding the security program for the ISFSI is contained in a separate enclosure, that is withheld from public disclosure in accordance with 10 CFR 2.790(d) and 10 CFR 73.21.

Chapter 10 OPERATING CONTROLS AND LIMITS

10.1 PROPOSED OPERATING CONTROLS AND LIMITS

The proposed operating controls and limits for the North Anna ISFSI are provided in the North Anna ISFSI Technical Specifications. The Technical Specifications contain definitions, functional and operating limits, limiting conditions for operation, the applicability for the limiting conditions, action statements, surveillance requirements, design features, and administrative controls. Functional and operating limits are utilized to protect the integrity of the stored fuel or SSSC, and to guard against the uncontrolled release of radioactive materials. The items addressed by the functional and operating limits are provided in Table 10-1. The limiting conditions for operation specify the lowest functional capability or performance levels for equipment required for safe operation. The items addressed by the limiting conditions for operation are provided in Table 10-2.

10.1.1 Content of Operating Controls and Limits

The functional and operating limits, and the limiting conditions for operation specify the required technical limits and operating status for the variables, technical characteristics and conditions, and equipment addressed by the Technical Specifications. The applicability specifies the equipment, time period, or operational condition to which the operating controls and limits apply. The action statements provide the corrective action instructions that must be followed if the technical limits or operating status requirements are not met. The surveillance requirements specify the verification needed to assure that the functional and operating limits, and the limiting conditions for operation are being met.

10.1.2 Bases for Operating Controls and Limits

A basis is provided with each functional and operating limit, and each limiting condition for operation in the North Anna ISFSI Technical Specifications. Each basis describes the significance to safety of the required technical limits and operating status established for the variables, technical characteristics and conditions, and equipment addressed by the Technical Specifications.

10.2 DEVELOPMENT OF OPERATING CONTROLS AND LIMITS

10.2.1 Functional and Operating Limits

Functional and operating limits have been established in order to define the requirements for the fuel to be stored at the ISFSI. The functional and operating limits for the parameters listed in Table 10-1 are provided in Chapter 2.0 of the North Anna ISFSI Technical Specifications.

10.2.2 Limiting Conditions for Operation

Limiting conditions for operation have been established to control the equipment, and technical conditions and characteristics of the ISFSI necessary for continued operation. The limiting conditions for operation of equipment address the lowest acceptable level of performance for a system or component, and the minimum portion of the system or the minimum number of components that should be available. The limiting conditions for operation for technical conditions and characteristics address allowable quantities during loading, transport, storage, and unloading operations. The limiting conditions for operation for the equipment, and technical conditions and characteristics listed in Table 10-2 are provided in Chapter 3.0 of the North Anna ISFSI Technical Specifications.

10.2.3 Surveillance Requirements

Surveillance requirements have been established in order to confirm that the limiting conditions for safe storage are met. Surveillance requirements have been established for each functional and operating limit, and limiting condition for operation, and are provided with them in Chapter 3.0 of the North Anna ISFSI Technical Specifications.

10.2.4 Design Features

The design features describe ISFSI design characteristics of importance. The design features are provided in Chapter 4.0 of the North Anna ISFSI Technical Specifications.

10.2.5 Administrative Controls

The administrative controls include the organization and management procedures, recordkeeping, review and audit, and reporting necessary to assure that the operations involved in the storage of spent fuel at the North Anna ISFSI is performed in a safe manner. The administrative controls are provided in Chapter 5.0 of the North Anna ISFSI Technical Specifications.

Table 10-1
FUNCTIONAL AND OPERATING LIMITS

- Fuel To Be Stored At The ISFSI

Table 10-2
LIMITING CONDITIONS FOR OPERATION

- SSSC Cavity Vacuum Drying Pressure
- SSSC Helium Backfill Pressure
- SSSC Combined Helium Leak Rate
- SSSC Internal Pressure
- SSSC Maximum Lifting Height
- Dissolved Boron Concentration
- SSSC Average Surface Dose Rates
- SSSC Surface Contamination
- Helium Purity
- SSSC Spacing
- Uranium Content per Assembly

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Chapter 11 QUALITY ASSURANCE

11.1 QUALITY ASSURANCE PROGRAM DESCRIPTION

10 CFR 72.140 requires that a quality assurance program be established and implemented for the structures, systems, and components of an ISFSI that are important to safety, commensurate with their importance to safety. However, 10 CFR 72.140 provides for the use of previously approved programs.

Since Virginia Power is currently licensed under 10 CFR 50 to operate nuclear power facilities, a quality assurance (QA) program meeting the requirements of 10 CFR 50, Appendix B is already in place. The governing document for this program is the Dominion Nuclear Facility Quality Assurance Program Description, Topical Report DOM-QA-1 (QA Program Topical Report), which has been reviewed and approved by the NRC. (See Section 1.5.) The document is updated in accordance with 10 CFR 50.54(a). The NRC is periodically notified of changes to the document. This program is implemented through the Virginia Power administrative and technical procedures. The objective of the company Quality Assurance Program for operating nuclear power stations is to comply with the criteria expressed in 10 CFR 50, Appendix B, as amended, and with the quality assurance program requirements for nuclear power plants as referenced in the Regulatory Guides and ANSI standards referenced in the QA Program Topical Report. This program will be applied to those activities associated with the North Anna ISFSI that are important to safety. No changes to this program are required for the ISFSI activities.

As indicated in previous chapters, the SSSCs are the only components with a safety function. As such, Virginia Power procedures delineate the requirements for the engineering, procurement, fabrication, and inspection of this equipment. The procurement documents (specifications, requisitions, etc.) are reviewed technically prior to use to ensure that the proper criteria have been specified. During the SSSC design phase, vendor information (drawings, specifications, procedures, etc.) are reviewed to ensure compliance with Virginia Power's technical requirements. During SSSC fabrication, Virginia Power's Vendor Surveillance Representative will visit the vendor's shop to ensure compliance with Virginia Power's requirements and to witness parts of the SSSC fabrication and testing.

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Appendix A
SSSC Specific Information

This appendix provides:

- A list of the Topical Safety Analysis Reports for SSSCs approved by the USNRC for use at the North Anna ISFSI (see Table A-1).
- A subappendix for each SSSC type that provides specific references to the SSSC Topical Safety Analysis Reports, and supplements the information contained in the SSSC Topical Safety Analysis Reports.

Table A-1
TOPICAL SAFETY ANALYSIS REPORTS FOR SSSCs APPROVED FOR USE AT THE NORTH ANNA ISFSI

A.1. *TN-32 Dry Storage Cask Topical Safety Analysis Report,* Revision 9A, Transnuclear, Inc., December 1996.

Appendix A.1
TN-32 Dry Storage Cask

A.1.1 General Description

The TN-32 cask is a smooth right circular cylinder of multi-wall construction that is approximately 16.8 feet high, 8.1 feet in diameter and weighs (empty) approximately 91.0 tons. The cask inner shell and containment vessel is a welded, carbon steel cylinder that is 1.5 inches thick and has a sprayed metallic aluminum coating for corrosion protection. Surrounding the outside of the containment vessel wall is a steel gamma shield with a wall thickness of 8.0 inches. The bottom end of the gamma shield has a thickness of 8.75 inches. The cask has a cylindrical cavity which holds a fuel basket designed to accommodate 32 PWR fuel assemblies. The loaded weight of the cask is approximately 115.5 tons. Four trunnions are welded on, two at the top end and two at the bottom end of the body.

During fabrication of the TN-32 cask, the inner containment vessel and the gamma shielding are fit together by a shrink-fit procedure. The gamma shielding is heated so that the inner containment vessel, with the flange attached, can be inserted into the outer gamma shielding vessel. This allows a close fit between the two cylindrical shells for good heat transfer. During the shrink fit operation, a small circumferential gap between the flange of the inner vessel and the gamma shielding forms as the heated gamma shield cools. Prior to welding the flange to the gamma shield, the gap is filled with shims made of one of the materials specified in the TN-32 TSAR for the gamma shield shell.

The cask is sealed with one carbon steel lid bolted to the top flange of the containment vessel. The lid is 10.5 inches thick and is secured to the cask body with 48 bolts. The lid and lid penetration covers are sealed with metallic O-ring seals.

Neutron shielding is provided by a 4.5-inch thick resin compound enclosed in long aluminum boxes that surround the gamma shield. The neutron shield boxes are enclosed by a painted carbon steel shell that is 0.50 inches thick.

In Chapter 1 of the TN-32 Topical Safety Analysis Report (Rev. 9A, 12/96), drawing 1049-70-2, Rev. 2, includes a view of a cask trunnion (item 6). The back side of the trunnion (weld prep) is shown at a 30 degree angle. This angle should actually be shown as 45 to 50 degrees.

Sections 3.1.1, Paragraph 3 of the TN-32 Topical Safety Analysis Report (Rev. 9A, 12/96) states that "Other structural and structural attachment welds are examined by the liquid penetrant or the magnetic particle method in accordance with Section V, Article 6 of the ASME Code. Acceptance standards are in accordance with Section III, Subsection NF, Paragraph NF-5350." However, Paragraph NF-5350 only pertains to liquid penetrant inspection. Paragraph NF-5340 pertains to magnetic particle inspection. Section 3.1.1, Paragraph 3 of the TN-32 Topical Safety Analysis Report (Rev. 9A, 12/96) should read "Other structural and structural attachment welds are examined by the liquid penetrant or the magnetic particle method in accordance with Section V, Article 6 of the ASME Code. Acceptance standards are in accordance with Section III, Subsection NF, Paragraph NF-5340 and NF-5350."

The weld between the aluminum plates separating the fuel storage tubes and the outer aluminum plates at twenty-four locations around the periphery of the fuel basket is shown on TN-32 TSAR drawing 1049-70-6, Rev. 3 as a 0.25-inch groove weld. In order to provide consistency with as-built conditions, this weld may alternatively be a 0.25-inch fillet weld.

The weld creating the longitudinal seam of the neutron shield outer shell is shown on TN-32 TSAR drawing 1049-70-2, Revision 2 as a full penetration weld. In order to provide improved heat transfer between the outer shell and the neutron shield tubes, this weld may alternatively be a partial penetration weld.

TN-32 TSAR Revision 9A drawing 1049-70-5 specifies that the top of borated aluminum plates in the fuel basket be placed nominally 11.88 inches from the top of the basket assembly. Revision 0 of the TN-32 FSAR, which contains analyses to support loading of fuel with higher burnup and enrichment, specifies that the top of the borated aluminum plates be placed nominally 12.00 inches from the top of the basket assembly. Since Revision 9A is the TN-32 TSAR of record for the North Anna ISFSI, the dimensions must be reconciled in order to facilitate future loading of TN-32 casks with North Anna fuel of higher burnup and enrichment. Therefore, the nominal dimension may be either 11.88 inches or 12.00 inches without any impact to cask criticality evaluations.

The lid bolt analysis presented in Appendix 3A.3 of the TN-32 TSAR has been updated to allow for torque in the range of 880 ft-lb to 1230 ft-lb, to incorporate High Purity Loctite N-5000 Antiseize lubricant, and to allow the use of silver-jacketed O-rings. In addition, the summary of bolt stresses presented in Table 3.4-7 of the TN-32 TSAR has been corrected. The updated analysis, figures, and tables are included as Attachment 1 to this appendix. The revised analysis concludes that the code allowable stresses on the bolts are not exceeded for both normal and accident conditions. Pages 3A.3-1 through 3A.3-13, Figures 3A.3-1, 3A.3-2, 3A.3-4, 3A.3-5 and 3A.3-6, and Table 3.4.7 in the TN-32 TSAR Revision 9A are replaced by the attached pages 3A.3-1 through 3A.3-15, Figures 3A.3-1, 3A.3-2, 3A.3-4, 3A.3-5 and 3A.3-6, and Table 3.4.7.

In addition to the sections above, Section 7.1.4 of the TN-32 TSAR, Revision 9A, states that the bolt torque for the main lid bolts is 930 ± 50 ft-lb and for the penetration port covers the torque is 60 ± 10 ft-lb. In accordance with the lid bolt analysis update, the required torque for the main lid bolts is 880 ft-lb to 1230 ft-lb. The required torque for the penetration cover bolts ranges from 60 ft-lb to 100 ft-lb depending on the bolt material supplied by the vendor.

The protective covers at the North Anna ISFSI have been modified from the cover described in TN-32 TSAR Revision 9A to the cover described in the drawings in Attachment 3. The modified protective cover includes a sealable bolt-on access plate that is both airtight and watertight. The access plate has a through-wall fitting that connects to the OP system on the inside of the protective cover and connects to tubing on the outside of the protective cover. This tubing runs down the side of the cask to an instrumentation box in which the pressure switches/transducers are located. In addition, another connection is located at the access plate which openly communicates to the atmosphere within the protective cover. The external connection to this fitting will connect to tubing that also is mounted along the side of the cask.

Drawing SK-VP-SAR-1 in Attachment 3 shows the cask with the modified protective cover and pressure switches. Figures VP1.2-1 and VP2.3-1 contained in Attachment 3 illustrate the confinement boundary components and pressure monitoring system. The confinement boundary components shown in Figures 1.2-1 and VP1.2-1 are:

1. Inner shell and bottom closure
2. Flanged and bolted lid
3. Flange
4. Vent cover
5. Drain cover

The containment boundary components are not changed with the alternate design.

The plastic structural analysis presented in Section 3C.3-1 of the TN-32 TSAR utilizes a value of 0.48" for the gap between center basket rails. The actual gap can range from 0.0" to 1.1326" while maintaining the required opening between opposite rails. Therefore, additional analyses have been performed to demonstrate that the structural integrity of the basket and rails is maintained for the full range of possible gap sizes. The additional analyses are included as Attachment 4 to this appendix.

Table 8.1-1 of the TN-32 TSAR Revision 9A describes the sequence of operations associated with the TN-32 cask. For installation of the modified protective cover, Step 13 will be performed prior to Step 11 in order to check the function of the overpressure system transducers or pressure switches. Step 11 will also be modified not to include specific instructions for checking the function of the transducers or switches before the protective cover is installed.

TN-32 casks used at the North Anna ISFSI are fabricated to the requirements of the TN-32 Topical Safety Analysis Report (TSAR), Revision 9A, or the TN-32 Final Safety Analysis Report (FSAR), Revision 0. TN-32 casks fabricated to the requirements of the TN-32 FSAR, Revision 0, have been evaluated with respect to the design bases for the TN-32 TSAR, Revision 9A, and have been found to be acceptable. Analyses included in the TN-32 FSAR, Revision 0, may not be credited in the use of TN-32 casks unless they have been added to the ISFSI SAR.

The only physical difference between TN-32 TSAR, Rev. 9A, casks and TN-32 FSAR, Rev. 0, casks is the design of the nonsafety related overpressure system. TN-32 TSAR, Rev. 9A, casks use an overpressure system with two pressure switches located under the protective cover and wiring through the protective cover that connects to the facility alarm panel. TN-32 FSAR, Rev. 0, casks use tubing through the protective cover to the pressure switches/transducers in a box on the side of the cask near ground level. An evaluation has shown that either overpressure system configuration is acceptable for use at the North Anna ISFSI.

The fabrication of TN-32 FSAR, Rev. 0, casks differs in the following two ways from the fabrication of TN-32 TSAR, Rev. 9A, casks.

1. The nil ductility transition temperature (NDTT) required for containment material is minus 80°F. The TN-32 TSAR, Rev. 9A, cask containment materials have a specified NDTT of no more than minus 40°F
2. Progressive PT and MT inspections are required of the bottom to gamma shield weld and the lid to lid shield weld. Progressive inspections were not required in the TN-32 TSAR, Rev. 9A.

These two changes provide additional margin in the structural evaluation performed for the TN-32 FSAR, Rev. 0, cask; however, this evaluation is not approved for use at the North Anna ISFSI. The TN-32 FSAR, Rev. 0, cask meets the structural design criteria for casks to be used at the North Anna ISFSI. The design and fabrication changes described above will be in effect for TN-32 casks number TN-32.32 and higher.

The US NRC has approved the generic use of TN-32 casks by 10 CFR Part 50 licensees. The TN-32 FSAR, Rev. 0, provides the licensing basis for this use and includes generic Technical Specifications. The North Anna ISFSI Technical Specifications, and the TSAR, Rev. 9A, however will govern the use of TN-32, Rev. 0, casks at the North Anna ISFSI, except to the extent that specific analyses (e.g., criticality or thermal performance) from the FSAR, Rev. 0, have been added to the ISFSI SAR. The analyses in Chapters 4 and 6 of the TN-32 FSAR, Rev. 0, have been added to this Appendix A.1.

A.1.2 Spent Fuel to Be Stored

Two types of burnable poison rod assemblies (BPRAs) exist at North Anna. One type, manufactured by Westinghouse Electric, contains an annular section of borosilicate glass contained within a stainless steel tube. The inside annular region of the glass also contains a stainless steel tube. The glass and tube region is plugged and seal-welded at both ends, and remains dry during operation, and forms one burnable poison (BP) rod. One end of the BP rod is attached to a flat baseplate, which is used to join other BP rods to form a single BPRA. One BPRA can have as many as twenty BP rods.

Framatome Cogema Fuels (FCF) manufactures the other type of BPRA used at North Anna. An FCF BP rod uses AL_2O_3 - B_4C (boron carbide in an alumina matrix) pellets encapsulated within a Zircaloy cladding. The cladding is plugged and seal-welded at both ends and remains dry during operation. A small gas plenum region is provided at the top of the pellet stack to accommodate helium off-gas. One end of the BP rod is attached to a flat baseplate, which is used to join other BP rods to form a single BPRA. One FCF BPRA can have as many as twenty-four individual rods; one for each of the thimble tubes in a Westinghouse 17 x 17 fuel assembly.

The Westinghouse and FCF BPRA baseplates are similar in design and manufactured from stainless steel.

The thimble plug devices (TPDs) used at North Anna were manufactured by Westinghouse. The purpose of the device was to restrict (plug) reactor coolant flow in the thimble tubes in fuel assemblies that contained no insert components (i.e., control rods, BPRAs, source assemblies, etc.). TPDs are no longer used in either Unit 1 or Unit 2 at North Anna. A TPD uses the same baseplate as a Westinghouse BPRA to attach twenty-four rodlets, each approximately 8 inches long. Each TPD rodlet is manufactured of solid stainless steel.

The structural evaluations of the TN-32 cask are provided in Chapters 3 and 11 of the Rev. 9A TN-32 Topical Report. These evaluations used a fuel weight of 1533 lb, which bounds all possible combinations of North Anna Units 1 and 2 fuel assemblies containing a BPRA or TPD.

An evaluation has also been performed on the effect to the cask surface dose rates as a result of placing BPRAs and/or TPDs in the fuel stored in the TN-32. If BPRAs or TPDs have at least one-year decay time after discharge from the reactor, the cask surface dose rates for the TN-32 remain less than the design basis dose rates used to calculate doses at the ISFSI perimeter fence and to the nearest resident.

An evaluation has been performed on the effect on criticality control from the storage of BPRAs and/or TPDs in the fuel stored in the TN-32. The criticality control analysis assumes that water borated to 2500 ppm is present in the cask cavity. This analysis was performed assuming that the borated water in the fuel assembly guide tubes was replaced with aluminum rods, which have lower neutron cross sections than a fully depleted BPRA. The results show a slight increase in reactivity which is well within the subcritical limit. TPDs are short and do not displace water in the guide tubes, therefore, their use will not affect reactivity.

The TN-32 is designed for a maximum internal pressure under normal and accident conditions, and helium buildup of pre-pressurization in BPRAs will affect this analysis. The confinement analysis for the TN-32 has been reanalyzed conservatively for thirty-two BPRAs, and this reanalysis shows that the maximum pressure under accident conditions would be 69.4 psig, when the design basis for this cask is 100 psig. This analysis bounds the storage of any type of Westinghouse or FCF 17 x 17 BPRA. The impact of TPDs on the confinement analysis is bounded by the impact of BPRAs.

To account for the additional decay heat from BPRAs and/or TPDs, fuel assembly decay heat estimates must include an estimate for the decay heat from the actual component in each fuel assembly. Therefore, the combined decay heat from the fuel assembly and its component must be less than the limit for a fuel assembly in the TN-32.

Based on these evaluations, the storage of fuel assemblies with BPRAs and/or TPDs is acceptable for the TN-32.

Rod clips have been attached to some fuel assemblies at North Anna. Rod clips resemble a fuel assembly grid strap, but are shorter in length and do not span the full row of rods as grid straps do. Rod clips are physically attached to the fuel rods mid-span between grids for the purpose of reducing rod vibration and ultimately eliminating baffle-jetting fuel rod failures, which occurred in North Anna Unit 1 prior to vessel upflow conversion. Rod clips may exist on one or two faces of a fuel assembly.

An evaluation has been performed on the effect on the TN-32 shielding analysis of rod clips on fuel assemblies stored in TN-32 casks. The analysis determined that the total actual Inconel-718 in the fuel zone region for an assembly with rod clips is less than the design basis value of 5.9 kilograms, which is the bounding analysis value from the TN-32 Topical and Final Safety Analysis Reports. Therefore, it is acceptable to load a fuel assembly with rod clips in a TN-32 cask.

A.1.3 Criticality Evaluation

The criticality evaluation from Chapter 6 of the TN-32 FSAR Revision 0 (Reference 2) includes an evaluation of the storage of the Westinghouse 17 x 17 Standard Fuel design. This evaluation is summarized below.

Criticality control in the TN-32 is provided by the basket structural components, which maintain the relative position of the spent fuel assemblies under normal and accident conditions, by the neutron absorbing plates between the basket compartments, and by dissolved boron in the spent fuel pool water.

Transnuclear evaluated five Westinghouse fuel designs to determine the most reactive fuel configuration. The five were the Westinghouse 14 x 14 Standard, 14 x 14 OFA, 15 x 15 Standard, 17 x 17 Standard, and 17 x 17 OFA designs. Of these five designs, the Westinghouse 17 x 17 Standard design with BPRA was determined to be the most reactive, and this fuel design was used for the criticality evaluation.

The contents of a TN-32 cask at the North Anna ISFSI are limited to the Westinghouse 17 x 17 Standard Fuel and North Anna Improved Fuel (NAIF) designs. The NAIF design envelope has dimensions identical to the Standard Fuel design, but several structural elements are made of different materials. These material differences do not affect the criticality analyses, however, and so the criticality evaluations for these fuel types are equivalent.

The fuel assemblies were evaluated with and without burnable poison rod assemblies (BPRA). BPRA were modeled using aluminum rods containing no boron. This displaces the borated water and bounds the effect of depleted BPRA. The criticality evaluations did not rely on any special loading patterns or orientation of the fuel assemblies for criticality control. However, a boron concentration of 2300 ppm in the water used in the cask was assumed in the TN-32 FSAR Rev. 0 analysis.

The evaluations assumed that each fuel assembly design contained a certain amount of uranium. In the case of the Westinghouse 17 x 17 Standard Fuel design, this content was 467.1 kgU per fuel assembly.

The criticality evaluations were performed by Transnuclear using the CSAS25 sequence from the SCALE-4.4 code system and the SCALE 27-group ENDF/B-IV cross section library. Within this sequence, resonance correction based on the fuel pin cell description is provided by NITAWL using the Nordheim Integral method, and k_{eff} was determined by the KENO—Va code. A sufficiently large number of neutron histories were run so that the standard deviation was below 0.0020 for all calculations.

The TN-32 was evaluated for a variety of configurations intended to bound all normal, off-normal, and accident conditions. The following conditions were evaluated individually.

1. Baseline: Most reactive TN-32 fuel configuration, 100% borated water density. The fuel assemblies are shifted toward the cask vertical axis until the outer pin cells contact the basket compartment wall. This condition bounds all possibilities of fuel assemblies positioned off-center in the compartment.

2. The neutron absorber plates and the active fuel zone are offset by two inches axially. This condition might occur due to fuel design differences in the distance from the bottom of the fuel assembly to the beginning of the active fuel, or due to fuel pins slipping in the spacer grids during handling.

3. The inside dimension of the compartment is increased and decreased by 0.06 inches. All compartments move correspondingly further apart or closer together. This condition bounds the dimensional tolerance on the basket tubes.

4. The width of the neutron poison plate is reduced by 0.06 inches, corresponding to its dimensional tolerance. It is not necessary to evaluate the tolerance in length because it is bounded by the two-inch axial offset condition above.

5. Fresh water is placed in the gap of all fuel rods. Although a fuel rod that develops a cladding breach during reactor operations could be saturated with unborated water at the end of its operating cycle, it is unlikely that the water in the fuel rod would remain unborated after years of storage in borated water.

6. The borated water density is varied, except in the homogenized basket rail/borated water zone, to simulate the reduction in density that might occur during unloading operations.

7. Borated water is drained down to the top of the active fuel, except in the basket rail zone. This is the most reactive configuration expected during loading and unloading operations, because it reduces the boron capture of reflected neutrons.

As expected, reduction of the neutron absorber plate width, reduction of compartment size, borated water drain-down, and inclusion of fresh water in the fuel rod gap all cause a slight increase in $k_{eff.}$ The optimal borated water density was found at about 95%.

These conditions were combined for a worst case normal condition and the borated water density was varied from 85% to 100%. This resulted in a maximum $k_{eff} = 0.9264 \pm 0.0009$ at 90% borated water density.

To evaluate accident conditions, the worst case normal model was re-run with a single fuel assembly of 5 weight percent U-235 enrichment. This fuel assembly was placed in one of the four center basket locations. This case demonstrated compliance with the requirement of 10 CFR 72.124 by combining at least two unlikely, independent, and concurrent changes in the conditions essential to nuclear criticality safety; worst case geometry and accidental loading of a fuel assembly with enrichment greater than assumed in the analysis. This resulted in a $k_{eff} = 0.9315 \pm 0.0009$.

Transnuclear performed additional analyses to determine what initial enrichment could be stored if the water in the spent fuel pool had a boron concentration of 2500 ppm. These analyses assumed that the most reactive fuel design and worst-normal configuration remained the same even with the boron increase.

The same criticality model as before was used, however the CSAS25 sequence from SCALE-4.4 was used to determine the k_{eff} using KENO—Va and the 44-group ENDF/V cross section library. The worst normal case from before with the enrichment changed to 4.30 weight percent U-235 and the soluble boron concentration changed to 2500 ppm was analyzed. As before, the water density was varied to simulate the reduction in density that might occur during unloading operations. Similarly, the accident condition (assembly misload), was simulated as before but with a loading of 4.30 weight percent assemblies and a misloaded 5 weight percent U-235 assembly in an interior cell. A new upper subcritical limit (USL) was determined using SCALE-4.4 for comparison to the calculated k_{eff}s for the analyzed conditions. These analyses verified that under normal, off-normal, and accident conditions, that the maximum value of $k_{eff} + 2\sigma$ is less than the USL of 0.9419. The worst case which combines the two independent conditions of a misloaded single fuel assembly with the "worst-normal" configuration at reduced (optimum, 92.5% density) water moderation has a $k_{eff} + 2\sigma = 0.9404$.

The TN-32 cask is designed to be substantially subcritical under all credible conditions. The criticality design is based on favorable geometry, fixed neutron poisons, and soluble poisons in the spent fuel pool, with unirradiated fuel having an initial enrichment, up to and including, 4.30 weight percent U-235. An appraisal of the fixed neutron poisons has shown that they will remain effective for the 20-year storage period, and there is no credible way to lose them. The analysis and evaluation of the criticality design and performance have demonstrated that the cask will provide for the safe storage of spent fuel for a minimum of 20 years with an adequate subcritical margin.

The criticality design features for the TN-32 are in compliance with 10 CFR 72 and the applicable design and acceptance criteria have been satisfied. The evaluation of the criticality design provides reasonable assurance that the TN-32 will allow the safe storage of spent fuel.

A.1.3.1 Neutron Absorber Tests

As allowed by NUREG/CR-5661 (Reference 3), the criticality evaluation performed in the TN-32 FSAR Revision 0 takes credit for 90% of the boron-10 in the borated aluminum absorber plates rather than the maximum value of 75% used in prior evaluations. Testing to verify the presence and uniformity of the neutron absorber are discussed below.

Effective boron-10 content of the borated aluminum fuel basket neutron absorber sheets is verified by neutron transmission testing of coupons taken from each sheet. The transmission through the coupons is compared with transmission through calibrated standards composed of a homogeneous boron compound without other significant neutron absorbers, for example zirconium diboride or titanium diboride. These standards are paired with aluminum shims sized to match the scattering by aluminum in the neutron absorber sheets. The effective boron-10 content of each coupon, minus 3σ based on the neutron counting statistics for that coupon, must be $\geq$ 10 mg boron-10/cm^2.

In the event that a coupon fails the single neutron transmission measurement, four additional measurements may be made on the coupon, and the average of the 5 measurements, less 3σ based on the counting statistics, must be $\geq$ 10 mg boron-10/cm^2.

Macroscopic uniformity of boron-10 distribution is verified by neutron radioscopy or radiography of the coupons. The acceptance criterion is that there be uniform luminance across the coupon. This inspection shall cover the entire coupon.

Normal sampling of coupons for neutron transmission measurements and radiography/radioscopy shall be 100%. Rejection of a given coupon shall result in rejection of the associated sheet. Reduced sampling (50% - every other coupon) may be introduced based upon acceptance of all coupons in the first 25% of the lot. A rejection during reduced inspection will require a return to 100% inspection of the lot. A lot is defined as all the sheets rolled from a single casting.

A.1.4 Thermal Evaluation

Chapter 4 of the TN-32 Final Safety Analysis Report, Revision 0 (Reference 2) includes a thermal evaluation for normal conditions that was based on the following inputs.

1. A maximum heat load of 32.7 kilowatts from 32 fuel assemblies with BPRAs or TPDs, or 1.02 kilowatt/fuel assembly.
2. An ambient temperature range of -30 to 115°F. The temperature range was averaged over 24 hours and a maximum daily averaged ambient temperature of 100°F was used for the maximum cask temperature evaluation.

3. A total solar heat load for a 12-hour period of 1475 Btu/ft^2 for curved surfaces and 2950 Btu/ft^2 for flat surfaces, per 10 CFR 71.71(c). Since the cask has a large thermal inertia, the total insolation was averaged over a 24-hour period.

The thermal analysis for normal storage concluded that the TN-32 design meets all applicable requirements. The maximum temperature of any confinement structure component was less than 315°F, which has an insignificant effect on the mechanical properties of the confinement materials used. The predicted maximum fuel cladding temperature was 565°F, which is well below the allowable fuel cladding temperature limit of 752°F (400°C) for loading, unloading, and normal operating conditions.

All fuel transfer operations occur when the cask is in the spent fuel pool with the cask lid removed. The fuel is always submerged in free-flowing water, permitting heat dissipation. After fuel loading is complete, the cask is removed from the pool, drained and the cavity is dried.

The loading condition evaluated for the TN-32 is the heatup of the cask before its cavity can be backfilled with helium. This occurs during the vacuum drying operation of the cask cavity. Transient thermal analyses were performed to predict the heatup time history for the cask components assuming air is in the cask cavity.

The results of the transient thermal analysis for the maximum heat load of 32.7 kw showed that in order to prevent cask component peak temperatures from exceeding their analyzed temperature range, in particular the basket, the time before backfilling the cask with helium must be limited to less than 36 hours. Backfilling the cask with helium within 36 hours of the completion of draining also provides assurance that the fuel pin cladding temperature does not exceed 400°C.

Unloading of a cask would require the flooding of the cask prior to the removal of the fuel. A quench analysis of the fuel concluded that the total stress on the fuel cladding was below the cladding material's minimum yield stress. In addition, by limiting the water flow rate into the cask and monitoring the pressure of the air/steam outflow mixture, the buildup of steam pressure in the cavity was limited to less than the cask design pressure.

The temperatures determined by the evaluation of the cask systems, structures and components important to safety will remain within their operating temperature ranges, and cask internal pressures under normal conditions were acceptable. The TN-32 cask provides adequate heat removal capacity without active cooling systems. The TN-32 cask is designed with a heat removal capability having testability and reliability consistent with its importance to safety. Spent fuel cladding will be protected against degradation that leads to significant fuel failures by maintaining the clad temperature below maximum allowable limits and by providing an inert environment in the cask cavity.

A supplemental thermal evaluation was performed and documented in Reference 4. The evaluation used lower than design basis heat loading (22 kw vs 32.7 kw) and an increased average ambient temperature (115 degrees vs 100 degrees). The results of the evaluation indicate that no cask components or fuel cladding temperature limits exceed the design basis case, therefore the original design basis remains bounding.

The thermal design of the TN-32 cask is in compliance with 10 CFR 72 and applicable design and acceptance criteria have been satisfied. The evaluation of the thermal design provides reasonable assurance that the TN-32 will allow the safe storage of spent fuel for 20 years.

A.1.5 Cask Sliding and Tip-over Analysis

Analysis demonstrates that the casks will not slide or tip-over as a result of the ISFSI design earthquake (Section 4.2.1.4). The analysis utilized a dynamic, soil-structure interaction analysis to determine the effect of the design earthquake on the casks and concrete storage pad. A "generic" cask, 16 feet high x 8 feet diameter, was used for the analysis. Since cask sliding was the major concern of the analysis effort, the generic cask approach is considered acceptably bounding and produces more conservative factors of safety for sliding. A comparison with the generic cask modeled and the TN-32 is shown below:

PROPERTY	GENERIC CASK	TN-32	TN-32—STABILITY ANALYSIS TSAR SECTION 2.2.3.2
Weight	230 kips	230.99 kips	228 kips
Vertical Distance to Center of Gravity, I_v	96 inches	92.09 inches	92 inches
Base Radial Distance to Center of Gravity, I_r	48 inches	43.875 inches	43.875 inches

A finite element model was used to perform the dynamic analysis. The casks were modeled as a rigid beam from the top of the concrete pad to the center of gravity of the generic casks and the transitional and rotary weights of the casks were lumped at the top of the 96-inch rigid beams. This is more conservative than using the 92-inch vertical distance of the TN-32 cask and will result in slightly higher accelerations for the casks and a higher moment arm for those accelerations.

The difference in weight between the generic cask and the TN-32 cask is negligible.

The factor of safety against sliding is determined as:

$FS = R/H$

where:

R = Resistance to sliding = $\mu \times W \times (1 - A_z)$

μ = Coefficient of friction = 0.3

W = Weight of cask on pad

A_z = Vertical acceleration of cask at cask center of gravity

H = Horizontal sliding force = $(S_x^2 + S_y^2)^{0.5}$

S_x, S_y = Horizontal cask forces at the cask center of gravity in x,y directions
= $W \times A_i$, i = x,y; A_i = horizontal accelerations

Thus,

$$FS = 0.3(1 - A_z)/(A_x^2 + A_y^2)^{0.5}$$

Higher accelerations will result in a lower factor of safety against sliding, therefore using the higher center of gravity of the generic casks is conservative and envelops the TN-32 cask. It should also be noted that the weight of the cask is not involved in the final calculation for the factor of safety against sliding.

Using the methodology of TSAR Section 2.2.3.2, the g value necessary to tip the cask is calculated below:

$$Mtip = gWI_v + (2/3)gWI_r \quad \text{and} \quad M_{stab} = WI_r$$

Where:

M_{tip} = Moment necessary to tip the cask

M_{stab} = Stabilizing moment on the cask

g = Acceleration value necessary to tip the cask

W = Weight of cask on pad

I_v = Vertical distance to cask center of gravity

I_r = Radial distance to cask center of gravity

Therefore, the g value necessary to tip the cask is found by equating M_{tip} to M_{stab}:

$$(gWI_v) + (2/3)gWI_r = WI_r$$

$$g = (I_r)/(I_v + 0.67 \times I_r)$$

Solving for the TN-32 cask, g = 0.36.

Solving for the generic cask, g = 0.37 which is virtually the same as for the TN-32 cask.

Using the higher center of gravity of the generic casks will result in higher cask accelerations and higher overturning moments which will result in a lower factor of safety against overturning and is therefore conservative.

It is concluded that the generic cask used in the analysis is more conservative than using the TN-32 cask for the critical sliding analysis and is essentially equivalent to the TN-32 cask for overturning which shows significant margin to the minimum 1.1 safety factor. The lowest factor of safety for overturning is about 1.6.

A.1.6 Evaluation of Tornado Missiles

An evaluation of the TN-32 cask using the North Anna ISFSI design basis tornado missiles was performed. The results are compared below with results provided for the design basis tornado missiles evaluated in TN-32 TSAR Sections 2.2.1.2 and 2.2.1.3. The effects from the design basis tornado missiles evaluated in the TN-32 TSAR bound the effects from the North Anna ISFSI design basis tornado missiles.

PARAMETER	TN-32 TSAR TORNADO MISSILES	NAPS ISFSI TORNADO MISSILES
Cask Sliding	7.6 inches	2.7 inches
Cask Tipping	8.9 degrees	2.8 degrees
Cask Penetration	2.03 inches	1.65 inches

The evaluation for cask sliding was performed after determining that the worst case was the 1-ton automobile traveling at 150 mph impacting the cask below the center of gravity. The evaluation for tipping also used the automobile, but with impact near the top of the cask. Five missiles were evaluated for penetration of the cask body, and the worst cask penetration was 1.65 inches for the 6-inch diameter steel pipe. Other scenarios mentioned in the SAR are bounded by these three conditions.

A.1.7 Revised Type B and C Tornado Missile Analyses

The structural analyses for missile types B and C, contained in Sections 2.2.1.3.2 and 2.2.1.3.3 of Revision 9A of the TN-32 TSAR, include the protective cover. Transnuclear has performed revised analyses which no longer credit the protective cover for missile protection. The revised analyses conclude that the code allowable stresses on the lid are not exceeded during a missile impact event. Section 2.2.1.3.2 and 2.2.1.3.3 of Revision 9A of the TN-32 TSAR are supplanted by the following sections providing a description of the revised analyses. The revised TSAR pages are included as Attachment 2 to this appendix.

A.1.8 SSSC Average Surface Dose Rate

The North Anna ISFSI design basis dose rates in Chapter 7 were determined based upon the use of TN-32 SSSCs utilizing design basis fuel loadings with no additional conservatisms applied other than those described in the calculational methodology.

A.1.8.1 SSSC Average Surface Dose Rate Measurement

In order to determine the average surface dose rates of TN-32 casks to compare with Technical Specifications limits the following method is applied.

Average Side Surface Dose Rate

The side surface dose rates shall be measured at approximately the following locations (see Figure A.1-1). Obtain separate measurements for gamma and neutron dose rates.

1. Above the Radial Neutron Shield (Map location A)

   Obtain four measurements, equally spaced circumferentially, midway between the top of the cask body flange and the top of the radial neutron shield. Do not obtain measurements over or in the immediate vicinity of the cask trunnions.

   Add the measurements together and divide by the number of measurements obtained in this area. The result is the dose rate above the neutron shield.

2. Sides of Radial Neutron Shield (Map locations B, C, and D)

   Obtain four measurements, equally spaced circumferentially, at each of the following approximate elevations: one sixth, one half and five sixths along the axial span of the radial neutron shield. Do not obtain measurements over or in the immediate vicinity of the cask trunnions.

   Add the measurements together and divide by the number of measurements obtained over the neutron shield. The result is the dose rate over the radial neutron shield.

3. Below Radial Neutron Shield (Map location E)

   Obtain four measurements, equally spaced circumferentially, midway between the bottom of the radial neutron shield and the bottom of the cask. Do not obtain measurements over or in the immediate vicinity of the cask trunnions. Also, it may not be possible for a neutron dose rate meter to access the surface at location E. If so, the neutron dose rate meter may be located as much as one foot away from the cask surface to obtain measurements.

   Add the measurements together and divide by the number of measurements obtained in this area. The result is the dose rate below the neutron shield.

Average Top Surface Dose Rate

4. Top of Cask (Map locations F, G, and H)

Obtain one measurement at the center of the protective cover (F). Obtain four measurements equally spaced circumferentially half way between the center and the knuckle (G). Obtain four measurements equally spaced circumferentially at the knuckle (H).

Add the measurements together and divide by the number of measurements obtained over the protective cover. The result is the dose rate over the top surface of the cask.

Final Surface Dose Rate

The average surface gamma and neutron dose rates shall be determined by the following formulae. Note that A, B, C, and D refer to the values obtained in steps 1, 2, 3, and 4 above, respectively. The 0.1 and 0.8 multipliers are area weighting factors.

Average Side Surface Gamma Dose Rate = $(0.1 \times A_\gamma) + (0.8 \times B_\gamma) + (0.1 \times C_\gamma)$

Average Side Surface Neutron Dose Rate = $(0.1 \times A_n) + (0.8 \times B_n) + (0.1 \times C_n)$

Average Top Surface Gamma Dose Rate = D_γ

Average Top Surface Neutron Dose Rate = D_n

A.1.9 Codes and Standards

The TN-32 cask is designed and fabricated in accordance with Section III of the 1992 edition of the ASME Code. Exceptions to the Code are listed in Table A.1-1.

Changes to Table A.1-1 or ASME Code exceptions not included in the Table shall be reviewed in accordance with 10 CFR 72.48. This review should demonstrate that:

1. The changes or exceptions would provide an acceptable level of quality and safety, or
2. Compliance with the specified requirements of Section III of the 1992 edition of the ASME Code would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

A.1.10 References

1. *TN-32 Dry Storage Cask Topical Safety Analysis Report,* Revision 9A, Transnuclear, Inc., December 1996.
2. *TN-32 Dry Storage Cask Final Safety Analysis Report*, Revision 0, Transnuclear, Inc., January 2000.
3. NUREG/CR-5661, *Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages*, 1997.
4. ETE-NAF-2014-0077, *Thermal Analysis During Recoating the Exterior of TN-32 Casks at the ISFSI*, Revision 0.

Table A.1-1
TN-32 ASME CODE EXCEPTIONS

List of ASME Code Exceptions for TN-32 Dry Storage Cask Confinement Boundary/Gamma Shielding/Basket

The cask confinement boundary is designed in accordance with the 1992 edition of the ASME Code, Section III, Subsection NB. The basket was designed in accordance with the 1992 edition of the ASME Code, Section III, Subsection NF. The gamma shielding, which is primarily for shielding, but also provides structural support to the confinement boundary during drop accidents, was analyzed in accordance with Subsection NB. Inspections of the gamma shielding are performed in accordance with the 1992 edition of the ASME Code as detailed in the TN-32 Topical Safety Analysis Report, Rev. 9A, December 1996 (the TSAR).

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
TN-32 Cask	NB-1100	Stamping and preparation of reports by the Certificate Holder	The TN-32 cask is not N stamped, nor is there a code design specification generated. A design criteria document was generated in accordance with TN's QA Program and the design and analysis is provided in the TSAR.
TN-32 Cask	NCA-3800	Quality Assurance Requirements	The Quality assurance requirements of NQA-1 or 10 CFR 72 Subpart G are imposed in lieu of NCA-3800 requirements.
Lid Bolts	NB-3232.3	Fatigue analysis of bolts	A fatigue analysis of the bolts is not performed for storage, since the bolts are not subject to significant cyclical loads.
Gamma Shielding	NB-1132.2	Non-pressure retaining structural attachments shall conform to Subsection NF	The primary function of the gamma shield is shielding, although credit is taken for the gamma shielding in the structural analysis. A surface examination of the welds is performed in accordance with the requirements of Subsection NF.

Table A.1-1 (CONTINUED)
TN-32 ASME CODE EXCEPTIONS

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
Pressure test of the confinement boundary	NB-6110	All pressure retaining components shall be pressure tested.	The TN-32 cask is not pressure limited. All confinement welds are fully radiographed. In addition, the gamma shielding supports the confinement boundary under all conditions, so a pressure test of the confinement vessel separately will not simulate actual loading conditions. If the pressure test is performed with the confinement vessel inside the gamma shield, the confinement boundary welds cannot be examined.

Table A.1-1 (CONTINUED)
TN-32 ASME CODE EXCEPTIONS

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
Confinement Vessel Material	NB-2120	Required materials to be ASME Class 1 materials	Standard Review Plan, NUREG-1536 has accepted the use of either Subsection NB (Class 1) or NC (Class 2 or 3) of the Code for the confinement. SA-203 Gr. D is similar to SA-203 Gr. E, which is a Class 1 material. The chemical content of the two grades are identical, except that Gr. E restricts the carbon to 0.20 max., while Gr. D further restricts the carbon content to 0.17 max. Gr. D is acceptable as a Class 2 material up to 500°F. SA-350, Gr. LF3 is the same material as the SA-203, Gr. D, except in a forged condition. SA-350, Gr. LF3 is a Class 1 material in the 1995 edition of the ASME Code, and a Class 2 material in the 1992 Code. Gr. D was selected because of its ductility, since the higher strength is not required. SA-203 Gr. D has better elongation than Gr. E and due to its lower strength is more likely to have the good fracture toughness at low temperatures. In selecting materials for storage and transport casks, one of the major selection criteria is fracture toughness at low temperatures. SA-203, Gr. D and SA-350, Gr. LF3 were selected on this basis. There is no similar requirement for pressure vessels, as they are used at much higher temperatures. For the SA-203 Gr. D and SA-350, Gr. LF3 materials, the allowable stress was based on S, the allowable stress for Class 2 components. This is conservative, since NB is based on S_m, which is 1/3 the tensile strength, while S is 1/4 the tensile strength. Thus there is additional margin over and above the margin required by the code for Class I materials.

Table A.1-1 (CONTINUED)
TN-32 ASME CODE EXCEPTIONS

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
Weld of lid Shield Plate to Lid	NB-4335	Impact testing of weld and heat affected zone of lid to shield plate	If two different materials are joined, the fracture toughness requirements of either may be used for the weld metal. There are no fracture toughness requirements on the shield plate, and therefore none are performed on the base metal or the heat affected zones. This weld is not subject to low temperatures, as it is inside the cask cavity. An evaluation of this weld at low temperatures is presented in Appendix 3E of the TN-32 FSAR.
Gamma Shielding	NB-2190	Material in the component support load path and not performing a pressure retaining function welded to pressure retaining material shall meet the requirements of NF-2000	The gamma shielding materials were procured to ASTM or ASME material specifications. Materials testing is performed in accordance with the applicable specification. Impact testing is not performed on the gamma shielding materials (including welding materials). An evaluation of the gamma shielding due to impact at low temperatures is presented in Appendix 3E of the TN-32 FSAR.
Confinement Vessel	NB-7000	Vessels are required to have overpressure protection	No overpressure protection is provided. Function of confinement vessel is to contain radioactive contents under normal, off normal, and accident conditions of storage. Confinement vessel is designed to withstand maximum internal pressure considering 100% fuel rod failure and maximum accident temperatures.
Confinement Vessel	NB-8000	State requirements for nameplates, stamping and reports per NCA-8000	TN-32 cask to be marked and identified in accordance with 10 CFR 72 requirements. Code stamping is not required. QA data package to be in accordance with Transnuclear approved QA program.

Table A.1-1 (CONTINUED)
TN-32 ASME CODE EXCEPTIONS

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
Confinement Vessel material	NB-2000	Requires materials to be supplied by ASME approved material supplier; Quality assurance to meet NCA requirements	Material will be supplied by Transnuclear approved suppliers with Certified Material Test reports (CMTR) in accordance with NB-2000 requirements. The cask is not code stamped. The quality assurance requirements of NQA-1 or 10 CFR 72 Subpart G may be imposed in lieu of the requirements of NCA-3800.
Corner Weld between bottom inner plate to inner shell	NB-5231	Full penetration corner welded joins require the fusion zone and the parent metal beneath the attachment surface to be UT inspected after welding	In lieu of the UT inspection, the joint will be examined by RT and either PT or MT methods in accordance with ASME Subsection NB requirements.
Boundary of Jurisdiction	NB-1131	The design specification shall define the boundary of a component to which another component is attached.	A code design specification was not prepared for the TN-32 cask. A TN design criteria was prepared in accordance with TN's QA program. The containment boundary is specified in Chapter 1 of the TSAR.

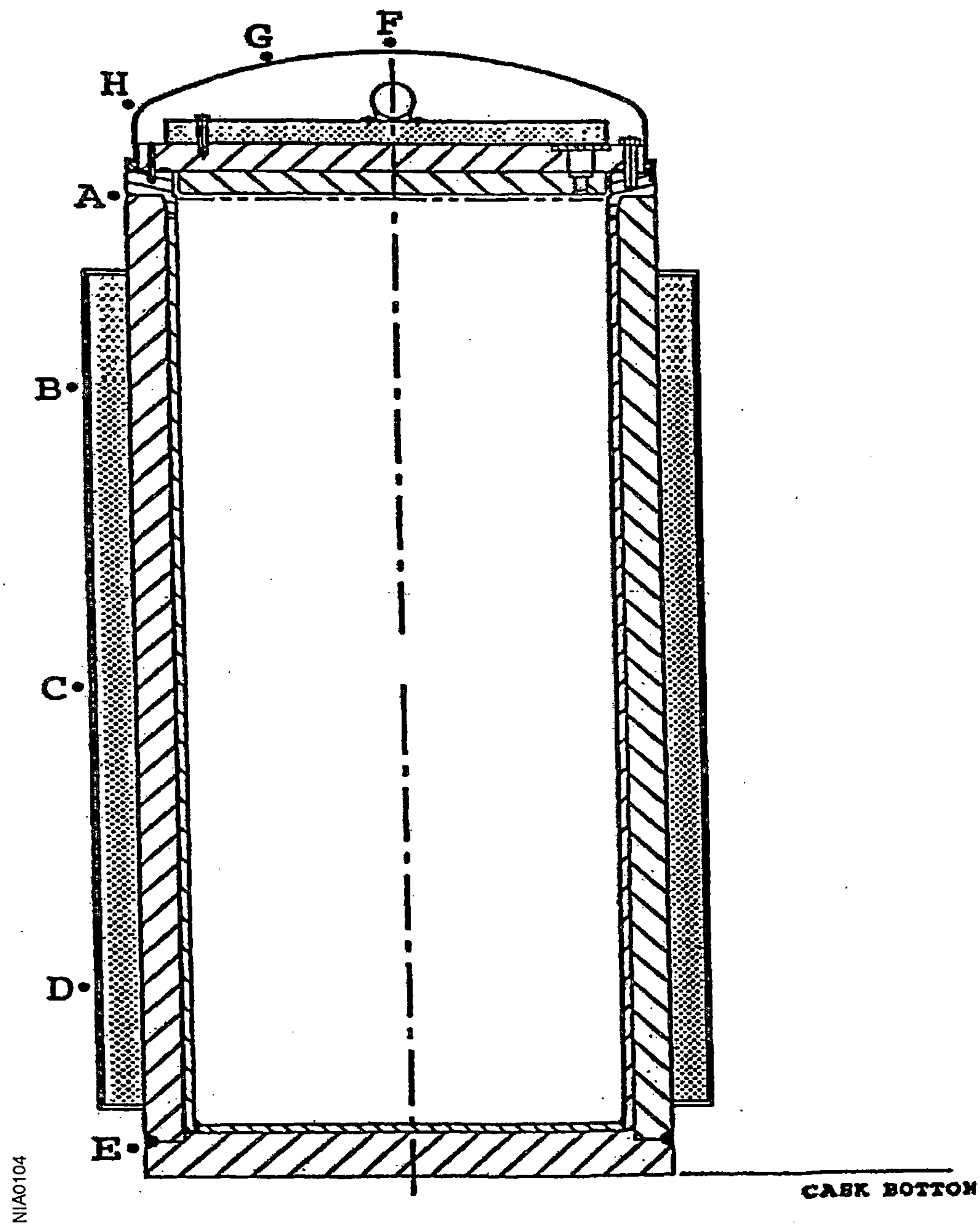
Table A.1-1 (CONTINUED)
TN-32 ASME CODE EXCEPTIONS

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
PT/MT inspection of plates	NB-5130	Weld preparations in plates 2 inches and over are required to be surface examined by PT or MT.	The final thickness of the shell is 1.5 inches, and therefore this requirement was not imposed. However, the confinement shells may be made from shells with original thickness greater than 1.5 inches. We interpret the code to mean the final thickness of the pressure vessel. The weld prep on one side of the wall is performed by back gouging after the opposite side is welded. An MT examination of this back gouged surface before welding is performed. A UT examination is performed on the plate material when purchased. This examination is intended to discover indications, both laminar and nonlaminar imperfections. Therefore the UT examination of the plate prior to welding can be expected to reveal any indications or imperfections that exist in the plate.
Surface examination after machining	NB-4121.3	If more than 1/8 inch of material is removed, a surface examination is required of components which have been previously surface examined.	The containment flanges and the lids are procured with both a UT and MT examination. More than 1/8 inch of material may be removed during processing, and no additional surface examinations are performed.
Aluminum basket plate and rail, neutron absorber plates	NF-2120	Materials to be ASME Class 1 materials	The aluminum plate strength is not used for structural analysis under normal operating loads nor the 50g accident end drop load. The aluminum plate strength is only assumed to be effective for the short duration dynamic loading from a tipover accident and for secondary thermal stress calculations. 6061-T6 is ASME code material (Class 2 or 3). The strength of the neutron absorber plates are not considered in any analysis.

Table A.1-1 (CONTINUED)
TN-32 ASME CODE EXCEPTIONS

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
Basket	NF-4000/NF-5000	Welding/NDE Inspections	Basket welding procedures are qualified in accordance with ASME Section IX. Due to the unique nature of these welds, special inspections and tests were developed for these welds.
Components other than the containment boundary and basket	Subsection NB		The code does not apply to components other than the containment boundary and basket. The gamma shielding has been analyzed and inspected in accordance with Subsection NB as defined at the beginning of this table.
Basket	NF-3000	Allowable Stresses	The ASME Code gives stress values up to 400°F. Stress values above 400°F are taken from "Aluminum Standards and Data," 1990. The allowable stresses used for the aluminum basket plate and rail are based on S, the allowable stress for a Class 2 or 3 component. This is conservative, since the analyses of the basket and rail are performed in accordance with the rules of Subsection NF. Subsection NF allowables are based on S_m which is 1/3 the ultimate strength, while S is 1/4 the ultimate strength. Thus there is additional margin built into the analysis of the basket and rail over and above the margin required by Subsection NF for class 1 materials.

Figure A.1-1
TN-32 SURFACE DOSE RATE MEASUREMENT LOCATIONS



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Appendix A.1, Attachment 1

Revision of Lid Bolt Analysis

Supplants the Analyses in TN-32 TSAR, Revision 9A, Section 3A.3 and TN-32 FSAR, Revision 0, Section 3A.3

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3A.3 Lid Bolt Analyses

The lid bolt analysis presented below is performed using the weight of the TN-32A lid (including top neutron shield) since it is slightly heavier than the standard TN-32 lid assembly (with top neutron shield). The use of either aluminum or silver metallic o-ring seals is discussed in the analysis below. Both are acceptable for use in a TN-32 cask lid system. O-ring parameters from either an aluminum or silver o-ring are used interchangeably in the following analyses, depending on which of the parameters from a particular o-ring provides the more limiting result.

3A.3.1 Normal Conditions

3A.3.1.1 Bolt Preload

The lid is secured to the cask body by forty-eight 1.5-in. diameter bolts. The selected bolt preload is such that the metallic confinement seals are properly compressed and the lid is seated against the flange with sufficient force to resist the maximum cavity internal pressure and any dead weight loads acting to unseat the lid. The maximum corresponding tensile reload stress in the bolts at temperature is 51,930 psi (corresponding to a maximum applied torque during cask loading of 1230 ft-lb. with lubrication) which is less than the stress allowable for the bolt material for Normal (Level A) Conditions. The minimum tensile preload stress in the bolts at temperature is 37,150 psi (corresponding to a minimum applied torque of 880 ft-lb. with lubrication) The load per bolt is:

$$\text{Maximum: } F_B = A_B \times 51{,}930$$
$$= 1.492 \times 51{,}930 = 77{,}480 \text{ lb./bolt}$$
$$\text{Minimum: } F_B = A_B \times 37{,}150$$
$$= 1.492 \times 39{,}260 = 55{,}430 \text{ lb./bolt}$$

Since we have 48 bolts, the maximum total seating force of all 48 bolts is 48 F_B = 3,719,000 lb. and the minimum total seating force is 2,661,000 lb.

The force required to seat the metallic O-rings (also referred to as seals), from Reference 1, is a line load of 1399 pounds per inch of seal circumference for aluminum seals, or 2284 pounds per inch of seal circumference for silver seals. The diameter of the outer seal is 72.65 in. and the diameter of the inner seal 71.05 in. The seal seating force is then:

$$F_{seating} = 1399\,\pi(72.65 + 71.05) = 631{,}570 \text{ lb. (aluminum)}$$
$$F_{seating} = 2284\,\pi(72.65 + 71.05) = 1{,}031{,}000 \text{ lb. (silver)}$$

The maximum cask cavity internal pressure is the Design Pressure of 100 psi. The force required to react the pressure load (conservatively assuming the pressure is applied over the outer seal diameter) is:

$$F_{Pressure} = 100\left(\frac{\pi}{4}\right)(72.65)^2 = 414{,}500 \text{ lbs.}$$

The TN-32 cask is always oriented vertical during loading, during transfer to the ISFSI and during storage on the pad. Dead weight of the lid and cask contents does not actually load the lid bolts. In fact the lid weight (and external pressure) helps to seat the lid. However, it is conservative to require that the bolt preload maintain lid seating in any cask orientation. The weights of the lid, fuel and basket are:

Lid Assembly Weight	= 14,480 lb.
Fuel Weight	= 49,060 lb.
Basket Weight	= 16,900 lb.
W_{Total}	80,440 lb.

The total of the seal seating force (conservatively assuming silver seals are used), pressure load and dead weight loads is:

$F_{seating}$	=	1,031,000 lb.
$F_{pressure}$	=	414,500 lb.
W_{Total}	=	80,440 lb.
	=	1,525,940 lb.

This force is less than the preload stresses achieved for the torque value range of 880 to 1230 ft-lbs. and shows that ample lid seating force is provided under Normal Conditions. Furthermore, the range of preload stresses is well below the limiting value of $2S_m$ (63,800 psi) for the bolt material at 300°F.

3A.3.1.2 Differential Thermal Expansion

The 48 lid bolts preload the outer rim of the closure lid against the cask body flange. The 1.5 in. diameter bolts are installed through 1.56 in. diameter clearance holes in the 4.50 in. thick lid periphery. Preloading of the bolts against the lid is accomplished by tightening the bolts so that the shank portions of the bolts within the clearance holes are stretched elastically. The bolt loads will therefore change from the initial installed values if any thermal expansion differences should occur between the lid (through thickness direction) and the bolts.

The bolt material is SA 320 Grade L43 (1 3/4 Ni 3/4 Cr 1/4 Mo). The lid and body flange are both SA 350 Grade LF3 (3 1/2 Ni). The Section III Code Appendices specify the same coefficient of thermal expansion for these materials. The bolts are in intimate contact with the lid and flange and will therefore operate at the same temperature as these components. Therefore there will be no thermal expansion differences between the lid and bolts, and the assembly preload will be maintained under all temperatures.

3A.3.1.3 Bolt Torsion

The torque required to preload the bolt is:

$T = K\ D_N\ F_a$ (Reference 2)

Where

$T_{max} = 0.127\ (1.5)\ (77{,}480) = 14{,}760$ in-lb. = 1,230 ft-lb.

$T_{min} = 0.127\ (1.5)\ (55{,}430) = 10{,}560$ in-lb. = 880 ft-lb.

K = Nut Factor = 0.127 for N-5000 lubricant (as determined experimentally on a TN-32 cask)

A_B = Bolt stress area = 1.492 in.^{2}

D_N = Bolt nominal diameter = 1.5 in.

F_{Bmax} = 51,930 psi preload stress x A_B = 77,480 lb.

F_{Bmin} = 37,150 psi preload stress x A_B = 55,130 lb.

The maximum residual torque in the bolt corresponds to the maximum applied torque and is:

$T_R = 0.5625T = 0.5625 \times 14{,}760 = 8{,}303$ in-lb.

The minimum residual torque in the bolt corresponds to the minimum applied torque and is:

$T_R = 0.5625T = 0.5625 \times 10{,}560 = 5{,}940$ in-lb.

The shear stress in the bolt due to the residual torque from the maximum preload given by Reference 3:

$$\tau_{torsion} = \frac{T_R r}{J}$$

where r and J are based on the bolt effective radius for the above stress area.

r = 0.689 in. effective bolt radius

J = torsional moment of inertia of threaded bolt

$$J = \frac{\pi r^4}{2} = 0.354 \text{ inch}^4$$

$\tau_{torsion}$ = 8,303 (0.689) /0.354 = 16,160 psi (Torsional Shear Maximum)

$\tau_{torsion}$ = 5,940 (0.689)/0.354 = 11,560 psi (Torsional Shear Minimum)

3A.3.1.4 Bolt Bending

It is assumed that bolt bending does not occur during seating of the lid against the cask body during assembly. The bolts are rotated as they are torqued so any slight relative movements between lid and body flange during preloading will not result in a net offset between the bolt head and tapped flange holes. In addition, since the lid, flange and bolt materials have the same coefficient of thermal expansion and will operate at essentially the same temperature, differential expansion between components will not produce bolt bending.

As internal pressure is applied to the cask cavity, the lid will bulge slightly and its edge will rotate. In addition, the body cylinder radius will increase slightly due to the internal pressure resulting in outward radial movement of the tapped bolt holes in the body flange. Since no net membrane stress is developed in the lid, the lid bolt holes (at the mid surface) will remain at the original location. Rotation of the edge of the lid will, however, produce radial movement of the outer surface of the lid at the bolt head location.

The hoop stress in the cask body cylinder is:

$$S_{hoop} = \frac{PRi}{t}$$

Where P = 100 psi Design Pressure

R_i = 34.375 in. inside radius

T = 9.5 in. thickness

$$S_{hoop} = \frac{100 \times 34.375}{9.5} = 361.8 \text{ psi}$$

The radial deflection at the bolt circle is:

$$\delta_{b.c.} = R_{bc} \text{ x } \frac{S_{hoop}}{E}$$

R_{bc} = 38.03 in. bolt circle radius

$$\delta_{b.c.} = \frac{38.03 \times 361.8}{28 \times 10^6} = 0.0004914 \text{ inches outward}$$

When pressure is applied to the lid, the edge rotation can be calculated assuming the lid is simply supported. From Reference 4, Table 24 Case 10:

$$\theta = \frac{3W(1-v)R^3}{2Et^3}$$

Where θ = edge rotation, radians

W = total applied load = 100 psi

v = Poisson's ratio = 0.3

R = 36.35 in. outer seal radius

T = 4.5 in. lid thickness

E = Young's modulus = 28 x 10^6

$$\theta = \frac{3 \times 100 \times (1-0.3)x(36.35)^3}{2 \times 28{\times}10^6 \times (4.5)^3} = 0.00198 \text{ radians}$$

Figure 3A.3-1 shows the net movement of the threaded hole and the Point on the lid under the bolt head.

If it is assumed that the bolt head doesn't slide on the lid surface, the head will be forced from position a to a' as the lid deflects. Point a' under the bolt head moves outward 0.00445 in. while the threaded hole moves only 0.0004914 in. outward. The bolt head will be bent laterally by 0.00445 - 0.0004914 in. or 0.00396 in. from the threaded end.

The bending model of the bolt is shown in Figure 3A.3-2. The moment on the bolt is calculated assuming the bolt is subjected to affect bending with the head and threaded end prevented from rotating. For a cantilevered bolt free to rotate at the head, the bending moment would be reduced by one half. Therefore the assumption of fixed ends is the most conservative and results in the highest stress.

The shear force, P, and bending moment, M, for a beam subjected to offset bending with ends prevented from rotating are:

$$P = \frac{12EI\delta}{L^3}$$

$$M = \frac{6EI\delta}{L^2}$$

Where

P = lateral load to deflect the bolt distance δ, lb.

δ = lateral displacement

= 0.00396 in.

E = Young's modulus, 28 x 10^6 psi @300°F

L = bolt length in bending

= 4.625 in. (including tapped hole chamfer)

I = $\pi r^4/4$

= 0.177in.^{4} (r = 0.689 in. based on stress area of 1.492 in.^{2})

Therefore

$$M_B = \frac{6 \times 28{\times}10^6 \times 0.177 \times 0.00396}{4.625^2}$$

= 5,500 in-lb.

$$P = \frac{12 \times 28{\times}10^6 \times 0.177 \times 0.00396}{4.625^2}$$

$= 2{,}380$ lb.

The bending stress in the bolt is

$$\sigma_b \frac{Mr}{I} = \frac{5,500 \times 0.689}{0.177}$$

$= 21{,}430$ psi

The shear stress due to the lateral force is

$$\tau_p = P/A = 2{,}380/1.492 = 1{,}595 \text{ psi}$$

3A.3.1.5 Combined Stresses

The total shear stress for the maximum preload stress (51,930 psi corresponding to a torque of 1230 ft-lbs.) is then equal to the residual torsional shear stress plus that due to force P.

$$\begin{aligned} \tau_{total} &= \tau_{torsion} + \tau_p \\ &= 16{,}160 + 1{,}595 \\ &= 17{,}755 \text{ psi} \end{aligned}$$

The total shear stress for the minimum preload (torque of 880 ft-lbs.) equals:

$$\tau_{total} = 11{,}560 + 1{,}595 = 13{,}155$$

The average tensile stress is the bolt preload stress:

$$\sigma_{average} = 51{,}930 \text{ psi}$$

The maximum tensile stress at two locations in the bolt is the preload stress plus the bending stress.

$$\sigma_{max} = 51{,}930 \text{ psi} + 21{,}430 = 73{,}360 \text{ psi}$$

Therefore, the average combined stress intensity is:

$$\begin{aligned} SI_{average} &= (\sigma_{average}{}^2 + 4\,(\tau_{total})^2)^{1/2} \\ &= (51{,}930^2 + 4 \text{ x } 17{,}755^2)^{1/2} \\ &= 62{,}910 \text{ psi } (62.9 \text{ ksi}) < 2S_m = 63.8 \text{ ksi} \end{aligned}$$

The maximum combined stress intensity is:

$$\begin{aligned} SI_{max} &= (\sigma_{max}{}^2 + 4\,(\tau_{total})^2)^{1/2} \\ &= (73{,}360^2 + 4 \text{ x } 17{,}755^2)^{1/2} \end{aligned}$$

$= 81{,}500$ psi - 81.5 ksi $< 3S_m = 95.7$ ksi

For Level A conditions, the average bolt stress is limited to 2 S_m or 2 x 31.9 = 63.8 ksi. The maximum bolt stress is limited to 3 S_m 95.7 ksi. The analyzed stresses are within these limits as well as the yield strength of the bolt material (also 95.7 ksi).

3A.3.2 Accident Conditions

The lid bolts are analyzed in this section under the loadings selected to bound those for the hypothetical bottom end drop and tipover onto the concrete storage pad.

3A.3.2.1 Bottom End Drop

The bottom end drop from a height of 5 feet onto the concrete storage pad is analyzed in Section 3A.2.3.2. That section indicates that the cask deceleration may reach 42 g. This analysis conservatively examines the effects (if any) of a 50 g quasistatic loading on the lid bolts.

During a bottom end drop, the rim of the lid is forced against the flange of the cask body. The lid is initially seated against the flange by preloading (torquing) the bolts. The bolt preload will not be affected if compressive yielding of the contact bearing area does not occur.

The contact force on the bearing area, conservatively neglecting internal pressure, is the bolt preload force less the seal compression force plus the 50 g inertial force of the lid system. The maximum preload force, from Section 3A.3.1, is 3,719,000 lb. The seal seating force is 631,570 lb. for the aluminum seal and 1,031,000 for the silver seal. The weight of the lid system (weight of lid plus weight of top neutron shield assembly, 11560 + 2960 = 14,480 lbs., the highest weight among TN-32, TN-32A and TN-32B casks) is 14,480 lb.

Therefore, during a 50 g deceleration in the axial direction, and conservatively assuming an aluminum seal is used (i.e., an aluminum seal has a lower seating force compared to the silver seal thus resulting in a greater contact force), the contact force between lid and cask body is:

$$
\begin{aligned}
F_{contact} &= F_{Bolt\ Preload} - F_{seal\ seating} + 50\,(W_{lid\ system}) \\
&= 3{,}719{,}000 - 631{,}570 + 50\,(14{,}480) \\
&= 3{,}811{,}000 \text{ lb.}
\end{aligned}
$$

Figure 3A.3-3 illustrates the bearing interface between lid edge and body flange. The bearing area equals the area within the diameter of the lid raised section (74.0 in.) less the outside of the body chamber (70.22 in.) less the area of the seal groove.

$$A_{Bearing} = \frac{\pi}{4}(74^2 - 72.95^2 + 70.75^2 - 70.22^2) = 180 \text{ in}^2$$

The bearing stress during impact is then equal to:

$$S_{bearing} = 3{,}811{,}000 / 180 = 21{,}170 \text{ psi (21.2 ksi)}$$

This contact stress is below the 33.2 ksi yield strength of the lid and flange material at 300°F. The bolt preload will not be affected by the bottom drop. Therefore, this hypothetical accident case will not affect the bolt stresses.

3A.3.2.2 Tipover

The tipover onto the concrete storage pad is analyzed in Appendix 3A.2.3.2 of Revision 9A of the TN-32 TSAR and Appendix 3D.2.5 of Revision 0 of the TN-32 FSAR. The tipover scenario is summarized in Figure 3A.3-4. The peak deceleration occurs at the top of the cask. The deceleration is much less at the center of gravity and essentially zero at the bottom corner pivot point. For this analysis the lateral deceleration at the lid end of the body is conservatively taken as 67g and that at the pivot point is zero.

There are two dynamic loadings acting on the lid tending to push or throw it off of the cask body (i-e. producing tensile forces in the lid bolts). There is a small axial (parallel to cask longitudinal axis) centrifugal inertia load due to the internals acting on the lid and the lid weight itself while the cask is rotating.

For the evaluation of the lid bolts it is assumed herein that the cask impacts on the corner at the lid end. There is no accident condition postulated that would cause greater load on the lid bolts. The cask orientation for the analysis is shown in Figure 3A.3-5. The axis of the cask is 30° from horizontal with the lid down. Note that this orientation is well beyond that predicted in the tipover analyses. If the lateral load, G_L, is 67g, then the axial load used is 67 x tan 30° or 38.7g.

The loads acting on the cask are shown in Figure 3A.3-5. The loads acting on the lid are shown in Figure 3A.3-6. Also shown is the reaction load at the cask interface and the pivot point, O, for analysis of lid rotation. Figure 3A.3-7 shows the lid bolt loads resisting rotation of the lid about pivot point O. The increase in bolt load beyond the preload varies uniformly from pivot point, O, to the bolt farthest from O.

The moment acting on the lid about pivot point, O, due to the inertia load is calculated as follows:

$$M_I = W_I \times 38.7 \times R_T + W_L \times 38.7 \times R_T + W_L \times 67 \times a + P_A \times R_T$$

Where M_I = Total moment about pivot point, in-lb

W_I = Weight of internals
= 16,900 + 49,060 = 65,950 lb.

W_L = Weight of lid system (including shield plate and resin disk), 14,480 lb.

and

P_A = Internal pressure load
= 414,500 lb.

R_T = Distance from center of lid to pivot point
= 39.75 in.

a = Moment arm of lid inertia load, W_L, in.
= 2.25 in. (very conservative since shield weight effect moves CG toward 0)

Therefore:

M_I = (65,960 x 38.7 x 39.75) + (14,480 x 38.7 x 39.75)
+ (14,480 x 67 x 2.25) + (414,500 x 39.75)
= 142.4 x 10^6 in-lb.

This moment is resisted by the effect of the preload on the lid bolts. The moment due to preload is calculated as follows:

$M_P = N \times F_B \times R_T$

Where

M_P = moment due to bolt preload, in-lb.
N = number of bolts, 48
F_B = Preload per bolt
= A_B x preload stress
= stress area bolt x preload stress
= 1.492 in.^{2} x 51,930 psi = 77,480 lb. with 1230 ft-lbs. torque
= 1.492 in.^{2} x 37,150 psi = 55,430 lb. with 880 ft-lbs. torque
R_T = distance from center of lid to pivot point, 39.75 in.

Therefore:

Torque = 1230 ft-lbs.:
M_P = 48 x 77,480 x 39.75
= 147.8 x 10^6 in-lb. > 142.4 x 10^6 in-lb.
Torque = 880 ft-lbs.:
M_P = 48 x 55,430 x 39.75
= 105.8 x 10^6 in-lb. < 142.4 x 10^6 in-lb.

Since the bolt preload moment, M_P, corresponding to the maximum torque value is higher than the moment due to inertial load, M_T, there will not be any additional load due to a tipover accident. However, the bolt preload moment corresponding to the minimum torque value is less than the moment due to inertial load. In this case, the inertial moment is partially resisted by the effect of the preload on the bolts. The increase in bolt load beyond the preload due to the inertia g loads created by the difference between M_I and M_P which is:

$M_T = M_I - M_P$

$M_T = 142.4 \times 10^6 - 105.8 \times 10^6$
$M_T = 36.6 \times 10^6$ in-lbs.

The lid bolts resist the above moment which tends to unseat the lid. The increase in lid bolt load (ΔF_{BO}) beyond the preload is proportional to the distance from the pivot point O. The additional resisting moment, M_R, applied by the bolts about point O is obtained from the following expressions. Refer to Figure 3A.3-8 of Revision 9A of the TN-32 TSAR for terminology.

$$\Delta \text{BoltForce} = \Delta F_{BO} \times \frac{[R + R\cos(n\Theta)B]}{2R + B}$$

ΔMoment for a given bolt = ΔBolt Force x [R + Rcos (nΘ) + B]

Therefore, the additional moment, M_R, can be expressed in general terms as follows:

$$M_R = \frac{\Delta F_{BO}\left[(2R+B)^2 + B^2 + 2\sum_{n=1}^{n=23}(R + R\cos(n\Theta)B)^2\right]}{(2R+B)}$$

R = 39.75 in.

B = 1.72 in.

$\Theta = 7.5°$

Substituting yields:

$M_R = 1421.7 \times \Delta F_{BO}$
Therefore, $\Delta F_{BO} = 36.6 \times 10^6 / 1421.7 = 25{,}740$ lb.
The increase in tensile stress in the bolt beyond the preload is
$\Delta F_{BO} / A_B$ where:
A_B = bolt area, 1.492 in.^{2}
The increased stress is then:
$\Delta F_{BO} / A_B = 25{,}740 / 1.492 = 17{,}250$ psi.

The total tensile stress in Bolt 0 is 37,150 + 17,250 = 54,440 psi. Therefore, the total tensile stress for a bolt subjected to cask tipover is greater for a bolt torqued to 880 ft-lbs. than for a bolt torqued to 1230 ft-lbs. The remainder of this tipover analysis will evaluate both the 880 ft-lbs. torque and the 1230 ft-lbs. torque scenarios.

When the tensile stress is combined with the bolt bending stress due to the lid edge rotation under internal pressure calculated in Section 3A.3.1, the maximum tensile plus bending stress is 54,450 psi plus 21,430 psi (bending) = 75,830 psi and the minimum is 51,930 psi + 21,430 psi = 73,360 psi. The total shear stress due to torquing and lid deformation from Section 3A.3.1.5 is 17,755 psi for the 1230 ft-lbs. case and 13,155 psi for 880 ft-lbs, The combined stress intensity is then:

The average combined stress intensity is:

$SI_{average} = (\sigma_{average}{}^2 + 4\ (\tau_{total})^2)^{1/2})$

1230 ft-lbs. torque: $SI_{average} = (51{,}930^2 + 4 \times 17{,}755^2)^{1/2}$

$SI_{average} = 62{,}910 \text{ psi} < S_y = 95{,}700 \text{ psi}$

880 ft-lbs. torque: $SI_{average} = (54{,}400^2 + 4 \times 13{,}155^2)^{1/2}$

$SI_{average} = 60{,}430 \text{ psi} < S_y = 95{,}700 \text{ psi}$

The maximum combined stress intensity is:

$SI_{max} = (\sigma_{max}{}^2 + 4\ (\tau_{total})^2)^{1/2}$

1230 ft-lbs. torque: $SI_{max} = (73{,}360^2 + 4 \times 17{,}755^2)^{1/2}$

$SI_{max} = 81{,}500 \text{ psi} < S_u = 113{,}930 \text{ psi}$

880 ft-lbs. torque: $SI_{max} = (75{,}830^2 + 4 \times 13{,}155^2)^{1/2}$

$SI_{max} = 80{,}260 \text{ psi} < S_u = 113{,}930 \text{ psi}$

In addition to the above calculations, the lid bolts are evaluated based on the interaction formula from Appendix F of the ASME Code (Reference 5) for tension and shear:

$$\frac{(f_t)^2}{(F_{tb})^2} + \frac{(f_v)^2}{(F_{vb})^2} \le 1$$

Where:

f_t and f_v are the applied tensile and shear stresses

F_{tb} = allowable tensile stress, smaller of ($0.7S_U$) or
S_y (TSAR Table 3.1-3) = 0.7 x 113,930 = 79,750 psi

F_{vb} = allowable shear stress, smaller of ($0.42S_U$) or
$0.6S_y$ (SAR Table 3.1-3) = 0.42 x 113,930 = 47,850 psi

1230 ft-lbs. torque:

$$\frac{51,930^2}{79,750^2}+\frac{17,755^2}{47,850^2} = 0.56 < 1$$

880 ft-lbs. torque:

$$\frac{54,400^2}{79,750^2}+\frac{13,155^2}{47,850^2} = 0.54 < 1$$

3A.3.3 Conclusions

Based on the above evaluation, it is concluded that:

1. The maximum normal and accident condition stresses in the lid bolts are acceptable.
2. A positive (compressive) load is maintained on seals during normal and accident condition loads as bolt preload is higher than the applied loads.

References

1. Resilient Metal Seals and Gaskets, Helicoflex Catalog H.001.002, Helicoflex Co., Boonton, N.J., 1983 pp.5-7.
2. NUREG/CR-6007, Stress Analysis of Closure Bolts for Shipping Casks, April 1992.
3. Hopper, A.G. and Thompson, G.V. "Stress in Preloaded Bolts," Product Engineering, 1964.
4. Roark, R.J.: "Formulas for Stress & Strain", 6th Edition, McGraw-Hill Book Co.
5. American Society of Mechanical Engineers; ASME Boiler and Pressure Vessel Code, Section III, Appendix F, 1992.

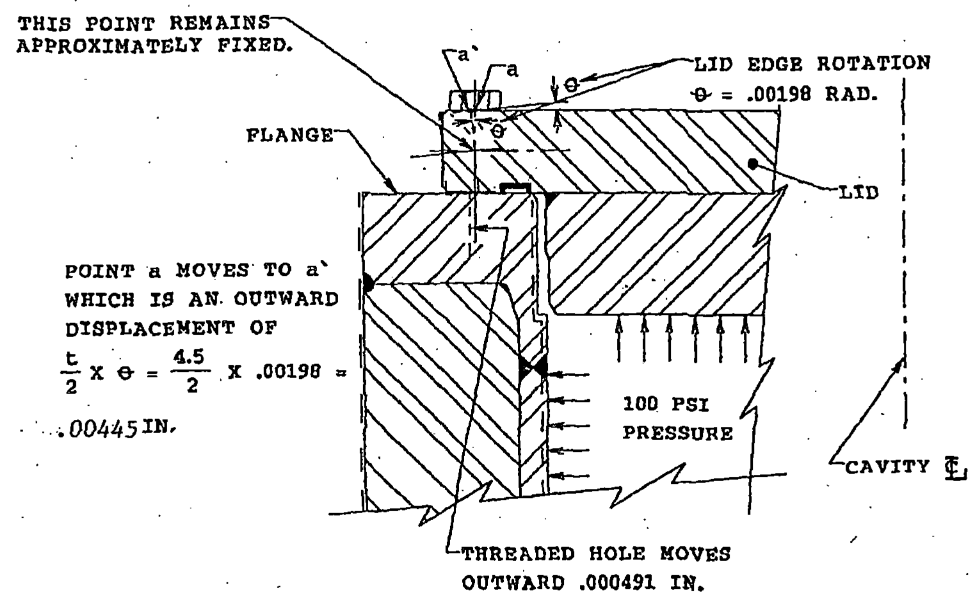


FIGURE 3A.3-1
SUMMARIZING THE BOLT END MOTIONS DUE TO 100 PSIG PRESSURE IN THE CASK CAVITY

REV. 9A 12/96

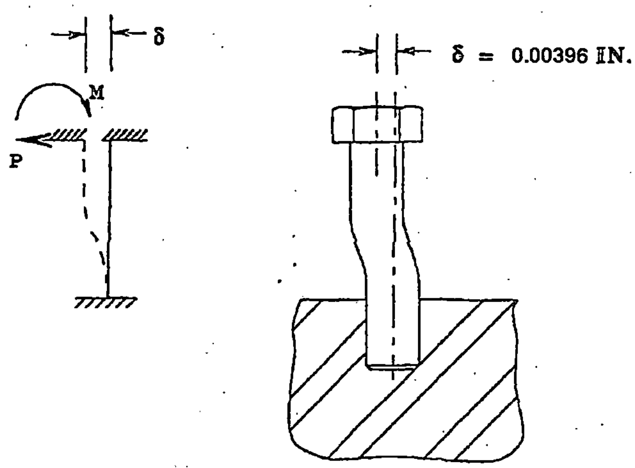
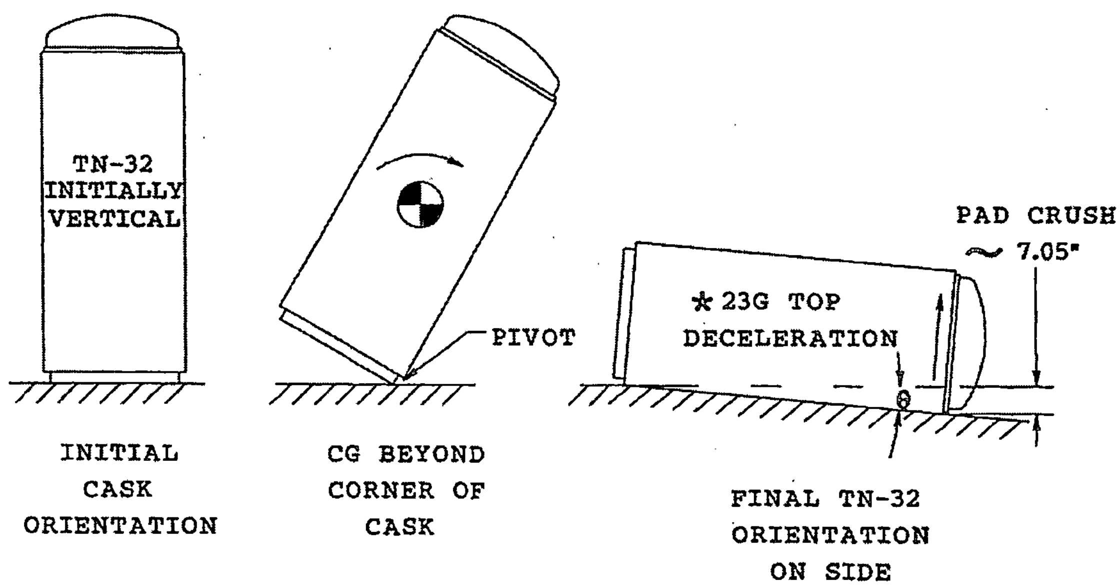


FIGURE 3A.3-2
LID BOLT BENDING DUE TO LID EDGE ROTATION UNDER INTERNAL PRESSURE

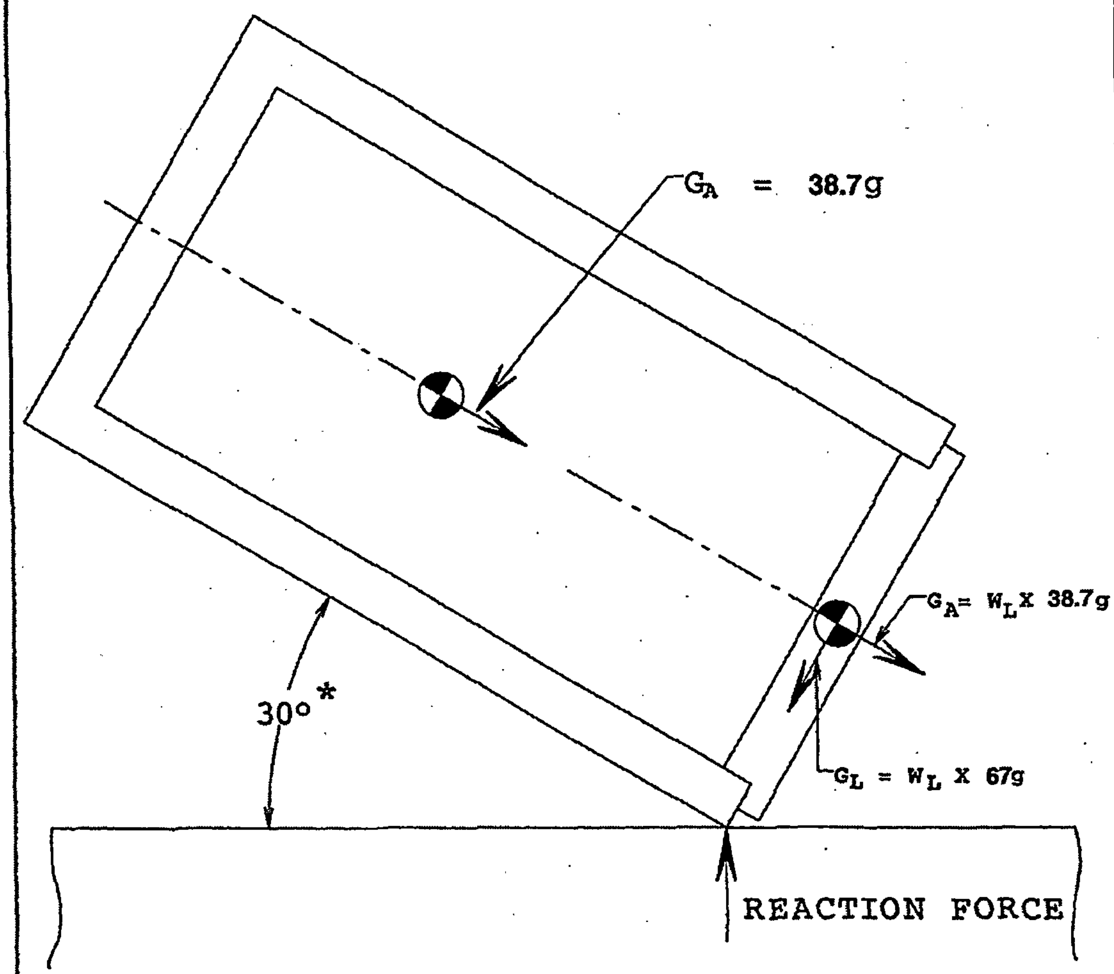
REV. 9A 12/96



$$\theta = \sin^{-1} \frac{7.05''}{184} \approx 2.2^\circ$$

* 67g IS CONSERVATIVELY USED FOR LID BOLT ANALYSIS

FIGURE 3A.3-4
TIPOVER ONTO CONCRETE
STORAGE PAD



* 30° WAS CONSERVATIVELY USED INSTEAD OF CALCULATED 2.2°

FIGURE 3A.3-5
SYSTEM OF INERTIA LOADS APPLIED ON CASK

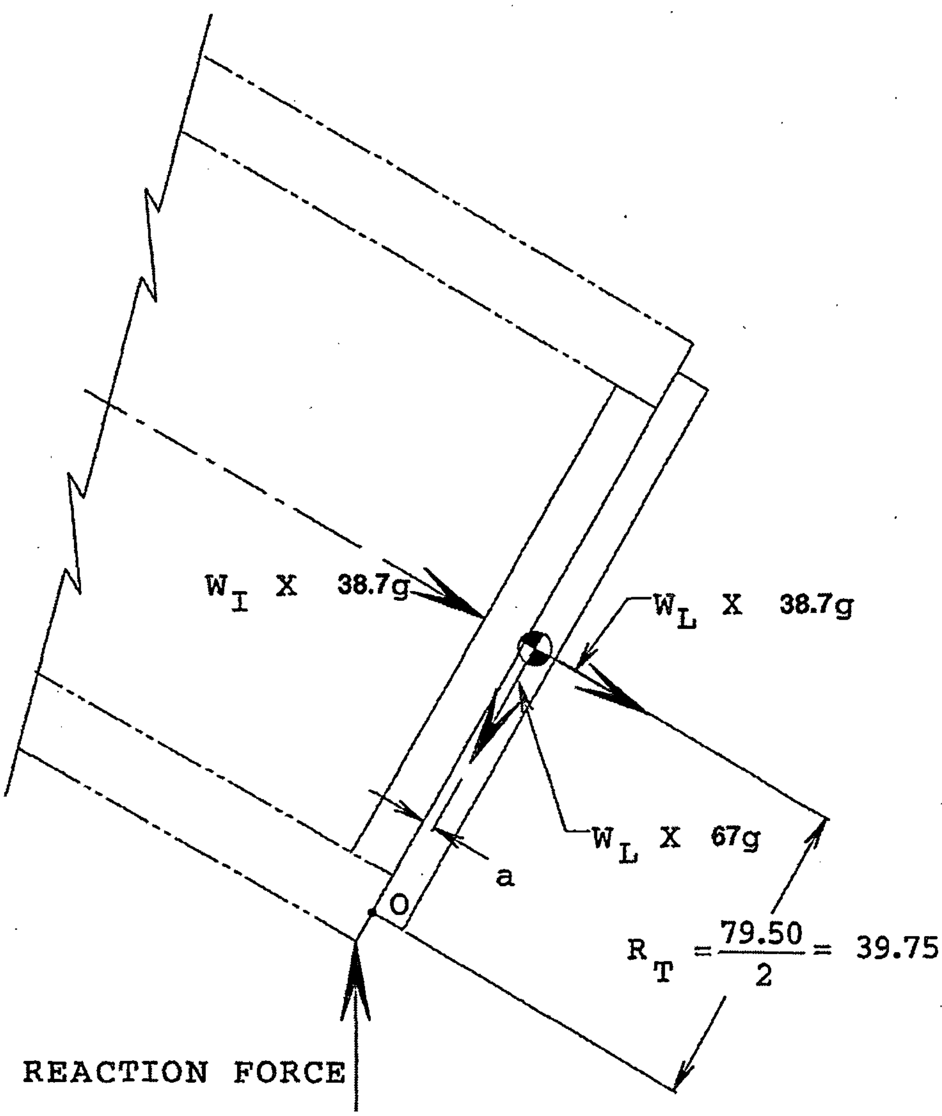


FIGURE 3A.3-6
INERTIA LOADS APPLIED ON LID

Table 3.4-7
Summary of Maximum Stress Intensity and Allowable Stress Limits for Lid Bolts

STRESS CATEGORY	SERVICE CONDITION	MAXIMUM CALCULATED STRESS (psi)	ALLOWABLE STRESS (psi)	SAFETY FACTOR
Tensile	Level A	51,930	63,800 ($2S_m$)	0.23
	Level D	54,440	79,750 ($0.7S_u$)	0.46
Tensile + Bending	Level A	73,360	95,700 ($3\ S_m$)	0.30
	Level D	75,830	113,930 (S_u)	0.50
Shear	Level A	17,755	38,280 ($0.4\ S_y$)	1.16
	Level D	17,755	45,572 ($0.4\ S_u$)	1.57
Combined S.I.	Level A	62,910	95,700 ($3\ S_m$)	0.52
	Level D	81,500	113,930 (S_u)	0.40

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Appendix A.1, Attachment 2

Revision of Tornado Missile Analysis

Excerpt from TN-32 TSAR (Rev. 9A, 12/96)

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2.2.1.3.2 Missile B

Missile B (rigid) partially penetrates the cask wall. The loss in kinetic energy is dissipated as strain energy in the cask wall. The force F_b developed by an 8 in. diameter missile penetrating the cask body is calculated below. With a yield strength of 31,900 psi at 300°F, used for the gamma shield material:

$$F_b = S_y(\tfrac{\pi}{4})(8)^2 = 1.603 \times 10^6 \text{ lbs.}$$

From conservation of energy:

$$F_b x = \tfrac{1}{2} m_b v^2{}_o$$

For a given puncture force F_b:

$$x = \frac{m_b v_o^2}{2F_b}$$

where x is the penetration distance.

The penetration distance is found to be 1.10 in. for a perpendicular impact of the missile.

When the impact angle is not 90 degrees, the missile will rotate during the impact limiting the energy available for penetration (conservatively neglected), since part of the energy will be transformed into rotational kinetic energy.

When hitting the weather protective cover, Missile B deforms the dished head before penetration begins. This will decrease the penetration distance from the above value.

If the missile were to impact the top of the cask in the vertical orientation, the missile velocity would be 88.2 mph (70% of the horizontal impact velocity of 126 mph). The kinetic energy would be:

KE = 0.5 x (276 lbs/32.2 ft/sec^2) x (88.2 mph x 5280 ft/mi/3600 sec/hr)^2 x 12 in/ft
= 860, 440 in lbs.

Ignoring the effect of the protective cover and the top neutron shield, the lid bending stresses under a top impact are evaluated. Reference 20 is used to evaluate the stresses two boundary conditions:

1. Modeling the lid as a simply supported plate.
2. Modeling the lid as a plate with the edges fixed.

For edges simply supported, Table X, Case 2 of Reference 20 is used. The maximum stresses occur at the center, where the plate thickness is t = 10.5 in. The impact force, $F_b = 1.603 \times 10^6$ lbs.

The maximum stress at the center is calculated below:

$$S_r = S_t = 3W/(2\pi m t^2) \times [m + (m + 1)\ln(a/r_o) - (m-1)r_o^2/4a^2]$$

Where r_o = uniform load radius = missile radius = 4 inches
m = 3.33
t = 10.5 inches
a = 38.03 inches (effective radius for a simply supported lid at the bolt circle)
W = $F_b = 1.603 \times 10^6$ lbs.

Therefore, $S_r = S_t \approx 28.5$ ksi

This is well below the Level D allowable stress of 63,000 psi.

For the second case, with the lid edges fixed. Table X, Case 7 of Reference 20 is used.

The maximum stress occurs at the edge, where the plate thickness, t = 4.5 inches.

$$S_r = 3W/(2\pi t^2)\ (1 - r_o^2/2a^2)$$

Where W = $F_b = 1.603 \times 10^6$ lbs.
r_o = uniform load radius = missile radius = 4 inches
t = 4.5 inches
a = 38.03 inches
$S_r \approx 37.0$ ksi

This is also well below the allowable Level D stress of 63,000 psi.

2.2.1.3.3 Missile C (steel sphere 1" diameter)

The impact of the steel sphere can result in a local dent by penetrating into the cask surface at the yield strength, S_y, for a penetration depth, d. The contact area on the cask surface is:

$$A = \pi(2Rd - d^2)$$

Where:

R is the radius of the sphere, 0.5 inches,
and d is the penetration depth

The kinetic energy of the steel sphere is dissipated by displacing the cask surface material:

$$KE = \tfrac{1}{2}(m_c v_o^2) = S_y \int_o^d \pi(2Rd-d^2)\partial_d$$

Where m_c = sphere mass

$KE = 0.5(4/3)(\pi)(0.5)^3(0.28)(1/32.2)(126 \times 5280/3600)^2 = 933$ in-lbs
$S_y \int_o^d \pi(2Rd-d^2)\partial_d = S_y\pi(Rd^2 - d^3/3) = KE = 933$ in-lbs

For a yield strength of 31,900 psi, by trial and error:

d = 0.14 in.

The area, A, is therefore 0.38 sq. inches. A maximum impact force of 12.1×10^3 lb. (A x S_y) will be developed. It can be concluded that only local denting of the cask will result.

If the impact is at the top of the cask (ignoring the protective cover and the neutron shielding), Reference 20, Table X, Case 4 is used to determine the stresses. The impact force is assumed to act at the center of the lid, where p = 0, r_o = 0.353 in. and a = 38.03 inches.

The maximum stress is:

$$S_r = S_t = 3W/(2\pi mt^2) \times [m + (m+1)\ln(a/r_o) - (m-1)r_o^2/4a^2] \approx 1.1 \text{ ksi}$$

Since all penetrations are covered, the steel sphere will have a negligible effect on the cask.

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Appendix A.1, Attachment 3

Modifications to the TN-32 Protective Cover
Drawing SK-VP-SAR-1
Figure VP1.2-1
Figure VP2.3-1

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TRANSNUCLEAR, INC.

TN-32 DRY STORAGE CASK
GENERAL ARRANGEMENT
FOR VIRGINIA POWER

SAR

NONE | B | SK-VP-SAR-1

Security-Related Information
Figure Withheld Under 10 CFR 2.390

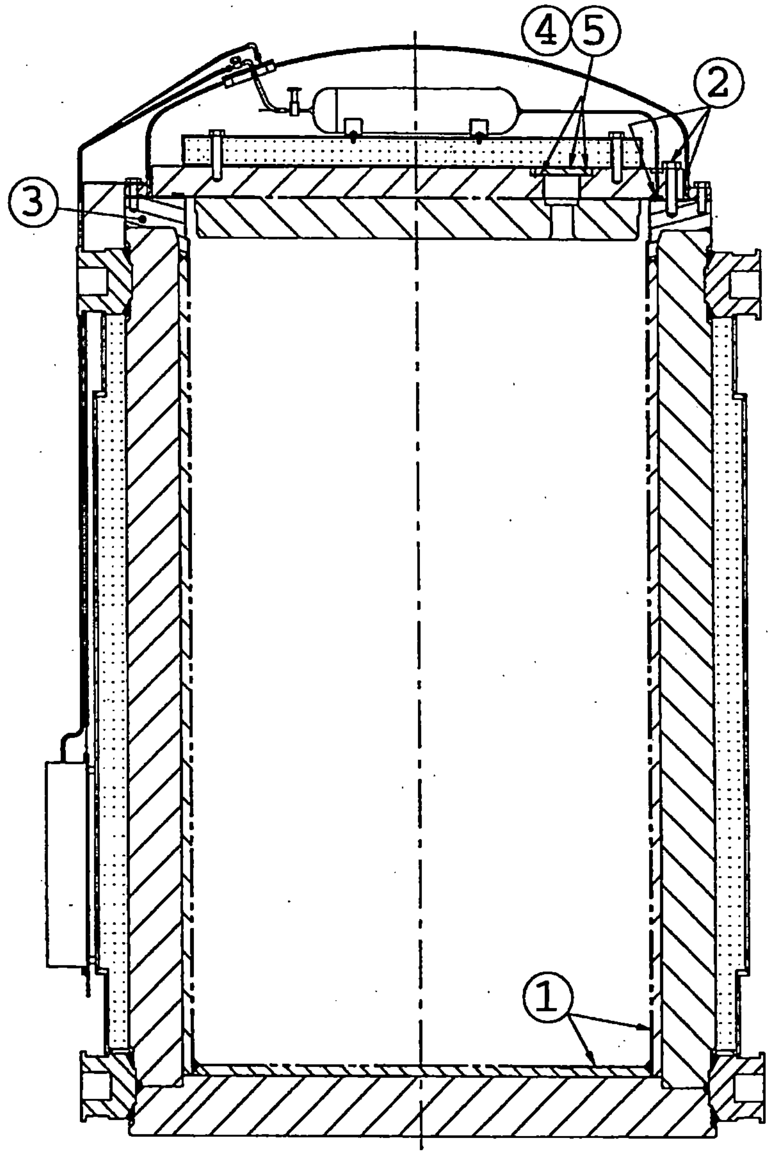
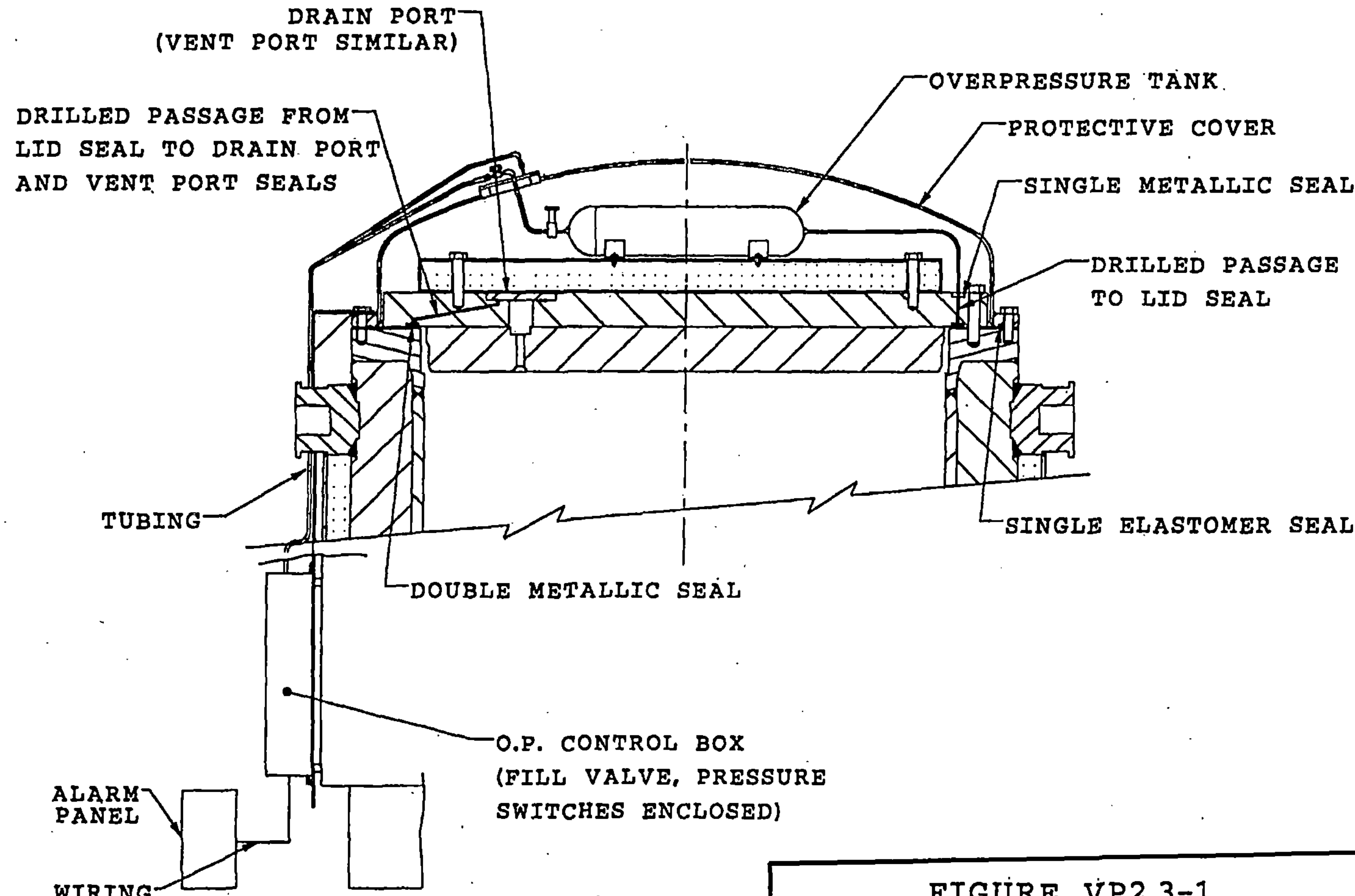


FIGURE VP1.2-1
TN-32 CONFINEMENT
BOUNDARY COMPONENTS

REV. 9A REF.



REV. 9A REF.

FIGURE VP2.3-1
TN-32 CASK SEAL
PRESSURE MONITORING SYSTEM

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Appendix A.1, Attachment 4

Supplement to the Structural Analyses in TN-32 TSAR, Revision 9A, Section 3C.3-1

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3C.3-1.1 Additional Evaluation due to gap size variations occurring from Basket Rail fabrication and Installation Tolerances

This section evaluates the structural effect of the gap size variation between two basket support rails

The buckling analysis of basket bottom rail performed in Section 3C.3-1 assumes a gap of 0.48 inches between the edge of two rails or 0.24 inches between the edge of the rail and centerline of the basket. However, due to fabrication and installation tolerances the gap between these two rails can vary from 0" to 1.1326" (or 0.5663" between the edge of the rail and centerline of the basket).

- Discussion

It is observed from Section 3C.3-1 that in the rail design the most critical locations are locations 1, 2, and 3 as shown on Figure 3C.3-4. Due to the gap changes, the loading and stress at these three locations are discussed as follows:

1. The collapse load calculated in accordance with ASME B&PV Code, Section III, NB-3213.25 and Appendix F, F-1341.3 at Location 1 is 96g which is higher than the 88-g assumed for the tipover accident. The collapse load was calculated conservatively by assuming that the vertical load from the basket is directly applied at the center span of the two vertical rail support plates as shown on Figure 3C.3-2. This loading condition results in a maximum bending stress at the center of the rail horizontal plate. If the location of the rail is shifted either toward or away from the centerline of the basket due to gap size change, then the applied vertical load will move closer to the rail vertical support plates and the bending stress at the rail horizontal plate will decrease. Therefore, the gap changes will not result in increasing the stress at Location 1.
2. The stability of the vertical plates at Locations 2 and 3 is analyzed using the interaction equations 20 and 21 of Paragraph NF-3322.1 (Equations 1 and 2 in Section 3C.3-1). These equations utilize membrane and bending stresses that were determined from three dimensional ANSYS calculations.

   For Location 2 and a gap of 0.24",

   equation (1) becomes,

   $0.0954 + 0.328 = 0.423 \leq 1.0$

equation (2) becomes,

$0.440 + 0.483 = 0.923 \leq 1.0$

and for Location 3, equation (1) becomes,

$0.06 + 0.31 = 0.37 \leq 1.0$

equation (2) becomes,

$0.369 + 0.477 = 0.846 \leq 1.0$

Since the membrane and bending stresses at Locations 2 and 3 will either increase or decrease due to the gap changes the interaction equation must be re-evaluated to insure that the structural integrity of the rail will be maintained.

- Analysis

The membrane and bending stresses presented in Section 3C.3-1 were calculated using a three dimensional ANSYS model. The purpose of this analysis is to determine the sensitivity of the stress values to a range of rail-to-rail gap dimensions, then re-evaluate the interaction equations to properly reflect the full range of stress values. A two-dimensional ANSYS model is sufficient to calculate such sensitivity.

Finite Element Model

In order to calculate the member and bending stress changes due to the gap size variations, an ANSYS two-dimension beam (BEAM 3) finite element model is constructed. This finite element model includes the rail and a small portion of basket for better load transfer to the rail. Gap elements (CONTAC 12) are used between the basket and rail to accurately simulate the basket load transfer to bottom support rail. One-inch widths of rail and basket are used for loading and beam elements section properties. The finite element model is shown on Figure 3C.3-14.

Material Properties

Following data is used in this run (material properties are taken at 350°F):

Material:

Aluminum Rail $E = 9.0 \times 10^6$ psi (Section 3C.3-4)

304SS Basket $E = 26.75 \times 10^6$ psi (from Table 3.3-5)

Loading Conditions

The membrane and bending stresses at locations 2 and 3 are computed by using unit loads F_1, F_2, F_3 and a distributed load w (for 1g). The locations of these loads and displacement boundary conditions are shown in Figure 3C.3-14.

Fuel Assembly Weight, W = 1,533 lbs. (Table 3.2-1)
Rail Length, L = 159.75 in. (Drawing 1049-70-5)

F_1 (at basket center line, x = 0.0) = 0.5 (No. of stacked fuel assemblies x W)/L
= 0.5 x 5 x 1533/159.75 = 23.991 lb.

F_3 (at basket centerline, x = 18.61") = 23.991 lb.

F_2 (at basket middle, x = 8.70 + 0.105 +.5 = 9.305") = (No. of stacked fuel assemblies x W)/L = 5 x 1533/159.75 = 47.981 lb.

Distributed Load, w = Fuel Assembly Weight / (L x Basket Span) = 1533 / (159.75 x 9.301) = 1.03174 lb/in

Section Properties:

Rail: Section Area, A = 0.47 (depth) x 1.0 (width) = 0.47 in^2
Moment of Inertia, I = 1.0 x $0.47^3/12$ = 0.008652 in^4

Basket: Steel - Aluminum Composite Section
E_s, Steel = 26.75 x 10^6 psi
E_a, aluminum = 9.0 x 10^6 psi

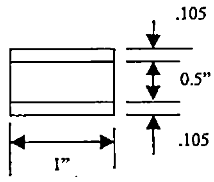
I_c, Composite Section = [1.0 ($0.71^3/12$ - 1.0 ($0.5^3/12$]+(1 x $0.5^3/12$) x (9.0 x $10^6/26.75$ x 10^6) = 0.022914 in^4

Depth, d_c = $(12 \text{ x } 0.022914)^{1/3}$ = 0.65 in.
A_c = 0.65 x 1.0 = 0.65 in^2

Contact Elements: K = 1.0 x 10^6

Coefficient of friction = 0

Composite Steel/Aluminum Section



Load Case 1

The analysis is performed to calculate the membrane and bending stresses by using the existing loading condition (0.48" gap or 0.24" gap for half model).

An elastic non-linear run was made using the above loads and section properties. The membrane and bending stress components at location 2 and 3 are recorded in Table 3C.3-1. The deformed shape of model is given in Figure 3C.3-16.

Load Case 2

The same model is run by shifting the rail to the right to simulate the maximum gap of 1.1326" or 0.5663" for the half model. In this run, all loads and section properties are same as in 0.24 in. gap case. However the finite element model was revised by transferring the 'x - coordinates' of rail nodes by 0.5663 0- 0.24 = 0.3263".

The membrane and bending stress components at location 2 and 3 are recorded in Table 3C.3-1. Also, the ratio between the values from this run and Load Case 1 are included in Table 3C.3-1. The deformed shape of model is given in Figure 3C.3-17.

Load Case 3

The same model is run by shifting the rail to the left to simulate the minimum gap of 0.0" for the half model. In this run, all loads and section properties are same as in 0.24 in. gap case. However the finite element model was revised by transferring the 'x - coordinates' of rail nodes by 0- 0.24 = -0.24".

The membrane and bending stress components at location 2 and 3 are recorded in Table 3C.3-1. Also, the ratio between the values from this run and Load Case 2 are included in Table 3C.3-1. The deformed shape of model is given in Figure 3C.3-18.

Evaluation

The interaction equation is re-evaluated by applying the results of the sensitivity analysis to the compression and bending components of the equation. Since the result from the equation (2) bounds equation (1), therefore only result from equation (2) is re-evaluated. So, for Case 2, which reflects the maximum gap between the two rails, at location 2:

$$0.440(1.034) + 0.483(1.101) = 0.987 \leq 1.0$$

and at Location 3:

$$0.369(1.076) + 0.477(1.084) = 0.914 \leq 1.0$$

For Case 3, which reflects the minimum gap between the rails, the interaction equation at Location 2 becomes

$$0.440(0.961) + 0.483(0.863) = 0.840 \leq 1.0$$

and at Location 3:

$$0.369(0.955) + 0.477(0.940) = 0.801 \leq 1.0$$

- Conclusion

The results of this analysis show the following conclusions:

1. As the gap between these two rail decreases, the likelihood of buckling decreases.
2. At the maximum possible rail gap of 1.1326" (or 0.5663" between the edge of the rail and centerline of the basket), the buckling interaction equations indicate that the rail will not buckle.
3. The stresses at Location 1 are not affected by a change in the rail gap size.

Therefore, for any possible gap sizes, the structural integrity of the rail will be maintained.

Table 3C.3-1
SUMMARY OF STRESSES AND INTERACTION EQUATION EVALUATION

Case	Type	At Location 2 (Node 71)	At Location 3 (Node 81)
0.48" Space between Rails	Membrane Stress (psi)	-59.182	-65.290
	Bending Stress (psi)	27.765	38.627
1.1326" Space between Rails	Membrane Stress (psi)	-61.181	-70.267
	Bending Stress (psi)	30.568	41.87
	Ratio Membrane Stresses For 0.5663" & 0.24" cases	-61.181/-59.182 = 1.034	-70.265/-65.290 = 1.076
	Ratio Bending Stresses For 0.5663" & 0.24" cases	30.568/27.765 = 1.101	41.871/38.627 = 1.084
	Interaction Equation	1.034(.44*) + 1.101(.483*) = 0.987	1.076(.369*) + 1.084(.477*) = 0.914
0.0" Space between Rails	Membrane Stress (psi)	-56.883	-62.327
	Bending Stress (psi)	23.962	36.315
	Ratio Membrane Stresses For 0.5663" & 0.24" cases	-56.883/-59.182 = 0.961	-62.327/-65.290 = 0.955
	Ratio Bending Stresses For 0.5663" & 0.24" cases	23.962/27.765 = 0.863	36.315/38.627 = 0.940
	Interaction Equation	0.961 (.44*) + 0.863(.483*) = 0.840	0.955(.369*) + 0.940(.477*) = 0.801

* These coefficients are calculated in Section 3C.3-1. Since the result from the equation (2) bounds equation (1), therefore only result from equation (2) is re-evaluated.

Figure 3C.3-14
FINITE ELEMENT MODEL - BOTTOM SUPPORT RAIL

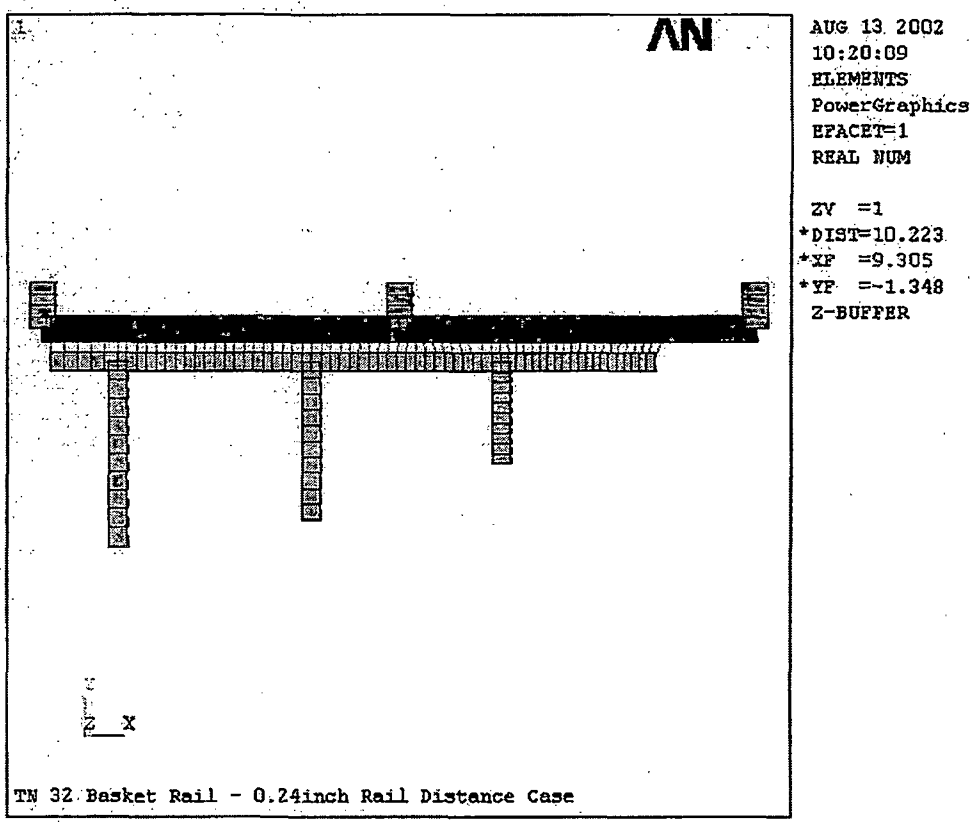


Figure 3C.3-15
FINITE ELEMENT MODEL - LOADING AND BOUNDARY CONDITIONS

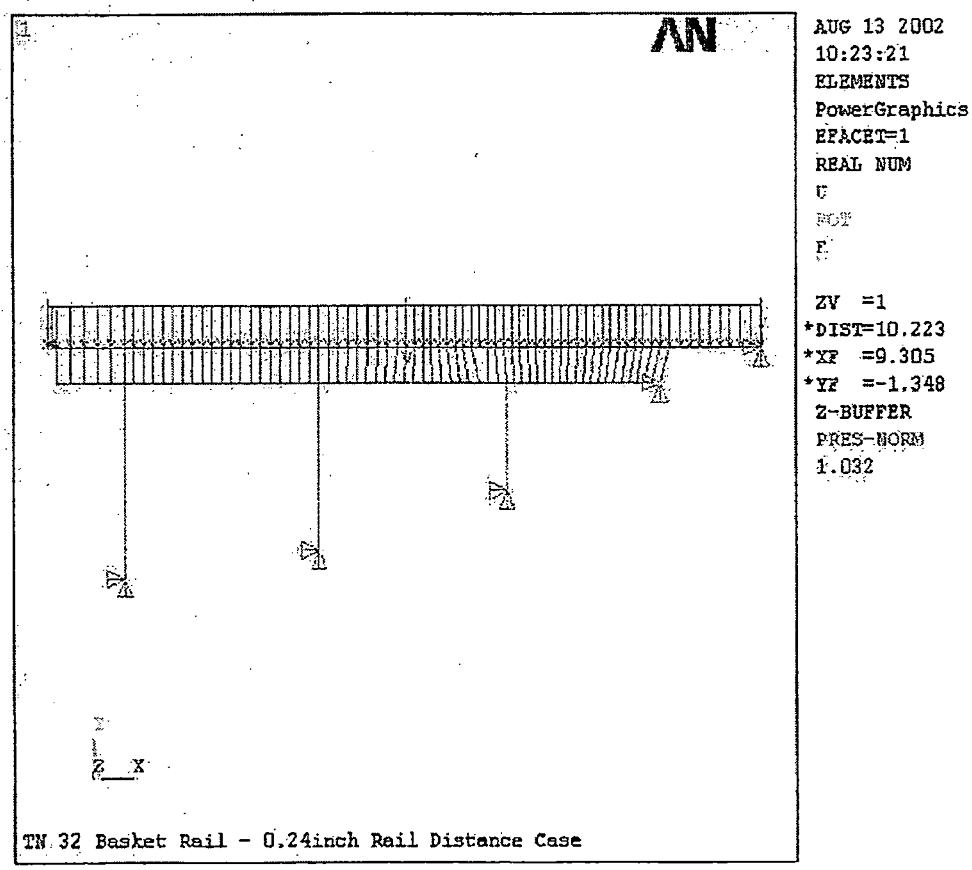


Figure 3C.3-16
FINITE ELEMENT MODEL - DEFORMED SHAPE, 0.24" DISTANCE

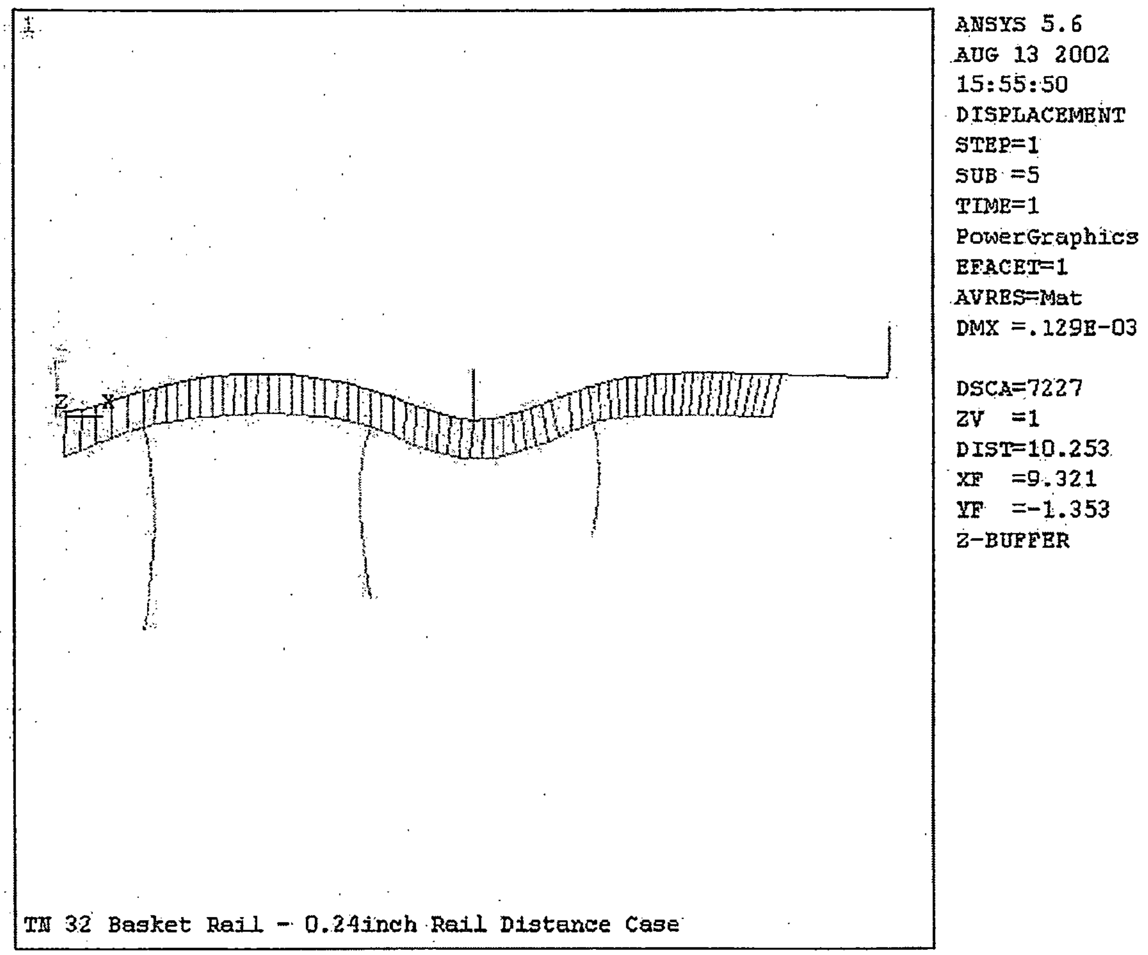


Figure 3C.3-17
FINITE ELEMENT MODEL - DEFORMED SHAPE, 0.5663" DISTANCE

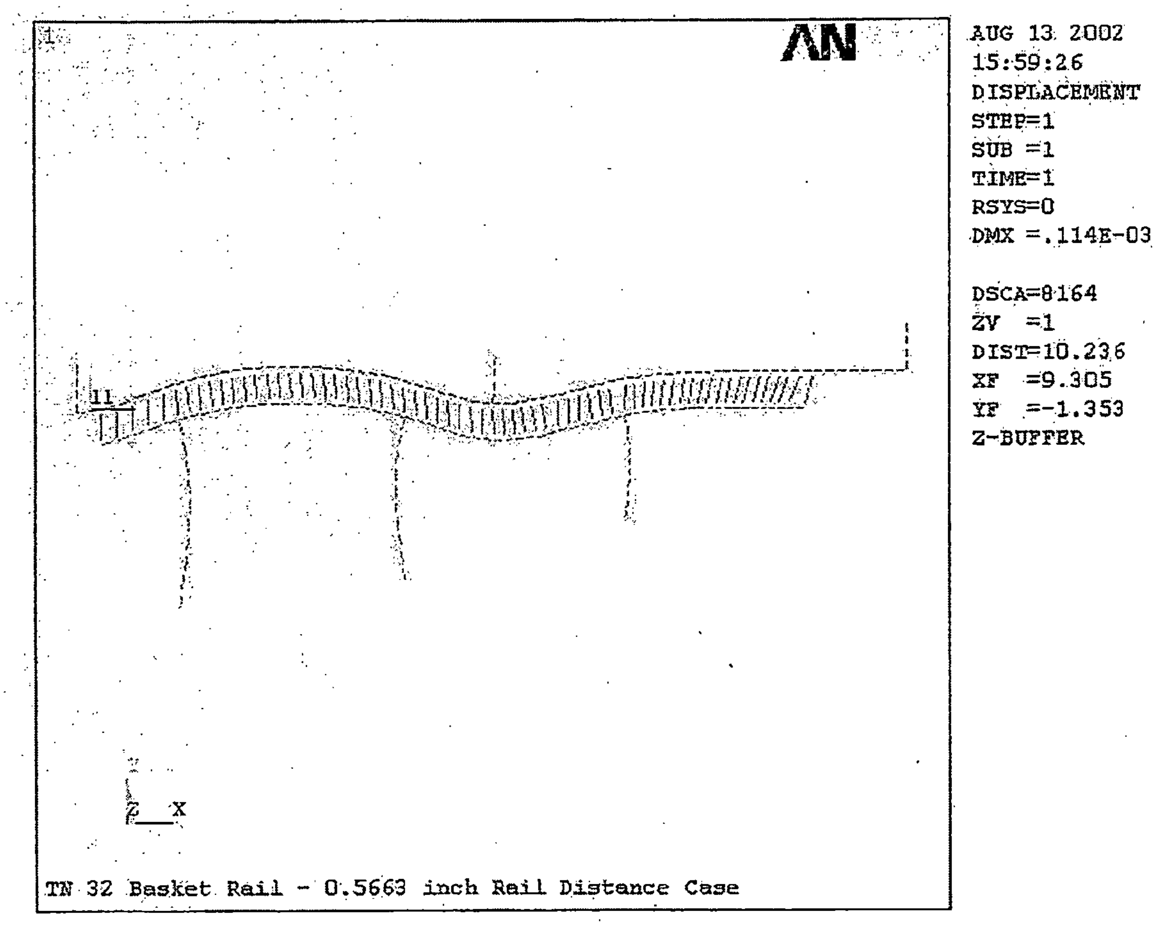
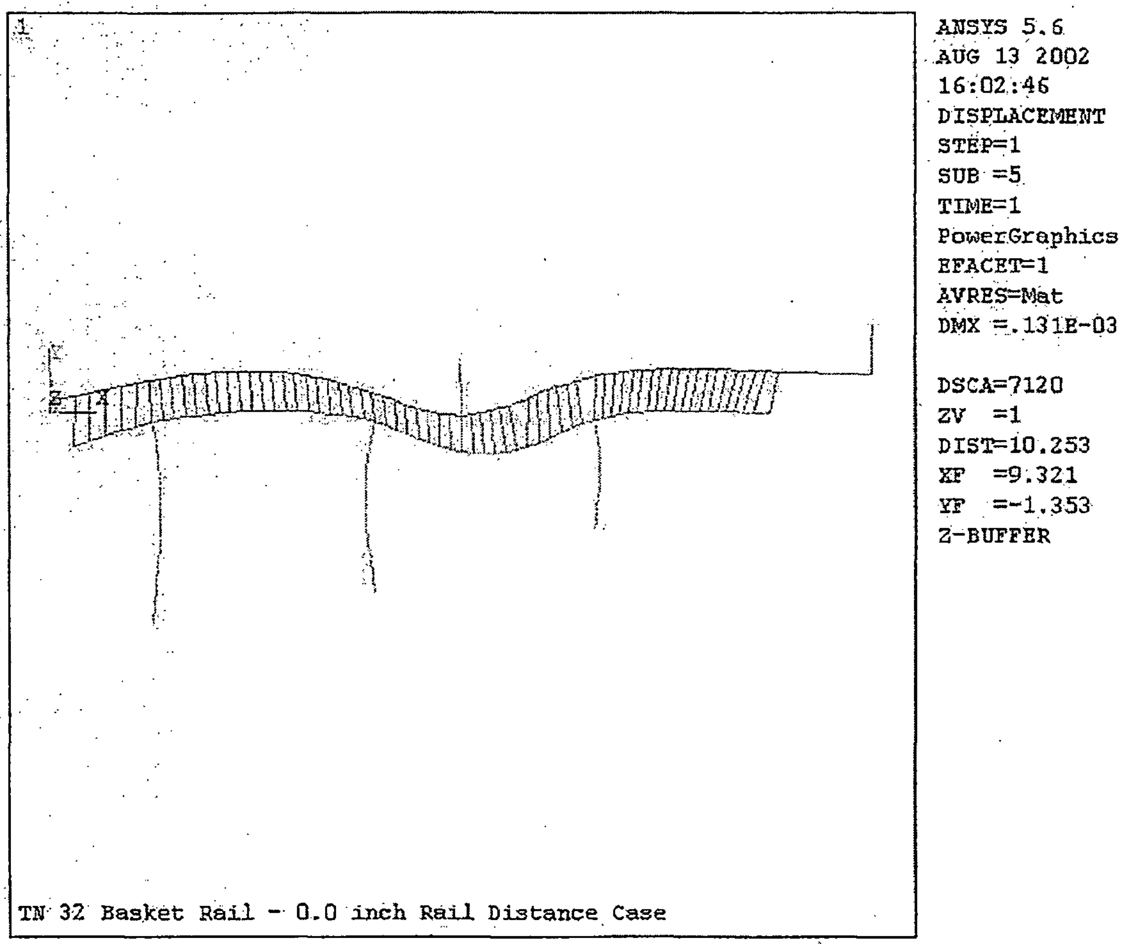


Figure 3C.3-18
FINITE ELEMENT MODEL - DEFORMED SHAPE, 0.0" DISTANCE



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AREVA

April 16, 2014
E-37975

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852

Subject: TN-32 Updated Final Safety Analysis Report (UFSAR), Revision 6 and 10 CFR 72.48 Summary Report for the Period 04/17/12 to 04/16/14

Reference: 1. TN-32 Updated Final Safety Analysis Report (UFSAR), Revision 5 and 10 CFR 72.48 Summary Report for the Period 04/17/10 to 04/16/12 (Docket 72-1021, April 16, 2012, ML12109A089)

Pursuant to 10 CFR 72.248, AREVA Inc. has updated the TN-32 UFSAR, last updated by Reference 1, and herewith submits UFSAR Revision 6 changes for docketing. This update to the UFSAR incorporates changes implemented by AREVA Inc. pursuant to 10 CFR 72.48 for the time period 04/17/12 to 04/16/14.

I certify that this submittal accurately presents changes made since the submittal of Reference 1.

Enclosure 1 provides new and replacement UFSAR pages, including a List of Effective Pages that identifies the Revision 6 pages. This submittal does not contain proprietary information; however, updated title pages for both the proprietary and the non-proprietary UFSAR versions are included. The proprietary version title page is included in Enclosure 1. The non-proprietary version title page is provided as Enclosure 2.

The changed areas are marked as follows:

- Changed pages show Rev. 6, 04/14 in the footer.
- Changed areas are indicated using revision bars in the right-hand margin.
- Newly inserted text is shown by italics.

Regarding the summary report required to be submitted pursuant to 10 CFR 72.48(d)(2), AREVA Inc. made no changes in facilities or spent fuel storage cask design, no changes in procedures, and no tests or experiments pursuant to paragraph (c)(2) of 10 CFR 72.48 during the period 04/17/12 to 04/16/14 for the TN-32.

AREVA TN

AREVA Inc.
7135 Minstrel Way - Suite 300 - Columbia, MD 21045 USA
Tel.: (410) 910-6900 - Fax: (410) 910-6902
us.areva.com/AREVATN

April 16, 2014
E-37975

Should you have any questions regarding this submittal, please do not hesitate to contact Mr. Don Shaw at 410-910-6878 or me at 410-910-6820.

Sincerely,

Paul Triska
Vice President, Technical Services

cc: B. Jennifer Davis (NRC SFST) in a separate mailing, as follows:
- Two paper copies of replacement pages for TN-32 UFSAR, Revision 6 (Proprietary Version)
- Two electronic copies (computer disk) of the TN-32 UFSAR, Revision 6 (Proprietary Version)

Enclosures:

1. Replacement Pages for TN-32 UFSAR, Revision 6 (Proprietary Version)
2. Replacement Title Page for TN-32 UFSAR, Revision 6 (Non-Proprietary Version)

AREVA

November 17, 2015
E-43839 Rev. 0

Don McGee, PM
Mail Code CLT-1D
7207 IBM Dr.
Charlotte, NC 28262

Subject: NRC Request #4 for Design Basis Information Supporting License Amendment Request Serial No. 15-369 to License SNM-2507 Docket No. 72-16

Dear Mr. McGee:

This correspondence is written to provide AREVA TN response to a request by the NRC to receive documentation for: 1) the B_4C rod material density and, 2) the computer input files for the SCALE model that supports review of License Amendment Request (LAR).

This LAR is for the storage of high burn up nuclear fuel at the North Anna Power Station as part of a project to monitor the effects of long-term storage. The information requested is being transmitted to Dominion Power and, subsequently, forwarded on to the NRC for their use in the review process.

The information is provided as attachments to this letter as specified below. Note that Item #2 on Attachment A was resolved as described in Attachment B.

Sincerely,

T. M. Edwards

Tom Edwards
Design Project Engineer

Attachment A: E-mail from Der Yuan Lee to Tom Edwards dated 11/16/15 – 1 page

Attachment B: E-mail from Tom Edwards to Brian Vitiello dated 11/16/15 – 1 page

cc: Phil Lozmack (PM)
Ken Legg (QAS)
Dennis Williford (Licensing)
Brian Vitiello (Dominion)
Rod Gooch (PM)
Lauren Naggs (DCA)
Project File 19885 – Outgoing Correspondence

AREVA TN

AREVA Inc.
7135 Minstrel Way - Suite 300 - Columbia, MD 21045 USA
Tel.: (410) 910-6900 - Fax: (410) 910-6902
us.areva.com/AREVATN

From: LEE Der Yuan (BE/LO)
Sent: Monday, November 16, 2015 11:35 AM
To: EDWARDS Tom (BE/LO)
Cc: PHAM Tan Trieu (BE/LO)
Subject: RE: HBU Demo Project - AI Resolution

Tom,

1. The material density of the B4C rod material density

In AREVA TN Calculation, 19885-0602 Revision 0, Section 5.3.2 spells out that, "The Oak Ridge National Laboratory (ORNL) SCALE code package [2-5] contains a standard material data library for common elements, compounds, and mixtures. All the materials used for the cask, basket, fuels, PRA and TC insert are available in this data library." Reference 2-5 points to, "2-5 SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluations, ORNL/TM-2005/39, Version 6, Vols. I–III, January 2009. Available from Radiation Safety Information Computational Center at Oak Ridge National Laboratory as CCC-750." In Section M8.2 of the SCALE Manuel, it states,

B4C Boron carbide: B4C; natural isotopic distribution obtained by default, 2.52 g/cc.

Table M8.2.4 gives more info,

Table M8.2.4. The Standard Composition Library - compounds and other materials (atoms per molecule)

Alphanumeric compound identifier	Density[a]	Nuclide	Number of atoms per molecule
B4C	2.52	5000	4
		6000	1

In the criticality input, the default B4C material density is applied to the criticality evaluation as shown below,

```
' pra
b4c   6 0.50 293.0 end
```

The third entry of the second line, 0.50, indicates that 50% of the B4C is credited.

2. The SCALE criticality analysis model

I have placed the criticality input files as \\adom\TN\Public\AREVAnet\delee\hbu.zip. I have also sent it through the MFT.

David Lee

From: EDWARDS Tom (BE/LO)
To: brian.j.vitiello@dom.com
Cc: JONES Adam (AREVA Federal Services LLC)
Subject: HBU Project 19885 Criticality Input Files
Date: Monday, November 16, 2015 5:05:00 PM
Attachments: ambw_mrc_mod-060.inp
ambw_mrc_mod-070.inp
ambw_mrc_mod-080.inp
ambw_mrc_mod-085.inp
ambw_mrc_mod-090.inp
ambw_mrc_mod-095.inp
ambw_mrc_mod-100.inp

Brian,

Attached are the 7 SCALE model input files obtained from the AREVA TN Nuclear Analysis group. See if that is in a format that works for you.

The e-mail response for B4C density will be forthcoming tomorrow.

TOM EDWARDS
Design Project Engineer
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A Division of AREVA Inc.
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```
=csas5 parm=nitawl
tn-32 demo cask mrc ambw
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read comp
uo2    1 0.960 293.0 92235 4.60 92238 95.40 end
zirc4  2 1.0   293.0 end
h2o    3 1.0   293.0 end
' fuel compartment
ss304  4 1.0   293.0 end
' moderation 60.0%
h2o    5 0.600 293.0 end
boron  5 den=0.00250 0.600 293.0 end
' pra
b4c    6 0.50 293.0 end
' cask iterior water
h2o    7 1.0 293.0 end
' al plate
al     8 1.0 293.0 end
' poison plate borated aluminum 9 mg/cm**2 0.04" thick plate
boron 9 den=2.693 0.039267 293.0 5010 83.77 5011 16.23 end
al    9 den=2.693 0.960733 293.0 end
' rail
al    10 0.303 293.0 end
boron 10 den=0.002500 0.697 293.0 end
h2o   10 0.697 293.0 end
' tc lance
al    15 1.0 293.0 end
' cask shell
carbonsteel 16 1.0 293.0 end
' exterior water
h2o         17 1.0 293.0 end
end comp
read celldata
latticecell squarepitch pitch=1.25984  5 fueld=0.81915  1 cladd=
0.94996  2 gapd=0.83566  3 end
end celldata
read param run=yes gen=805 npg=1000 nsk=5 end param
read geom
unit 1
array 3 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -12.5603 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 2
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 3
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 4
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 5
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -11.9761 213.36 -193.04
unit 6
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 12.7762 -11.9761 213.36 -193.04
unit 7
array 1 -10.9728 -10.9728 -175.2601
```

```
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.2395 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 8
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
unit 9
array 2 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 12.5603 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 10
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 11
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
```

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unit 12
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 13
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.9761 -11.8745 213.36 -193.04
unit 14
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.2395 -11.3411 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 11.9761 -12.7762 213.36 -193.04
unit 15
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.2395 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 16
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
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cuboid 8 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
unit 17
array 2 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -12.5603 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 18
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 19
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 20
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 21
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
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hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -11.9761 213.36 -193.04
unit 22
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 12.7762 -11.9761 213.36 -193.04
unit 23
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.2395 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 24
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
unit 25
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 12.5603 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 26
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
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cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 27
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 28
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 29
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.8745 213.36 -193.04
unit 30
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.3411 -11.2395 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 11.9761 -12.7762 213.36 -193.04
unit 31
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
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cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.2395 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 32
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
'plug
unit 331
xcylinder 4 1 2.0701 0.050799 0.0
unit 332
cuboid 9 1 0.050799 -0.0 2p10.4013 2p10.16
hole 331 0.0  5.55 0.0
hole 331 0.0 -5.55 0.0
unit 341
ycylinder 4 1 2.0701 0.0 -0.050799
unit 342
cuboid 9 1 2p10.4013 0.0 -0.050799 2p10.16
hole 341  5.55 0.0 0.0
hole 341 -5.55 0.0 0.0
unit 351
xcylinder 4 1 2.0701 0.050799 -0.050799
unit 352
cuboid 9 1 2p0.050799 2p10.4013 2p10.16
hole 351 0.0  5.55 0.0
hole 351 0.0 -5.55 0.0
unit 361
ycylinder 4 1 2.0701 0.050799 -0.050799
unit 362
cuboid 9 1 2p10.4013 2p0.050799 2p10.16
hole 361  5.55 0.0 0.0
hole 361 -5.55 0.0 0.0
' poison plate
unit 33
array 33 0.0 -10.4013 -182.88
unit 34
array 34 -10.4013 -0.050799 -182.88
unit 35
array 35 -0.050799 -10.4013 -182.88
unit 36
array 36 -10.4013 -0.050799 -182.88
```

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' exterior fuel compart ment and al plate
unit 37
cuboid 8 1 1.27 -0.0 2p46.3952 213.36 -193.04
cuboid 4 1 1.5367 -0.0 2p46.3952 213.36 -193.04
unit 38
cuboid 8 1 2p46.3952 1.27 -0.0 213.36 -193.04
cuboid 4 1 2p46.3952 1.5367 -0.0 213.36 -193.04
' fuel
unit 41
array 12 -48.9204 0.0 -193.04
unit 42
array 13 -48.9204 -23.2156 -193.04
unit 43
array 14 0.0 -49.1871 -193.04
unit 44
array 15 -22.5806 -49.1871 -193.04
' exetrior steel waraper
unit 45
cuboid 4 1 0.2667 -0.0 22.3013 -0.0 213.36 -193.04
' fuel pin
unit 51
cylinder 1 1 0.409575 182.88 -182.88
cylinder 3 1 0.417830 182.88 -182.88
cylinder 2 1 0.474980 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' guide tube
unit 52
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' instrument tube
unit 53
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' pra
unit 54
cylinder 6 1 0.37465 182.88 -182.88
cylinder 0 1 0.41783 182.88 -182.88
cylinder 4 1 0.47498 182.88 -182.88
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' tc lance
unit 55
cylinder 15 1 0.37084 182.88 -182.88
cylinder  0 1 0.57150 182.88 -182.88
cylinder  2 1 0.61214 182.88 -182.88
cuboid    5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
'
global
unit 47
```

```
array 16 -48.9204 -48.2854 -193.04
cylinder 10 1 87.3125 213.36 -193.04
hole 41  0.0        48.2855 0.0
hole 42  0.0       -48.2855 0.0
hole 43  48.9205     0.0    0.0
hole 44 -48.9205     0.0    0.0
hole 37  71.5012     0.0    0.0
hole 37 -73.0379     0.0    0.0
hole 38  0.0        71.5012 0.0
hole 38  0.0       -73.0379 0.0
hole 45  48.92051  49.1872 0.0
hole 45 -49.18721  49.1872 0.0
hole 45  48.9205  -71.4885 0.0
hole 45 -49.1872  -71.4885 0.0
cylinder   5 1  87.3125 213.3600 -193.0400
cylinder   0 1  87.3125 221.6150 -193.0400
cylinder  16 1 111.4425 248.2850 -219.0750
replicate 17 1 3*3.0  10
end geom
read array
ara=1 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 52 51 51 52 51 51 52 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' pra
ara=2 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 54 51 51 51 51 51 51 51 51 51 54 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 54 51 51 54 51 51 54 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 53 51 51 54 51 51 54 51 51
```

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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 54 51 51 54 51 51 54 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 54 51 51 51 51 51 51 51 51 51 54 51 51 51
 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' tc lance
ara=3 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 55 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 53 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 52 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
ara=12 nux=4 fill 24 23  7  8 end fill
ara=13 nux=4 fill 32 31 15 16 end fill
ara=14 nuy=4 fill 14 11  3  6 end fill
ara=15 nuy=4 fill 30 27 19 22 end fill
ara=16 nux=4 nuy=4 fill 29 28 12 13 26 25 9 10 18 17 1 2 21 20 4
5 end fill
ara=33 nuz=18 fill f332 end fill
ara=34 nuz=18 fill f342 end fill
ara=35 nuz=18 fill f352 end fill
ara=36 nuz=18 fill f362 end fill
end array
read bounds
all=vacuum
end bounds
end data
end
```

```
=csas5 parm=nitawl
tn-32 demo cask mrc ambw
44groupndf5
read comp
uo2    1 0.960 293.0 92235 4.60 92238 95.40 end
zirc4  2 1.0   293.0 end
h2o    3 1.0   293.0 end
' fuel compartment
ss304  4 1.0   293.0 end
' moderation 70.0%
h2o    5 0.700 293.0 end
boron  5 den=0.00250 0.700 293.0 end
' pra
b4c    6 0.50 293.0 end
' cask iterior water
h2o    7 1.0 293.0 end
' al plate
al     8 1.0 293.0 end
' poison plate borated aluminum 9 mg/cm**2 0.04" thick plate
boron 9 den=2.693 0.039267 293.0 5010 83.77 5011 16.23 end
al    9 den=2.693 0.960733 293.0 end
' rail
al    10 0.303 293.0 end
boron 10 den=0.002500 0.697 293.0 end
h2o   10 0.697 293.0 end
' tc lance
al    15 1.0 293.0 end
' cask shell
carbonsteel 16 1.0 293.0 end
' exterior water
h2o         17 1.0 293.0 end
end comp
read celldata
latticecell squarepitch pitch=1.25984  5 fueld=0.81915  1 cladd=
0.94996  2 gapd=0.83566  3 end
end celldata
read param run=yes gen=805 npg=1000 nsk=5 end param
read geom
unit 1
array 3 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -12.5603 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 2
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 3
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 4
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 5
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -11.9761 213.36 -193.04
unit 6
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 12.7762 -11.9761 213.36 -193.04
unit 7
array 1 -10.9728 -10.9728 -175.2601
```

```
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.2395 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 8
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
unit 9
array 2 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 12.5603 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 10
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 11
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
```

```
unit 12
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 13
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.9761 -11.8745 213.36 -193.04
unit 14
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.2395 -11.3411 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 11.9761 -12.7762 213.36 -193.04
unit 15
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.2395 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 16
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
```

```
cuboid 8 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
unit 17
array 2 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -12.5603 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 18
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 19
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 20
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 21
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
```

```
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -11.9761 213.36 -193.04
unit 22
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 12.7762 -11.9761 213.36 -193.04
unit 23
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.2395 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 24
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
unit 25
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 12.5603 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 26
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
```

```
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 27
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 28
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 29
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.8745 213.36 -193.04
unit 30
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.3411 -11.2395 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 11.9761 -12.7762 213.36 -193.04
unit 31
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.2395 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 32
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
'plug
unit 331
xcylinder 4 1 2.0701 0.050799 0.0
unit 332
cuboid 9 1 0.050799 -0.0 2p10.4013 2p10.16
hole 331 0.0  5.55 0.0
hole 331 0.0 -5.55 0.0
unit 341
ycylinder 4 1 2.0701 0.0 -0.050799
unit 342
cuboid 9 1 2p10.4013 0.0 -0.050799 2p10.16
hole 341  5.55 0.0 0.0
hole 341 -5.55 0.0 0.0
unit 351
xcylinder 4 1 2.0701 0.050799 -0.050799
unit 352
cuboid 9 1 2p0.050799 2p10.4013 2p10.16
hole 351 0.0  5.55 0.0
hole 351 0.0 -5.55 0.0
unit 361
ycylinder 4 1 2.0701 0.050799 -0.050799
unit 362
cuboid 9 1 2p10.4013 2p0.050799 2p10.16
hole 361  5.55 0.0 0.0
hole 361 -5.55 0.0 0.0
' poison plate
unit 33
array 33 0.0 -10.4013 -182.88
unit 34
array 34 -10.4013 -0.050799 -182.88
unit 35
array 35 -0.050799 -10.4013 -182.88
unit 36
array 36 -10.4013 -0.050799 -182.88
```

```
' exterior fuel compart ment and al plate
unit 37
cuboid 8 1 1.27 -0.0 2p46.3952 213.36 -193.04
cuboid 4 1 1.5367 -0.0 2p46.3952 213.36 -193.04
unit 38
cuboid 8 1 2p46.3952 1.27 -0.0 213.36 -193.04
cuboid 4 1 2p46.3952 1.5367 -0.0 213.36 -193.04
' fuel
unit 41
array 12 -48.9204 0.0 -193.04
unit 42
array 13 -48.9204 -23.2156 -193.04
unit 43
array 14 0.0 -49.1871 -193.04
unit 44
array 15 -22.5806 -49.1871 -193.04
' exetrior steel waraper
unit 45
cuboid 4 1 0.2667 -0.0 22.3013 -0.0 213.36 -193.04
' fuel pin
unit 51
cylinder 1 1 0.409575 182.88 -182.88
cylinder 3 1 0.417830 182.88 -182.88
cylinder 2 1 0.474980 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' guide tube
unit 52
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' instrument tube
unit 53
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' pra
unit 54
cylinder 6 1 0.37465 182.88 -182.88
cylinder 0 1 0.41783 182.88 -182.88
cylinder 4 1 0.47498 182.88 -182.88
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' tc lance
unit 55
cylinder 15 1 0.37084 182.88 -182.88
cylinder  0 1 0.57150 182.88 -182.88
cylinder  2 1 0.61214 182.88 -182.88
cuboid    5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
'
global
unit 47
```

```
array 16 -48.9204 -48.2854 -193.04
cylinder 10 1 87.3125 213.36 -193.04
hole 41  0.0        48.2855 0.0
hole 42  0.0       -48.2855 0.0
hole 43  48.9205    0.0     0.0
hole 44 -48.9205    0.0     0.0
hole 37  71.5012    0.0     0.0
hole 37 -73.0379    0.0     0.0
hole 38  0.0        71.5012 0.0
hole 38  0.0       -73.0379 0.0
hole 45  48.92051  49.1872 0.0
hole 45 -49.18721  49.1872 0.0
hole 45  48.9205  -71.4885 0.0
hole 45 -49.1872  -71.4885 0.0
cylinder   5 1  87.3125 213.3600 -193.0400
cylinder   0 1  87.3125 221.6150 -193.0400
cylinder  16 1 111.4425 248.2850 -219.0750
replicate 17 1 3*3.0  10
end geom
read array
ara=1 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 52 51 51 52 51 51 52 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
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 51 51 52 51 51 52 51 51 52 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' pra
ara=2 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 54 51 51 51 51 51 51 51 51 51 54 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 54 51 51 54 51 51 54 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 53 51 51 54 51 51 54 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 54 51 51 54 51 51 54 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 54 51 51 51 51 51 51 51 51 51 54 51 51 51
 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' tc lance
ara=3 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 55 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 52 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
ara=12 nux=4 fill 24 23  7  8 end fill
ara=13 nux=4 fill 32 31 15 16 end fill
ara=14 nuy=4 fill 14 11  3  6 end fill
ara=15 nuy=4 fill 30 27 19 22 end fill
ara=16 nux=4 nuy=4 fill 29 28 12 13 26 25 9 10 18 17 1 2 21 20 4
5 end fill
ara=33 nuz=18 fill f332 end fill
ara=34 nuz=18 fill f342 end fill
ara=35 nuz=18 fill f352 end fill
ara=36 nuz=18 fill f362 end fill
end array
read bounds
all=vacuum
end bounds
end data
end
```

```
=csas5 parm=nitawl
tn-32 demo cask mrc ambw
44groupndf5
read comp
uo2    1 0.960 293.0 92235 4.60 92238 95.40 end
zirc4  2 1.0   293.0 end
h2o    3 1.0   293.0 end
' fuel compartment
ss304  4 1.0   293.0 end
' moderation 80.0%
h2o    5 0.800 293.0 end
boron  5 den=0.00250 0.800 293.0 end
' pra
b4c    6 0.50 293.0 end
' cask iterior water
h2o    7 1.0 293.0 end
' al plate
al     8 1.0 293.0 end
' poison plate borated aluminum 9 mg/cm**2 0.04" thick plate
boron 9 den=2.693 0.039267 293.0 5010 83.77 5011 16.23 end
al    9 den=2.693 0.960733 293.0 end
' rail
al    10 0.303 293.0 end
boron 10 den=0.002500 0.697 293.0 end
h2o   10 0.697 293.0 end
' tc lance
al    15 1.0 293.0 end
' cask shell
carbonsteel 16 1.0 293.0 end
' exterior water
h2o         17 1.0 293.0 end
end comp
read celldata
latticecell squarepitch pitch=1.25984  5 fueld=0.81915  1 cladd=
0.94996  2 gapd=0.83566  3 end
end celldata
read param run=yes gen=805 npg=1000 nsk=5 end param
read geom
unit 1
array 3 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -12.5603 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 2
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 3
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 4
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 5
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -11.9761 213.36 -193.04
unit 6
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 12.7762 -11.9761 213.36 -193.04
unit 7
array 1 -10.9728 -10.9728 -175.2601
```

```
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.2395 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 8
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
unit 9
array 2 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 12.5603 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 10
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 11
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
```

```
unit 12
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 13
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.9761 -11.8745 213.36 -193.04
unit 14
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.2395 -11.3411 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 11.9761 -12.7762 213.36 -193.04
unit 15
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.2395 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 16
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
```

```
cuboid 8 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
unit 17
array 2 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -12.5603 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 18
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 19
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 20
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 21
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
```

```
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -11.9761 213.36 -193.04
unit 22
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 12.7762 -11.9761 213.36 -193.04
unit 23
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.2395 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 24
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
unit 25
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 12.5603 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 26
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
```

```
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 27
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 28
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 29
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.8745 213.36 -193.04
unit 30
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.3411 -11.2395 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 11.9761 -12.7762 213.36 -193.04
unit 31
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.2395 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 32
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
'plug
unit 331
xcylinder 4 1 2.0701 0.050799 0.0
unit 332
cuboid 9 1 0.050799 -0.0 2p10.4013 2p10.16
hole 331 0.0  5.55 0.0
hole 331 0.0 -5.55 0.0
unit 341
ycylinder 4 1 2.0701 0.0 -0.050799
unit 342
cuboid 9 1 2p10.4013 0.0 -0.050799 2p10.16
hole 341  5.55 0.0 0.0
hole 341 -5.55 0.0 0.0
unit 351
xcylinder 4 1 2.0701 0.050799 -0.050799
unit 352
cuboid 9 1 2p0.050799 2p10.4013 2p10.16
hole 351 0.0  5.55 0.0
hole 351 0.0 -5.55 0.0
unit 361
ycylinder 4 1 2.0701 0.050799 -0.050799
unit 362
cuboid 9 1 2p10.4013 2p0.050799 2p10.16
hole 361  5.55 0.0 0.0
hole 361 -5.55 0.0 0.0
' poison plate
unit 33
array 33 0.0 -10.4013 -182.88
unit 34
array 34 -10.4013 -0.050799 -182.88
unit 35
array 35 -0.050799 -10.4013 -182.88
unit 36
array 36 -10.4013 -0.050799 -182.88
```

```
' exterior fuel compart ment and al plate
unit 37
cuboid 8 1 1.27 -0.0 2p46.3952 213.36 -193.04
cuboid 4 1 1.5367 -0.0 2p46.3952 213.36 -193.04
unit 38
cuboid 8 1 2p46.3952 1.27 -0.0 213.36 -193.04
cuboid 4 1 2p46.3952 1.5367 -0.0 213.36 -193.04
' fuel
unit 41
array 12 -48.9204 0.0 -193.04
unit 42
array 13 -48.9204 -23.2156 -193.04
unit 43
array 14 0.0 -49.1871 -193.04
unit 44
array 15 -22.5806 -49.1871 -193.04
' exetrior steel waraper
unit 45
cuboid 4 1 0.2667 -0.0 22.3013 -0.0 213.36 -193.04
' fuel pin
unit 51
cylinder 1 1 0.409575 182.88 -182.88
cylinder 3 1 0.417830 182.88 -182.88
cylinder 2 1 0.474980 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' guide tube
unit 52
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' instrument tube
unit 53
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' pra
unit 54
cylinder 6 1 0.37465 182.88 -182.88
cylinder 0 1 0.41783 182.88 -182.88
cylinder 4 1 0.47498 182.88 -182.88
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' tc lance
unit 55
cylinder 15 1 0.37084 182.88 -182.88
cylinder  0 1 0.57150 182.88 -182.88
cylinder  2 1 0.61214 182.88 -182.88
cuboid    5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
'
global
unit 47
```

```
array 16 -48.9204 -48.2854 -193.04
cylinder 10 1 87.3125 213.36 -193.04
hole 41  0.0        48.2855 0.0
hole 42  0.0       -48.2855 0.0
hole 43  48.9205     0.0    0.0
hole 44 -48.9205     0.0    0.0
hole 37  71.5012     0.0    0.0
hole 37 -73.0379     0.0    0.0
hole 38  0.0        71.5012 0.0
hole 38  0.0       -73.0379 0.0
hole 45  48.92051  49.1872 0.0
hole 45 -49.18721  49.1872 0.0
hole 45  48.9205  -71.4885 0.0
hole 45 -49.1872  -71.4885 0.0
cylinder   5 1  87.3125 213.3600 -193.0400
cylinder   0 1  87.3125 221.6150 -193.0400
cylinder  16 1 111.4425 248.2850 -219.0750
replicate 17 1 3*3.0  10
end geom
read array
ara=1 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
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 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' pra
ara=2 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 54 51 51 51 51 51 51 51 51 51 54 51 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 53 51 51 54 51 51 54 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 54 51 51 54 51 51 54 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
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 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' tc lance
ara=3 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
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 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
ara=12 nux=4 fill 24 23  7  8 end fill
ara=13 nux=4 fill 32 31 15 16 end fill
ara=14 nuy=4 fill 14 11  3  6 end fill
ara=15 nuy=4 fill 30 27 19 22 end fill
ara=16 nux=4 nuy=4 fill 29 28 12 13 26 25 9 10 18 17 1 2 21 20 4
5 end fill
ara=33 nuz=18 fill f332 end fill
ara=34 nuz=18 fill f342 end fill
ara=35 nuz=18 fill f352 end fill
ara=36 nuz=18 fill f362 end fill
end array
read bounds
all=vacuum
end bounds
end data
end
```

```
=csas5 parm=nitawl
tn-32 demo cask mrc ambw
44groupndf5
read comp
uo2    1 0.960 293.0 92235 4.60 92238 95.40 end
zirc4  2 1.0   293.0 end
h2o    3 1.0   293.0 end
' fuel compartment
ss304  4 1.0   293.0 end
' moderation 80.0%
h2o    5 0.800 293.0 end
boron  5 den=0.00250 0.800 293.0 end
' pra
b4c    6 0.50 293.0 end
' cask iterior water
h2o    7 1.0 293.0 end
' al plate
al     8 1.0 293.0 end
' poison plate borated aluminum 9 mg/cm**2 0.04" thick plate
boron 9 den=2.693 0.039267 293.0 5010 83.77 5011 16.23 end
al    9 den=2.693 0.960733 293.0 end
' rail
al    10 0.303 293.0 end
boron 10 den=0.002500 0.697 293.0 end
h2o   10 0.697 293.0 end
' tc lance
al    15 1.0 293.0 end
' cask shell
carbonsteel 16 1.0 293.0 end
' exterior water
h2o         17 1.0 293.0 end
end comp
read celldata
latticecell squarepitch pitch=1.25984  5 fueld=0.81915  1 cladd=
0.94996  2 gapd=0.83566  3 end
end celldata
read param run=yes gen=805 npg=1000 nsk=5 end param
read geom
unit 1
array 3 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -12.5603 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 2
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 3
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 4
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 5
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -11.9761 213.36 -193.04
unit 6
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 12.7762 -11.9761 213.36 -193.04
unit 7
array 1 -10.9728 -10.9728 -175.2601
```

```
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.2395 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 8
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
unit 9
array 2 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 12.5603 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 10
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 11
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
```

```
unit 12
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 13
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.9761 -11.8745 213.36 -193.04
unit 14
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.2395 -11.3411 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 11.9761 -12.7762 213.36 -193.04
unit 15
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.2395 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 16
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
```

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cuboid 8 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
unit 17
array 2 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -12.5603 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 18
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 19
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 20
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 21
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
```

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hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -11.9761 213.36 -193.04
unit 22
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 12.7762 -11.9761 213.36 -193.04
unit 23
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.2395 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 24
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
unit 25
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 12.5603 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 26
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
```

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cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 27
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 28
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 29
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.8745 213.36 -193.04
unit 30
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.3411 -11.2395 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 11.9761 -12.7762 213.36 -193.04
unit 31
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
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cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.2395 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 32
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
'plug
unit 331
xcylinder 4 1 2.0701 0.050799 0.0
unit 332
cuboid 9 1 0.050799 -0.0 2p10.4013 2p10.16
hole 331 0.0  5.55 0.0
hole 331 0.0 -5.55 0.0
unit 341
ycylinder 4 1 2.0701 0.0 -0.050799
unit 342
cuboid 9 1 2p10.4013 0.0 -0.050799 2p10.16
hole 341  5.55 0.0 0.0
hole 341 -5.55 0.0 0.0
unit 351
xcylinder 4 1 2.0701 0.050799 -0.050799
unit 352
cuboid 9 1 2p0.050799 2p10.4013 2p10.16
hole 351 0.0  5.55 0.0
hole 351 0.0 -5.55 0.0
unit 361
ycylinder 4 1 2.0701 0.050799 -0.050799
unit 362
cuboid 9 1 2p10.4013 2p0.050799 2p10.16
hole 361  5.55 0.0 0.0
hole 361 -5.55 0.0 0.0
' poison plate
unit 33
array 33 0.0 -10.4013 -182.88
unit 34
array 34 -10.4013 -0.050799 -182.88
unit 35
array 35 -0.050799 -10.4013 -182.88
unit 36
array 36 -10.4013 -0.050799 -182.88
```

```
' exterior fuel compart ment and al plate
unit 37
cuboid 8 1 1.27 -0.0 2p46.3952 213.36 -193.04
cuboid 4 1 1.5367 -0.0 2p46.3952 213.36 -193.04
unit 38
cuboid 8 1 2p46.3952 1.27 -0.0 213.36 -193.04
cuboid 4 1 2p46.3952 1.5367 -0.0 213.36 -193.04
' fuel
unit 41
array 12 -48.9204 0.0 -193.04
unit 42
array 13 -48.9204 -23.2156 -193.04
unit 43
array 14 0.0 -49.1871 -193.04
unit 44
array 15 -22.5806 -49.1871 -193.04
' exetrior steel waraper
unit 45
cuboid 4 1 0.2667 -0.0 22.3013 -0.0 213.36 -193.04
' fuel pin
unit 51
cylinder 1 1 0.409575 182.88 -182.88
cylinder 3 1 0.417830 182.88 -182.88
cylinder 2 1 0.474980 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' guide tube
unit 52
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' instrument tube
unit 53
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' pra
unit 54
cylinder 6 1 0.37465 182.88 -182.88
cylinder 0 1 0.41783 182.88 -182.88
cylinder 4 1 0.47498 182.88 -182.88
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' tc lance
unit 55
cylinder 15 1 0.37084 182.88 -182.88
cylinder  0 1 0.57150 182.88 -182.88
cylinder  2 1 0.61214 182.88 -182.88
cuboid    5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
'
global
unit 47
```

```
array 16 -48.9204 -48.2854 -193.04
cylinder 10 1 87.3125 213.36 -193.04
hole 41  0.0        48.2855 0.0
hole 42  0.0       -48.2855 0.0
hole 43  48.9205     0.0    0.0
hole 44 -48.9205     0.0    0.0
hole 37  71.5012     0.0    0.0
hole 37 -73.0379     0.0    0.0
hole 38  0.0        71.5012 0.0
hole 38  0.0       -73.0379 0.0
hole 45  48.92051  49.1872 0.0
hole 45 -49.18721  49.1872 0.0
hole 45  48.9205  -71.4885 0.0
hole 45 -49.1872  -71.4885 0.0
cylinder   5 1  87.3125 213.3600 -193.0400
cylinder   0 1  87.3125 221.6150 -193.0400
cylinder  16 1 111.4425 248.2850 -219.0750
replicate 17 1 3*3.0  10
end geom
read array
ara=1 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
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 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' pra
ara=2 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 54 51 51 51 51 51 51 51 51 51 54 51 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 53 51 51 54 51 51 54 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
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 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' tc lance
ara=3 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 55 51 51 52 51 51 52 51 51
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 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
ara=12 nux=4 fill 24 23  7  8 end fill
ara=13 nux=4 fill 32 31 15 16 end fill
ara=14 nuy=4 fill 14 11  3  6 end fill
ara=15 nuy=4 fill 30 27 19 22 end fill
ara=16 nux=4 nuy=4 fill 29 28 12 13 26 25 9 10 18 17 1 2 21 20 4
5 end fill
ara=33 nuz=18 fill f332 end fill
ara=34 nuz=18 fill f342 end fill
ara=35 nuz=18 fill f352 end fill
ara=36 nuz=18 fill f362 end fill
end array
read bounds
all=vacuum
end bounds
end data
end
```

```
=csas5 parm=nitawl
tn-32 demo cask mrc ambw
44groupndf5
read comp
uo2    1 0.960 293.0 92235 4.60 92238 95.40 end
zirc4  2 1.0   293.0 end
h2o    3 1.0   293.0 end
' fuel compartment
ss304  4 1.0   293.0 end
' moderation 85.0%
h2o    5 0.850 293.0 end
boron  5 den=0.00250 0.850 293.0 end
' pra
b4c    6 0.50 293.0 end
' cask iterior water
h2o    7 1.0 293.0 end
' al plate
al     8 1.0 293.0 end
' poison plate borated aluminum 9 mg/cm**2 0.04" thick plate
boron 9 den=2.693 0.039267 293.0 5010 83.77 5011 16.23 end
al    9 den=2.693 0.960733 293.0 end
' rail
al    10 0.303 293.0 end
boron 10 den=0.002500 0.697 293.0 end
h2o   10 0.697 293.0 end
' tc lance
al    15 1.0 293.0 end
' cask shell
carbonsteel 16 1.0 293.0 end
' exterior water
h2o          17 1.0 293.0 end
end comp
read celldata
latticecell squarepitch pitch=1.25984  5 fueld=0.81915  1 cladd=
0.94996  2 gapd=0.83566  3 end
end celldata
read param run=yes gen=805 npg=1000 nsk=5 end param
read geom
unit 1
array 3 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -12.5603 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 2
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 3
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 4
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 5
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -11.9761 213.36 -193.04
unit 6
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 12.7762 -11.9761 213.36 -193.04
unit 7
array 1 -10.9728 -10.9728 -175.2601
```

```
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.2395 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 8
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
unit 9
array 2 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 12.5603 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 10
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 11
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
```

```
unit 12
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 13
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.9761 -11.8745 213.36 -193.04
unit 14
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.2395 -11.3411 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 11.9761 -12.7762 213.36 -193.04
unit 15
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.2395 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 16
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
```

```
cuboid 8 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
unit 17
array 2 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -12.5603 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 18
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 19
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 20
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 21
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
```

```
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -11.9761 213.36 -193.04
unit 22
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 12.7762 -11.9761 213.36 -193.04
unit 23
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.2395 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 24
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
unit 25
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 12.5603 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 26
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
```

```
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 27
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 28
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 29
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.8745 213.36 -193.04
unit 30
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.3411 -11.2395 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 11.9761 -12.7762 213.36 -193.04
unit 31
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.2395 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 32
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
'plug
unit 331
xcylinder 4 1 2.0701 0.050799 0.0
unit 332
cuboid 9 1 0.050799 -0.0 2p10.4013 2p10.16
hole 331 0.0  5.55 0.0
hole 331 0.0 -5.55 0.0
unit 341
ycylinder 4 1 2.0701 0.0 -0.050799
unit 342
cuboid 9 1 2p10.4013 0.0 -0.050799 2p10.16
hole 341  5.55 0.0 0.0
hole 341 -5.55 0.0 0.0
unit 351
xcylinder 4 1 2.0701 0.050799 -0.050799
unit 352
cuboid 9 1 2p0.050799 2p10.4013 2p10.16
hole 351 0.0  5.55 0.0
hole 351 0.0 -5.55 0.0
unit 361
ycylinder 4 1 2.0701 0.050799 -0.050799
unit 362
cuboid 9 1 2p10.4013 2p0.050799 2p10.16
hole 361  5.55 0.0 0.0
hole 361 -5.55 0.0 0.0
' poison plate
unit 33
array 33 0.0 -10.4013 -182.88
unit 34
array 34 -10.4013 -0.050799 -182.88
unit 35
array 35 -0.050799 -10.4013 -182.88
unit 36
array 36 -10.4013 -0.050799 -182.88
```

```
' exterior fuel compart ment and al plate
unit 37
cuboid 8 1 1.27 -0.0 2p46.3952 213.36 -193.04
cuboid 4 1 1.5367 -0.0 2p46.3952 213.36 -193.04
unit 38
cuboid 8 1 2p46.3952 1.27 -0.0 213.36 -193.04
cuboid 4 1 2p46.3952 1.5367 -0.0 213.36 -193.04
' fuel
unit 41
array 12 -48.9204 0.0 -193.04
unit 42
array 13 -48.9204 -23.2156 -193.04
unit 43
array 14 0.0 -49.1871 -193.04
unit 44
array 15 -22.5806 -49.1871 -193.04
' exetrior steel waraper
unit 45
cuboid 4 1 0.2667 -0.0 22.3013 -0.0 213.36 -193.04
' fuel pin
unit 51
cylinder 1 1 0.409575 182.88 -182.88
cylinder 3 1 0.417830 182.88 -182.88
cylinder 2 1 0.474980 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' guide tube
unit 52
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' instrument tube
unit 53
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' pra
unit 54
cylinder 6 1 0.37465 182.88 -182.88
cylinder 0 1 0.41783 182.88 -182.88
cylinder 4 1 0.47498 182.88 -182.88
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' tc lance
unit 55
cylinder 15 1 0.37084 182.88 -182.88
cylinder  0 1 0.57150 182.88 -182.88
cylinder  2 1 0.61214 182.88 -182.88
cuboid    5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
'
global
unit 47
```

```
array 16 -48.9204 -48.2854 -193.04
cylinder 10 1 87.3125 213.36 -193.04
hole 41  0.0        48.2855 0.0
hole 42  0.0       -48.2855 0.0
hole 43  48.9205    0.0     0.0
hole 44 -48.9205    0.0     0.0
hole 37  71.5012    0.0     0.0
hole 37 -73.0379    0.0     0.0
hole 38  0.0        71.5012 0.0
hole 38  0.0       -73.0379 0.0
hole 45  48.92051  49.1872 0.0
hole 45 -49.18721  49.1872 0.0
hole 45  48.9205  -71.4885 0.0
hole 45 -49.1872  -71.4885 0.0
cylinder   5 1  87.3125 213.3600 -193.0400
cylinder   0 1  87.3125 221.6150 -193.0400
cylinder  16 1 111.4425 248.2850 -219.0750
replicate 17 1 3*3.0  10
end geom
read array
ara=1 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 52 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
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 51 51 52 51 51 52 51 51 52 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' pra
ara=2 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 54 51 51 51 51 51 51 51 51 51 54 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 54 51 51 54 51 51 54 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 53 51 51 54 51 51 54 51 51
```

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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 54 51 51 54 51 51 54 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 54 51 51 51 51 51 51 51 51 51 54 51 51 51
 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' tc lance
ara=3 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 55 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 52 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
ara=12 nux=4 fill 24 23  7  8 end fill
ara=13 nux=4 fill 32 31 15 16 end fill
ara=14 nuy=4 fill 14 11  3  6 end fill
ara=15 nuy=4 fill 30 27 19 22 end fill
ara=16 nux=4 nuy=4 fill 29 28 12 13 26 25 9 10 18 17 1 2 21 20 4
5 end fill
ara=33 nuz=18 fill f332 end fill
ara=34 nuz=18 fill f342 end fill
ara=35 nuz=18 fill f352 end fill
ara=36 nuz=18 fill f362 end fill
end array
read bounds
all=vacuum
end bounds
end data
end
```

```
=csas5 parm=nitawl
tn-32 demo cask mrc ambw
44groupndf5
read comp
uo2    1 0.960 293.0 92235 4.60 92238 95.40 end
zirc4  2 1.0   293.0 end
h2o    3 1.0   293.0 end
' fuel compartment
ss304  4 1.0   293.0 end
' moderation 90.0%
h2o    5 0.900 293.0 end
boron  5 den=0.00250 0.900 293.0 end
' pra
b4c    6 0.50 293.0 end
' cask iterior water
h2o    7 1.0 293.0 end
' al plate
al     8 1.0 293.0 end
' poison plate borated aluminum 9 mg/cm**2 0.04" thick plate
boron 9 den=2.693 0.039267 293.0 5010 83.77 5011 16.23 end
al    9 den=2.693 0.960733 293.0 end
' rail
al    10 0.303 293.0 end
boron 10 den=0.002500 0.697 293.0 end
h2o   10 0.697 293.0 end
' tc lance
al    15 1.0 293.0 end
' cask shell
carbonsteel 16 1.0 293.0 end
' exterior water
h2o         17 1.0 293.0 end
end comp
read celldata
latticecell squarepitch pitch=1.25984  5 fueld=0.81915  1 cladd=
0.94996  2 gapd=0.83566  3 end
end celldata
read param run=yes gen=805 npg=1000 nsk=5 end param
read geom
unit 1
array 3 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -12.5603 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 2
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 3
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 4
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 5
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -11.9761 213.36 -193.04
unit 6
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 12.7762 -11.9761 213.36 -193.04
unit 7
array 1 -10.9728 -10.9728 -175.2601
```

```
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.2395 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 8
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
unit 9
array 2 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 12.5603 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 10
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 11
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
```

```
unit 12
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 13
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.9761 -11.8745 213.36 -193.04
unit 14
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.2395 -11.3411 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 11.9761 -12.7762 213.36 -193.04
unit 15
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.2395 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 16
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
```

```
cuboid 8 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
unit 17
array 2 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -12.5603 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 18
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 19
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 20
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 21
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
```

```
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -11.9761 213.36 -193.04
unit 22
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 12.7762 -11.9761 213.36 -193.04
unit 23
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.2395 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 24
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
unit 25
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 12.5603 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 26
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
```

```
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 27
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 28
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 29
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.8745 213.36 -193.04
unit 30
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.3411 -11.2395 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 11.9761 -12.7762 213.36 -193.04
unit 31
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.2395 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 32
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
'plug
unit 331
xcylinder 4 1 2.0701 0.050799 0.0
unit 332
cuboid 9 1 0.050799 -0.0 2p10.4013 2p10.16
hole 331 0.0  5.55 0.0
hole 331 0.0 -5.55 0.0
unit 341
ycylinder 4 1 2.0701 0.0 -0.050799
unit 342
cuboid 9 1 2p10.4013 0.0 -0.050799 2p10.16
hole 341  5.55 0.0 0.0
hole 341 -5.55 0.0 0.0
unit 351
xcylinder 4 1 2.0701 0.050799 -0.050799
unit 352
cuboid 9 1 2p0.050799 2p10.4013 2p10.16
hole 351 0.0  5.55 0.0
hole 351 0.0 -5.55 0.0
unit 361
ycylinder 4 1 2.0701 0.050799 -0.050799
unit 362
cuboid 9 1 2p10.4013 2p0.050799 2p10.16
hole 361  5.55 0.0 0.0
hole 361 -5.55 0.0 0.0
' poison plate
unit 33
array 33 0.0 -10.4013 -182.88
unit 34
array 34 -10.4013 -0.050799 -182.88
unit 35
array 35 -0.050799 -10.4013 -182.88
unit 36
array 36 -10.4013 -0.050799 -182.88
```

```
' exterior fuel compart ment and al plate
unit 37
cuboid 8 1 1.27 -0.0 2p46.3952 213.36 -193.04
cuboid 4 1 1.5367 -0.0 2p46.3952 213.36 -193.04
unit 38
cuboid 8 1 2p46.3952 1.27 -0.0 213.36 -193.04
cuboid 4 1 2p46.3952 1.5367 -0.0 213.36 -193.04
' fuel
unit 41
array 12 -48.9204 0.0 -193.04
unit 42
array 13 -48.9204 -23.2156 -193.04
unit 43
array 14 0.0 -49.1871 -193.04
unit 44
array 15 -22.5806 -49.1871 -193.04
' exetrior steel waraper
unit 45
cuboid 4 1 0.2667 -0.0 22.3013 -0.0 213.36 -193.04
' fuel pin
unit 51
cylinder 1 1 0.409575 182.88 -182.88
cylinder 3 1 0.417830 182.88 -182.88
cylinder 2 1 0.474980 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' guide tube
unit 52
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' instrument tube
unit 53
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' pra
unit 54
cylinder 6 1 0.37465 182.88 -182.88
cylinder 0 1 0.41783 182.88 -182.88
cylinder 4 1 0.47498 182.88 -182.88
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' tc lance
unit 55
cylinder 15 1 0.37084 182.88 -182.88
cylinder  0 1 0.57150 182.88 -182.88
cylinder  2 1 0.61214 182.88 -182.88
cuboid    5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
'
global
unit 47
```

```
array 16 -48.9204 -48.2854 -193.04
cylinder 10 1 87.3125 213.36 -193.04
hole 41  0.0        48.2855 0.0
hole 42  0.0       -48.2855 0.0
hole 43  48.9205    0.0     0.0
hole 44 -48.9205    0.0     0.0
hole 37  71.5012    0.0     0.0
hole 37 -73.0379    0.0     0.0
hole 38  0.0        71.5012 0.0
hole 38  0.0       -73.0379 0.0
hole 45  48.92051  49.1872 0.0
hole 45 -49.18721  49.1872 0.0
hole 45  48.9205  -71.4885 0.0
hole 45 -49.1872  -71.4885 0.0
cylinder   5 1  87.3125 213.3600 -193.0400
cylinder   0 1  87.3125 221.6150 -193.0400
cylinder  16 1 111.4425 248.2850 -219.0750
replicate 17 1 3*3.0  10
end geom
read array
ara=1 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 52 51 51 52 51 51 52 51 51
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 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' pra
ara=2 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 54 51 51 51 51 51 51 51 51 51 54 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 53 51 51 54 51 51 54 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 54 51 51 54 51 51 54 51 51 54 51 51 54 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 54 51 51 51 51 51 51 51 51 51 54 51 51 51
 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' tc lance
ara=3 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
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 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
ara=12 nux=4 fill 24 23  7  8 end fill
ara=13 nux=4 fill 32 31 15 16 end fill
ara=14 nuy=4 fill 14 11  3  6 end fill
ara=15 nuy=4 fill 30 27 19 22 end fill
ara=16 nux=4 nuy=4 fill 29 28 12 13 26 25 9 10 18 17 1 2 21 20 4
5 end fill
ara=33 nuz=18 fill f332 end fill
ara=34 nuz=18 fill f342 end fill
ara=35 nuz=18 fill f352 end fill
ara=36 nuz=18 fill f362 end fill
end array
read bounds
all=vacuum
end bounds
end data
end
```

```
=csas5 parm=nitawl
tn-32 demo cask mrc ambw
44groupndf5
read comp
uo2    1 0.960 293.0 92235 4.60 92238 95.40 end
zirc4  2 1.0   293.0 end
h2o    3 1.0   293.0 end
' fuel compartment
ss304  4 1.0   293.0 end
' moderation 95.0%
h2o    5 0.950 293.0 end
boron  5 den=0.00250 0.950 293.0 end
' pra
b4c    6 0.50 293.0 end
' cask iterior water
h2o    7 1.0 293.0 end
' al plate
al     8 1.0 293.0 end
' poison plate borated aluminum 9 mg/cm**2 0.04" thick plate
boron 9 den=2.693 0.039267 293.0 5010 83.77 5011 16.23 end
al    9 den=2.693 0.960733 293.0 end
' rail
al    10 0.303 293.0 end
boron 10 den=0.002500 0.697 293.0 end
h2o   10 0.697 293.0 end
' tc lance
al    15 1.0 293.0 end
' cask shell
carbonsteel 16 1.0 293.0 end
' exterior water
h2o         17 1.0 293.0 end
end comp
read celldata
latticecell squarepitch pitch=1.25984  5 fueld=0.81915  1 cladd=
0.94996  2 gapd=0.83566  3 end
end celldata
read param run=yes gen=805 npg=1000 nsk=5 end param
read geom
unit 1
array 3 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -12.5603 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 2
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 3
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 4
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 5
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -11.9761 213.36 -193.04
unit 6
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 12.7762 -11.9761 213.36 -193.04
unit 7
array 1 -10.9728 -10.9728 -175.2601
```

```
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.2395 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 8
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
unit 9
array 2 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 12.5603 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 10
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 11
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
```

```
unit 12
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 13
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.9761 -11.8745 213.36 -193.04
unit 14
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.2395 -11.3411 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 11.9761 -12.7762 213.36 -193.04
unit 15
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.2395 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 16
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
```

```
cuboid 8 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
unit 17
array 2 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -12.5603 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 18
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 19
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 20
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 21
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
```

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hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -11.9761 213.36 -193.04
unit 22
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 12.7762 -11.9761 213.36 -193.04
unit 23
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.2395 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 24
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
unit 25
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 12.5603 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 26
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
```

```
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 27
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 28
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 29
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.8745 213.36 -193.04
unit 30
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.3411 -11.2395 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 11.9761 -12.7762 213.36 -193.04
unit 31
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

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cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.2395 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 32
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
'plug
unit 331
xcylinder 4 1 2.0701 0.050799 0.0
unit 332
cuboid 9 1 0.050799 -0.0 2p10.4013 2p10.16
hole 331 0.0  5.55 0.0
hole 331 0.0 -5.55 0.0
unit 341
ycylinder 4 1 2.0701 0.0 -0.050799
unit 342
cuboid 9 1 2p10.4013 0.0 -0.050799 2p10.16
hole 341  5.55 0.0 0.0
hole 341 -5.55 0.0 0.0
unit 351
xcylinder 4 1 2.0701 0.050799 -0.050799
unit 352
cuboid 9 1 2p0.050799 2p10.4013 2p10.16
hole 351 0.0  5.55 0.0
hole 351 0.0 -5.55 0.0
unit 361
ycylinder 4 1 2.0701 0.050799 -0.050799
unit 362
cuboid 9 1 2p10.4013 2p0.050799 2p10.16
hole 361  5.55 0.0 0.0
hole 361 -5.55 0.0 0.0
' poison plate
unit 33
array 33 0.0 -10.4013 -182.88
unit 34
array 34 -10.4013 -0.050799 -182.88
unit 35
array 35 -0.050799 -10.4013 -182.88
unit 36
array 36 -10.4013 -0.050799 -182.88
```

```
' exterior fuel compart ment and al plate
unit 37
cuboid 8 1 1.27 -0.0 2p46.3952 213.36 -193.04
cuboid 4 1 1.5367 -0.0 2p46.3952 213.36 -193.04
unit 38
cuboid 8 1 2p46.3952 1.27 -0.0 213.36 -193.04
cuboid 4 1 2p46.3952 1.5367 -0.0 213.36 -193.04
' fuel
unit 41
array 12 -48.9204 0.0 -193.04
unit 42
array 13 -48.9204 -23.2156 -193.04
unit 43
array 14 0.0 -49.1871 -193.04
unit 44
array 15 -22.5806 -49.1871 -193.04
' exetrior steel waraper
unit 45
cuboid 4 1 0.2667 -0.0 22.3013 -0.0 213.36 -193.04
' fuel pin
unit 51
cylinder 1 1 0.409575 182.88 -182.88
cylinder 3 1 0.417830 182.88 -182.88
cylinder 2 1 0.474980 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' guide tube
unit 52
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' instrument tube
unit 53
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' pra
unit 54
cylinder 6 1 0.37465 182.88 -182.88
cylinder 0 1 0.41783 182.88 -182.88
cylinder 4 1 0.47498 182.88 -182.88
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' tc lance
unit 55
cylinder 15 1 0.37084 182.88 -182.88
cylinder  0 1 0.57150 182.88 -182.88
cylinder  2 1 0.61214 182.88 -182.88
cuboid    5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
'
global
unit 47
```

```
array 16 -48.9204 -48.2854 -193.04
cylinder 10 1 87.3125 213.36 -193.04
hole 41  0.0        48.2855 0.0
hole 42  0.0       -48.2855 0.0
hole 43  48.9205     0.0    0.0
hole 44 -48.9205     0.0    0.0
hole 37  71.5012     0.0    0.0
hole 37 -73.0379     0.0    0.0
hole 38  0.0        71.5012 0.0
hole 38  0.0       -73.0379 0.0
hole 45  48.92051  49.1872 0.0
hole 45 -49.18721  49.1872 0.0
hole 45  48.9205  -71.4885 0.0
hole 45 -49.1872  -71.4885 0.0
cylinder   5 1  87.3125 213.3600 -193.0400
cylinder   0 1  87.3125 221.6150 -193.0400
cylinder  16 1 111.4425 248.2850 -219.0750
replicate 17 1 3*3.0  10
end geom
read array
ara=1 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
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 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' pra
ara=2 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 54 51 51 51 51 51 51 51 51 51 54 51 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
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 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' tc lance
ara=3 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 55 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 53 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 52 51 51 52 51 51 52 51 51 52 51 51 52 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 52 51 51 51 51 51 51 51 51 51 52 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
ara=12 nux=4 fill 24 23  7  8 end fill
ara=13 nux=4 fill 32 31 15 16 end fill
ara=14 nuy=4 fill 14 11  3  6 end fill
ara=15 nuy=4 fill 30 27 19 22 end fill
ara=16 nux=4 nuy=4 fill 29 28 12 13 26 25 9 10 18 17 1 2 21 20 4
5 end fill
ara=33 nuz=18 fill f332 end fill
ara=34 nuz=18 fill f342 end fill
ara=35 nuz=18 fill f352 end fill
ara=36 nuz=18 fill f362 end fill
end array
read bounds
all=vacuum
end bounds
end data
end
```

```
=csas5 parm=nitawl
tn-32 demo cask mrc ambw
44groupndf5
read comp
uo2    1 0.960 293.0 92235 4.60 92238 95.40 end
zirc4  2 1.0   293.0 end
h2o    3 1.0   293.0 end
' fuel compartment
ss304  4 1.0   293.0 end
' moderation 100.0%
h2o    5 1.000 293.0 end
boron  5 den=0.00250 1.000 293.0 end
' pra
b4c    6 0.50 293.0 end
' cask iterior water
h2o    7 1.0 293.0 end
' al plate
al     8 1.0 293.0 end
' poison plate borated aluminum 9 mg/cm**2 0.04" thick plate
boron 9 den=2.693 0.039267 293.0 5010 83.77 5011 16.23 end
al    9 den=2.693 0.960733 293.0 end
' rail
al    10 0.303 293.0 end
boron 10 den=0.002500 0.697 293.0 end
h2o   10 0.697 293.0 end
' tc lance
al    15 1.0 293.0 end
' cask shell
carbonsteel 16 1.0 293.0 end
' exterior water
h2o         17 1.0 293.0 end
end comp
read celldata
latticecell squarepitch pitch=1.25984  5 fueld=0.81915  1 cladd=
0.94996  2 gapd=0.83566  3 end
end celldata
read param run=yes gen=805 npg=1000 nsk=5 end param
read geom
unit 1
array 3 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -12.5603 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 2
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 3
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 4
array 2 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.8745 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 5
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.8745 -11.9761 213.36 -193.04
unit 6
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 12.7762 -11.9761 213.36 -193.04
unit 7
array 1 -10.9728 -10.9728 -175.2601
```

```
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.2395 -11.9761 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 8
array 1 -10.9728 -10.9728 -175.2601
cuboid 3 1 10.4445 -10.9728 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.2395 -11.3411 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.2395 -11.9761 213.36 -193.04
unit 9
array 2 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 11.8745 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 12.5603 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 10
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 12.5095 -11.9761 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5095 -11.9761 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 11
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 2p11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
cuboid 8 1 11.2395 -11.3411 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
```

```
unit 12
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.8745 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 13
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.9761 11.9761 -11.8745 213.36 -193.04
unit 14
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.2395 -11.3411 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.2395 -11.3411 11.9761 -12.7762 213.36 -193.04
unit 15
array 3 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.8745 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 11.8745 -12.5603 11.9761 -11.2395 213.36 -193.04
hole 33 -12.5603 0.0 0.0
unit 16
array 1 -10.9728 -10.4445 -175.2601
cuboid 3 1 10.4445 -10.9728 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.2395 -11.3411 11.3411 -11.2395 213.36 -193.04
hole 35 -11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
```

```
cuboid 8 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 12.5095 -11.9761 11.9761 -11.2395 213.36 -193.04
unit 17
array 2 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -12.5603 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 -12.5095 0.0
unit 18
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 19
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 11.8745 -12.5095 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.8745 -12.5603 213.36 -193.04
hole 34 0.0 -12.5095 0.0
unit 20
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.8745 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.8745 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 21
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
```

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hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.8745 -11.9761 213.36 -193.04
unit 22
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.9761 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 12.7762 -11.9761 213.36 -193.04
unit 23
array 3 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 3p11.2395 -11.3411 213.36 -193.04
hole 36 0.0 -11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.2395 -11.9761 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.2395 -11.9761 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 24
array 1 -10.4445 -10.9728 -175.2601
cuboid 3 1 10.9728 -10.4445 10.4445 -10.9728 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.2395 -11.3411 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 -11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.2395 -11.9761 213.36 -193.04
unit 25
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 8 1 12.5095 -11.8745 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 12.5603 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
hole 34 0.0 12.5603 0.0
unit 26
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
```

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cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.9761 -12.5095 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.9761 -12.5095 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 27
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 2p11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
cuboid 8 1 11.3411 -11.2395 12.5095 -11.8745 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 12.5603 -11.8745 213.36 -193.04
hole 34 0.0 12.5603 0.0
unit 28
array 2 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.8745 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.8745 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 29
array 3 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.8745 213.36 -193.04
unit 30
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.3411 -11.2395 11.9761 -12.5095 213.36 -193.04
cuboid 4 1 11.3411 -11.2395 11.9761 -12.7762 213.36 -193.04
unit 31
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
```

```
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 2p11.2395 11.3411 -11.2395 213.36 -193.04
hole 36 0.0 11.2903 0.0
cuboid 8 1 12.5095 -11.8745 11.9761 -11.2395 213.36 -193.04
cuboid 0 1 12.5603 -11.8745 11.9761 -11.2395 213.36 -193.04
hole 33 12.5095 0.0 0.0
unit 32
array 1 -10.4445 -10.4445 -175.2601
cuboid 3 1 10.9728 -10.4445 10.9728 -10.4445 190.50 -185.42
cuboid 5 1 4p10.9728 190.50 -193.04
cuboid 7 1 4p10.9728 213.36 -193.04
cuboid 4 1 4p11.2395 213.36 -193.04
cuboid 0 1 11.3411 -11.2395 11.3411 -11.2395 213.36 -193.04
hole 35 11.2903 0.0 0.0
hole 36 0.0 11.2903 0.0
cuboid 8 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
cuboid 4 1 11.9761 -12.5095 11.9761 -11.2395 213.36 -193.04
'plug
unit 331
xcylinder 4 1 2.0701 0.050799 0.0
unit 332
cuboid 9 1 0.050799 -0.0 2p10.4013 2p10.16
hole 331 0.0  5.55 0.0
hole 331 0.0 -5.55 0.0
unit 341
ycylinder 4 1 2.0701 0.0 -0.050799
unit 342
cuboid 9 1 2p10.4013 0.0 -0.050799 2p10.16
hole 341  5.55 0.0 0.0
hole 341 -5.55 0.0 0.0
unit 351
xcylinder 4 1 2.0701 0.050799 -0.050799
unit 352
cuboid 9 1 2p0.050799 2p10.4013 2p10.16
hole 351 0.0  5.55 0.0
hole 351 0.0 -5.55 0.0
unit 361
ycylinder 4 1 2.0701 0.050799 -0.050799
unit 362
cuboid 9 1 2p10.4013 2p0.050799 2p10.16
hole 361  5.55 0.0 0.0
hole 361 -5.55 0.0 0.0
' poison plate
unit 33
array 33 0.0 -10.4013 -182.88
unit 34
array 34 -10.4013 -0.050799 -182.88
unit 35
array 35 -0.050799 -10.4013 -182.88
unit 36
array 36 -10.4013 -0.050799 -182.88
```

```
' exterior fuel compart ment and al plate
unit 37
cuboid 8 1 1.27 -0.0 2p46.3952 213.36 -193.04
cuboid 4 1 1.5367 -0.0 2p46.3952 213.36 -193.04
unit 38
cuboid 8 1 2p46.3952 1.27 -0.0 213.36 -193.04
cuboid 4 1 2p46.3952 1.5367 -0.0 213.36 -193.04
' fuel
unit 41
array 12 -48.9204 0.0 -193.04
unit 42
array 13 -48.9204 -23.2156 -193.04
unit 43
array 14 0.0 -49.1871 -193.04
unit 44
array 15 -22.5806 -49.1871 -193.04
' exetrior steel waraper
unit 45
cuboid 4 1 0.2667 -0.0 22.3013 -0.0 213.36 -193.04
' fuel pin
unit 51
cylinder 1 1 0.409575 182.88 -182.88
cylinder 3 1 0.417830 182.88 -182.88
cylinder 2 1 0.474980 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' guide tube
unit 52
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' instrument tube
unit 53
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' pra
unit 54
cylinder 6 1 0.37465 182.88 -182.88
cylinder 0 1 0.41783 182.88 -182.88
cylinder 4 1 0.47498 182.88 -182.88
cylinder 5 1 0.57150 182.88 -182.88
cylinder 2 1 0.61214 182.88 -182.88
cuboid   5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
' tc lance
unit 55
cylinder 15 1 0.37084 182.88 -182.88
cylinder  0 1 0.57150 182.88 -182.88
cylinder  2 1 0.61214 182.88 -182.88
cuboid    5 1 0.62992 -0.62992 0.62992 -0.62992 182.88 -182.88
'
global
unit 47
```

```
array 16 -48.9204 -48.2854 -193.04
cylinder 10 1 87.3125 213.36 -193.04
hole 41  0.0        48.2855 0.0
hole 42  0.0       -48.2855 0.0
hole 43  48.9205     0.0    0.0
hole 44 -48.9205     0.0    0.0
hole 37  71.5012     0.0    0.0
hole 37 -73.0379     0.0    0.0
hole 38  0.0        71.5012 0.0
hole 38  0.0       -73.0379 0.0
hole 45  48.92051  49.1872 0.0
hole 45 -49.18721  49.1872 0.0
hole 45  48.9205  -71.4885 0.0
hole 45 -49.1872  -71.4885 0.0
cylinder   5 1  87.3125 213.3600 -193.0400
cylinder   0 1  87.3125 221.6150 -193.0400
cylinder  16 1 111.4425 248.2850 -219.0750
replicate 17 1 3*3.0  10
end geom
read array
ara=1 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
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 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' pra
ara=2 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
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 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
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 51 51 51 51 51 54 51 51 54 51 51 54 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
' tc lance
ara=3 nux=17 nuy=17 nuz=1
fill
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
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 51 51 51 51 51 52 51 51 52 51 51 52 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
end fill
ara=12 nux=4 fill 24 23  7  8 end fill
ara=13 nux=4 fill 32 31 15 16 end fill
ara=14 nuy=4 fill 14 11  3  6 end fill
ara=15 nuy=4 fill 30 27 19 22 end fill
ara=16 nux=4 nuy=4 fill 29 28 12 13 26 25 9 10 18 17 1 2 21 20 4
5 end fill
ara=33 nuz=18 fill f332 end fill
ara=34 nuz=18 fill f342 end fill
ara=35 nuz=18 fill f352 end fill
ara=36 nuz=18 fill f362 end fill
end array
read bounds
all=vacuum
end bounds
end data
end
```