9. CONDUCT OF OPERATIONS

9.1 Organizational Structure

9.1.1 Corporate Organization

The ISFSI may be operated under the same corporate management organization which is responsible for operation of the licensee's plant.

9.1.1.1 Corporate Functions, Responsibilities and Authorities

The various departments within the licensee's organization have responsibility for construction, quality assurance, testing and operation of the ISFSI. TN West's corporate functions, responsibilities and authorities for quality assurance, as described in Chapter 11 are applicable for design and procurement of NUHOMS® ISFSI components.

9.1.1.2 Applicant's In-House Organization

The licensee has specific responsibility for design of plant specific structures and systems, specifications, and procurement of materials and equipment, and preparation of construction and installation drawings for the ISFSI. The licensee maintains responsibility for the management of spent fuel and is responsible for operation and maintenance of the ISFSI.

9.1.1.3 Interrelationship with Contractors and Suppliers

The prime contractor for design of the NUHOMS® ISFSI and supply of its components is TN West of Fremont, California. The ISFSI is to be owned and operated by the licensee. Construction of the ISFSI is the responsibility of an approved construction contractor, to be selected by the licensee. Subsurface investigations at the ISFSI site are to be performed by the licensee's soils engineer.

9.1.1.4 Applicant's Technical Staff

The licensee's technical staff supporting the ISFSI is typically described in the plant's FSAR.

9.1.2 Operating Organization, Management and Administrative Control System

9.1.2.1 On-Site Organization

The licensee's on-site organization is responsible for operation of the ISFSI and typically maintains primary responsibility for spent fuel storage.

9.1.2.2 Personnel Functions, Responsibilities and Authorities

The functions, responsibilities and authorities of major personnel positions, including discussions of specific succession of responsibility for overall operation of the plant are the responsibility of the licensee. These functions, responsibilities and authorities typically extend to the ISFSI.

9.1.3 Personnel Qualification Requirements

The minimum qualification requirements for major operating, technical and maintenance supervisory personnel, as well as the qualification of persons assigned to managerial and technical positions, are the responsibility of the licensee.

9.1.4 Liaison with Other Organizations

Arrangements made with outside organizations are the responsibility of the licensee.

9.2 Pre-Operational Testing and Operation

A comprehensive pre-operational testing program has been carried out at Carolina Power and Light's Robinson plant NUHOMS® ISFSI. This program was developed jointly and conducted by Carolina Power and Light, the Department of Energy, the Electric Power Research Institute and NUTECH (now TN West). These pre-operational testing results (9.1), provide sufficient data to demonstrate that the analytical methods described in this SAR provide conservative thermal and radiological results.

Prior to operation of the ISFSI for a particular plant, the licensee should perform functional tests of the in-plant operations, the on-site transport operations, and DSC insertion and retrieval (operations at the ISFSI). These tests are intended to verify that the storage system components (e.g., DSC, HSM, transfer cask, transfer equipment, etc.) operate safely and effectively. Such a program has been successfully completed for the NUHOMS® ISFSI at Duke Power Company's Oconee Nuclear Station, Baltimore Gas and Electric Company's Calvert Cliffs Nuclear Power Plant, Pennsylvania Power & Light Company's Susquehanna Steam Supply Electric Station and Toledo Edison's Davis Besse Nuclear Station. Since the loading steps, transfer equipment and license conditions for the site specific and general licenses are similar, licensees using previously licensed and pre-operationally tested transfer equipment, in conjunction with the general license HSMs and DSCs, may limit dry runs to the new interfaces and operational aspects of general license HSMs and DSCs.

9.2.1 Administrative Procedures for Conducting Test Programs

Preoperational testing is typically governed by existing plant procedures for conducting testing.

9.2.2 Test Program Description

The testing program conducted by the licensee utilizes a DSC loaded with mock-up fuel, the transfer cask and associated transfer equipment, and an HSM. The tests should simulate, as nearly as possible, the actual operations involved in preparing a DSC for storage and ensure that they can be performed safely during actual emplacement of spent fuel in the ISFSI. Verification of ALARA practices, which are not completely achievable during dry runs, takes place during the initial fuel loadings. Guidelines for such tests are provided in the following paragraphs.

A. An actual DSC should be utilized for preoperational testing. The DSC should be loaded into the transfer cask to verify fit and adequacy of the cask/DSC annulus

seal. Additionally, the DSC may be used in operational testing of the transfer equipment and HSM.

B. Functional testing is to be performed with the transfer cask and lifting yoke. These tests are to ensure that the transfer cask can be safely lifted from the plant's cask receiving area to the cask washdown area. It should then be, as a minimum, partially lowered into the spent fuel pool and positioned in the cask loading area to verify clearances and travel path.

C. The transfer cask should be placed on the transport trailer, which should then be transported to the ISFSI along a predetermined route and aligned with an HSM. Compatibility of the transport trailer with the transfer cask, verification of the transfer route to the ISFSI, and maneuverability within the confines of the ISFSI should be verified.

D. The transfer trailer should be aligned and docked with the HSM. The hydraulic ram should be used to insert a DSC loaded with test weights in the HSM and then retrieve it. Transfer of the DSC to the HSM should verify that the support skid positioning system and the hydraulic ram system operate safely for both insertion and retrieval of a DSC.

9.2.3 Test Discussion

Implementation of the test program is discussed in the paragraphs which follow.

A. The purpose of the preoperational tests is to ensure that a DSC can be properly and safely placed in the spent fuel pool, loaded with spent fuel, transported to the ISFSI, inserted in the HSM, and retrieved from the HSM. Proper operation of the DSC, transfer cask, and transfer equipment, as well as the associated auxiliary equipment (e.g., automated welding equipment and vacuum drying system), provides such assurance.

B. Detailed procedures should be developed and implemented by licensee's personnel who are responsible for ensuring that the test requirements are satisfied.

C. The expected results of the preoperational tests are the successful completion of the following: placement of a DSC into the transfer cask, placement of the transfer cask into and out of the spent fuel pool, transporting the transfer cask loaded with a DSC and test weights to the ISFSI, and transfer of a DSC to/from the HSM. The tests are deemed successful if the expected results are achieved safely and without damage to any of the components or associated equipment.

D. Should any equipment or components require modification in order to achieve the expected results, it should be retested to confirm that the modification is adequate. Should any pre-operational procedures change in order to achieve the expected results, the changes should be incorporated into the appropriate operating procedures.

E. Plant operation is not affected by testing of the ISFSI. Testing operations in the plant's fuel/reactor building can generally be conducted concurrently with plant operation except during refueling operations. Testing is to be conducted within the plant's fuel/reactor building and should be scheduled so that there is no conflict with refueling. All normal prerequisites for safe handling of components in, or near, the spent fuel pool should be satisfied, and normal safety and radiological practices should be employed.

9.3 Training Program

All personnel working at the ISFSI should receive training and indoctrination aimed at providing and maintaining a well-qualified work force for safe and efficient operation of the ISFSI. The licensee may utilize the existing plant training program to provide this training and indoctrination. Additional sections to the program should be added to include information specific to the ISFSI.

9.3.1 Program Description

9.3.1.1 Training for Operations Personnel

Generalized training should be provided to plant operations personnel in the applicable regulations and standards and in the engineering principles of passive cooling, radiological shielding, and structural characteristics of the ISFSI. Detailed operator training should be provided for DSC preparation and handling, fuel loading, transfer cask preparation and handling, and transfer trailer loading.

9.3.1.2 Training for Maintenance Personnel

Generalized training should be provided to plant maintenance personnel on the applicable regulations and standards and in the engineering principles of passive cooling, radiological shielding, and structural characteristics of the ISFSI. Specific training should be provided for use of the DSC vacuum drying system; the automated welding equipment for DSC closure; operation of the transfer trailer; alignment of the cask skid with the HSM; assembly of the hydraulic ram system; and normal and off-normal operation of the hydraulic ram. Specific training should also be provided for cleaning of the HSM air inlets and outlets.

9.3.1.3 Training for Health Physics Personnel

Generalized training should be provided to plant health physics personnel on the applicable regulations and standards and in the engineering principles of passive cooling, radiological shielding, and structural characteristics of the ISFSI. Specific training should be provided in radiological shielding design of the system, particularly the DSC top shield plug, the transfer cask and the HSM.

9.3.1.4 Training for Security Personnel

Details of the training program for security personnel are provided in the Security Plan to be maintained by the licensee, which is to be withheld from public disclosure in accordance with 10CFR2.790(d) and 10CFR73.21.

9.3.2 Retraining Program

Retraining should generally be consistent with the retraining requirements in effect at the plant for personnel involved in fuel handling operations.

9.3.3 Administration and Records

The licensee's organization responsible for training programs and for maintaining up-to-date records on the status of personnel training is generally the existing plant training organization.

9.4 Normal Operations

The ISFSI provides for independent storage of spent fuel separate from the existing plant facilities. With the exception of some limited physical and continuous electronic security surveillance, the ISFSI functions as a passive system once fuel has been placed in dry storage. Periodic placement of spent fuel in the ISFSI require specific procedures that are separate from those of normal plant operations.

9.4.1 Procedures

Operating, testing, and maintenance procedures should be prepared, reviewed, revised, and approved by the licensee in accordance with existing plant standards for procedure preparation, revision, review and approval. Procedures should be developed to control (a) preparation of the DSC for transport to the ISFSI, including fuel loading, sealing, drying, backfilling and placement of the cask onto the transport trailer, and (b) transport of the DSC/transfer cask to the ISFSI and placement of the DSC into the HSM.

Maintenance procedures should be developed to provide for periodic maintenance of the transfer and auxiliary equipment.

9.4.2 Records

The ISFSI records should be maintained by the licensee in accordance with the requirements of 10CFR72 and with the existing plant records retention practices.

9.5 Emergency Planning

The Emergency Response Plan (ERP) for the plant should be demonstrated by the licensee to be adequate for events which might occur involving the ISFSI by the licensee. These ERPs have generally been prepared in accordance with the requirements of 10CFR50.47, and therefore, should satisfy the requirements of 10CFR72.32.

The ERP is intended to protect the general public and site personnel from possible consequences of an emergency condition. This plan, combined with its implementation procedures and the corresponding plans of the jurisdictional state and local agencies, should allow for (a) early recognition and classification of a possible emergency condition; (b) prompt notification, via reliable communication channels, of agencies and personnel to augment the normal operating personnel; and (c) planned actions to be taken to protect the population-at-risk.

The existing plant staff is typically trained to cope with emergencies. Licensee agreements with federal agencies, private contractors, and coordinated state and local agency emergency plans provide assistance to ensure that resources can be readily available in as short a time as possible to cope with emergencies and protect the population-at-risk. The agencies, and the resources they provide, are described in the licensee's ERP, including the roles of the various state and local agencies and their interfaces for carrying out protective and parallel actions in a 10-mile-radius plume zone and a 50-mile-radius ingestion zone.

The ERP should describe (1) the emergency classification system used at the plant; (2) the organizational control of emergencies, including on-site, off-site, and augmentation organizations; (3) the emergency measures to be taken; and (4) available emergency facilities and equipment.

Procedures are to be prepared by the licensee for implementation of the ERP. These procedures are provided to those individuals, and facilities where immediate availability of such procedures would be required during an emergency. The procedures are used in conjunction with applicable plant operating, radiological control, and security procedures to correct the emergency condition and to mitigate the consequences of the accident.

The existing 10CFR50 emergency plan shall be reviewed under 10CFR72.212(b)(6) of Subpart K to determine if its effectiveness is decreased as a result of implementation of an ISFSI and, if so, prepare the necessary changes and seek the necessary approvals.

9.6 Decommissioning Plan

Decommissioning of a NUHOMS® ISFSI can be performed in a manner consistent with that for decommissioning of the plant itself. It is anticipated that the DSCs will be transported intact to a Federal repository off-site when such a facility is operational. However, should the storage facility not accept the DSCs intact, the NUHOMS® system allows the DSCs to be brought back into the spent fuel pool and the fuel off-loaded to racks for subsequent loading into transport casks provided by the Department of Energy.

All components of the NUHOMS® system are manufactured of materials similar to those found at existing plants (e.g., reinforced concrete, stainless steel, lead). These components can therefore be decommissioned by the same methods in place to handle those materials within the plant. Any of the components that may be contaminated can be cleaned and/or disposed of using the decommissioning technology available at the time of decommissioning.

The NUHOMS® system is a dry containment system that effectively confines all contamination within the DSC. When the DSC is removed from the HSM, the free-standing HSM can be manually decontaminated for any trace activity, dismantled and removed from the site. It is possible that a thin layer of material comprising the inner wall of the HSM could become activated by the neutron flux from the fuel after an extended period of service. Estimates of the potential for activation are difficult due to the variability of rare earths which may be present in the local aggregate. The specific activity of the HSM inner wall surfaces may be measured at the time of decommissioning and compared with the existing guidelines to determine whether the values are below regulatory concern (BRC). Disposal procedures can then be developed which comply with existing guidelines at the time of decommissioning.

Removal of fuel assemblies from the DSC can be accomplished in the plant's spent fuel pool, as described in Chapter 5. The DSC is also being qualified for off-site shipment in a compatible transportation cask licensed to 10CFR71. If such transport is made, the DSC may be disposed of as-is at the permanent geologic repository in a suitable overpack container. If the DSC is not compatible with the repository handling or packaging systems, fuel transfer to a suitable container can be performed in a large hot cell or off-site fuel pool.

The general license holder under 10CFR72.210 shall meet the requirements specified in 10CFR72.30.

9.7 References

9.1 Electric Power Research Institute, "NUHOMS® Modular Spent-Fuel Storage System: Performance Testing," EPRI Report NP-6941, September 1990.

10. OPERATING CONTROLS AND LIMITS

The information previously presented in SAR Chapter 10, Operating Controls and Limits is contained in the Technical Specifications of NUHOMS® CoC 1004. Hence, the contents of SAR Chapter 10.0 are being deleted in their entirety.

SAR Chapter 10 requirements are currently referenced in various TN West documents. Table 10-1 provides a cross-reference index of these requirements against the corresponding requirements currently listed in the NUHOMS® CoC.

Table 10-1

Index of CoC Requirements v/s Historical SAR References

CoC Section No.	Title of CoC Requirements	Historical **SAR** Reference
1.2	**Technical Specifications, Functional and Operating Limits**	**10.3**
1.2.1	Fuel Specification	10.3.1
1.2.2	DSC Vacuum Pressure During Drying	10.3.2
1.2.3	DSC Helium Backfill Pressure	10.3.3
1.2.3a	61BT DSC Helium Backfill Pressure	—
1.2.4	DSC Helium Leak Rate of Inner Seal Weld	10.3.4
1.2.4a	61BT DSC Helium Leak Rate of Inner Seal Weld	—
1.2.5	DSC Dye Penetrant Test of Closure Welds	10.3.5
1.2.6	Deleted	10.3.6
1.2.7	HSM Dose Rates	10.3.7
1.2.8	HSM Maximum Air Exit Temperature	10.3.8
1.2.9	Transfer Cask Alignment with HSM	10.3.9
1.2.10	DSC Handling Height Outside the Spent Fuel Pool Building	10.3.10
1.2.11	Transfer Cask Dose Rates	10.3.11
1.2.12	Maximum DSC Removable Surface Contamination	10.3.12
1.2.13	TC/DSC Lifting Heights as a Function of Low Temperature and Location	10.3.13
1.2.14	TC/DSC Transfer Operations at High Ambient Temperatures	10.3.14
1.2.15	Boron Concentration in the DSC Cavity Water (24-P Design Only)	10.3.15
1.2.16	Provision of TC Seismic Restraint Inside the Spent Fuel Building as a function of Horizontal Acceleration and Loaded Cask Weight	10.3.16
1.2.17	Vacuum Drying Duration Limits	
Table 1-1a	PWR Fuel Specifications of Fuel to be Stored in the Standardized NUHOMS®-24P DSC	Table 10.3-1
Table 1-1b	BWR Fuel Specifications of Fuel to be Stored in the Standardized NUHOMS®-24P DSC	Table 10.3-2
Table 1-1c	BWR Fuel Specification of Fuel to be Stored in the Standardized NUHOMS®-61BT DSC	—
Table 1-1d	BWR Fuel Assembly Design Characteristics	—
Figure 1.1	PWR Fuel Criticality Acceptance Curve	Figure 10.3.1
1.3	**Surveillance and Monitoring**	**10.4**
1.3.1	Visual Inspection of HSM Air Inlets and Outlets (Front Wall and Roof Birdscreen)	10.4.1
1.3.2	HSM Thermal Performance	10.4.2
Table 1.3.1	Summary of Surveillance and Monitoring Requirements	Table 10.4-1

CoC Section No.	Title of CoC Requirements	Historical **SAR** Reference
Table 1-2a	PWR Fuel Qualification Table for the Standardized NUHOMS®-24P DSC (Fuel without BPRAs)	—
Table 1-2b	BWR Fuel Qualification Table for the Standardized NUHOMS®-BWR DSC	—
Table 1-2c	PWR Fuel Qualification Table for the Standardized NUHOMS®-24P DSC (Fuel with BPRAs)	—

11. QUALITY ASSURANCE

The Quality Assurance Program to be applied to the "important-to-safety" and " safety related" activities associated with the standardized NUHOMS® system is as described in the TN West Quality Assurance Manual unless noted otherwise.

11.1 Introduction

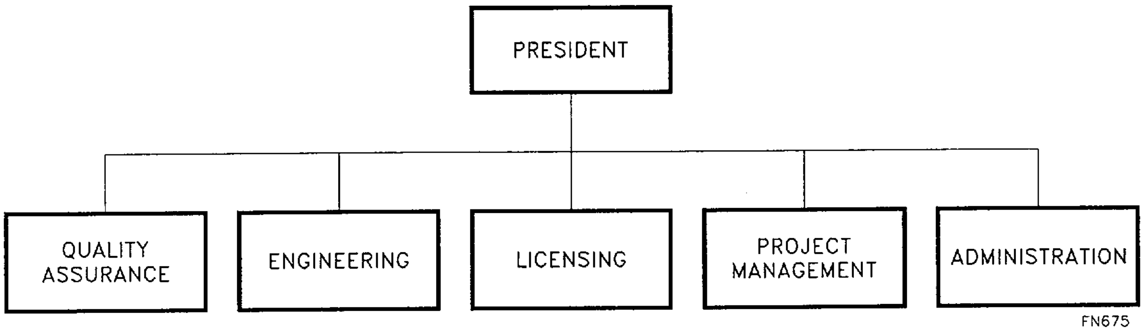
This section provides a brief summary of the quality assurance controls which apply to activities affecting the quality of NUHOMS® parts, components, and systems designated as "important to safety" and "safety related.". System components which are "important to safety" are defined herein. Activities affecting quality are defined by site-specific contract and may include any or all of the following: design, procurement, fabrication, handling, shipping, storage, cleaning, erection, inspection, test, repair, or modification. These activities shall be performed in accordance with a quality assurance program which meets the requirements specified herein.

TN West's Quality Assurance Program shall be applied to the important-to-safety activities within TN West's scope of responsibility as defined herein. The TN West Quality Assurance Program complies with the criteria and requirements of 10CFR72, Subpart G. The complete description and specific commitments of the TN West Quality Assurance Program are contained in the TN West Quality Assurance Manual. The Nuclear Regulatory Commission (NRC) has approved the TN West QA Manual for 10CFR72, Subpart G. Changes to the TN West QA program shall be submitted to the NRC for approval within thirty (30) days of implementation. Changes to the TN West QA program which decrease or delete previously approved quality assurance commitments shall be submitted to the NRC for approval prior to implementation.

A matrix comparing 10CFR72, Subpart G criteria with the TN West QA Manual is provided in Table 11.1-1.

Table 11.1-1
Quality Assurance Criteria Matrix

10CFR72, Subpart G	TN West QA Manual	
.142	1.0	Organization
.144	2.0	QA Program
.146	3.0	Design Control
.148	4.0	Procurement Document Control
.150	5.0	Procedures, Instructions, and Drawings
.152	6.0	Document Control
.154	7.0	Control of Purchased Items and Services
.156	8.0	Identification and Control of Materials, Parts, and Components
.158	9.0	Control of Special Processes
.160	10.0	Inspection
.162	11.0	Test Control
.164	12.0	Control of Measuring and Test Equipment
.166	13.0	Handling, Storage, and Shipping
.168	14.0	Inspection and Test Status
.170	15.0	Control of Nonconforming Items
.172	16.0	Corrective Action
.174	17.0	Records
.176	18.0	Audits



Notes:

1. Licensing may report to Engineering.
2. Administrative activities may report to various other organizations.

Figure 11.1-1
NUHOMS® Project Organization Chart

11.2 "Important-to-Safety" and "Safety Related" NUHOMS® System Components

TN West will apply the TN West Quality Assurance Program to those NUHOMS® components for which TN West has responsibility and which are "important to safety" and "safety related" as delineated in Section 3.4. These include the DSC with closure weld filler metal, the HSM, and the transfer cask. The lifting yoke is classified as "safety related".

Each item is first identified as "important to safety," "safety related" or "not important to safety." Items that are considered "important to safety" are further categorized using a graded quality approach. When the graded quality approach is used, a list shall be developed for each "important to safety" item which includes an assigned quality category consistent with the item's importance to safety. Quality categories shall be determined based on the guidance from Regulatory Guide 7.10:

Category A items are critical to safe operation. These items include structures, components, and systems whose failure or malfunction could result directly in a condition adversely affecting (1) safe spent fuel storage, (2) integrity of the spent fuel, or (3) public health and safety. This would include conditions as loss of primary containment with subsequent release of radioactive material, loss of shielding or an unsafe geometry compromising criticality control.

Category B items have a major impact on safety. These items include structures, components, and systems whose failure or malfunction could indirectly result in a condition adversely affecting (1) safe spent fuel storage, (2) integrity of the spent fuel, or (3) public health and safety. An unsafe operation could result only if a primary event occurs in conjunction with a secondary event or other failure or environmental occurrence.

Category C items have a minor impact on safety. These items include structures, components, and systems whose failure or malfunction would not significantly reduce the packaging effectiveness and would be unlikely to create a condition adversely affecting (1) safe spent fuel storage, (2) integrity of the spent fuel, or (3) public health and safety.

The Quality Assurance Program as described in paragraph 11.3 is applicable to each "important to safety" graded category and is limited as follows For "safety related" items the program is applied as described in Category A items. Appendix K provides clarification for the procurement of Category A items for the NUHOMS®-61BT DSC. Appendix L provides clarification for the procurement of Category A items for the NUHOMS®-24PT2 DSC.

Category A

A. The design is based on the most stringent industrial codes or standards, and design verification shall be accomplished by prototype testing or formal design review.

B. Vendors for items and services for this category may only be selected from the Approved Suppliers List.

C. TN West suppliers and subtier suppliers must have a QA program based on applicable criteria in Subpart G to 10CFR72, or equivalent.

D. Complete traceability of raw materials and the use of certified welders and processes is required.

E. All personnel performing Quality Assurance related inspection, tests, and examinations shall be qualified and certified in accordance with the requirements of the QA program.

F. Only qualified and certified auditors and lead auditors shall perform audits.

G. TN West Quality personnel shall be required to inspect and/or approve supplier fabricated components prior to authorizing shipment release.

H. Welding consumables shall be procured as a Category A item if the intended use is unknown. If purchased for a specific B or C application, material must so be identified and its use be restricted to fabrication of the same level.

Category B

A. The design shall be based on the most stringent industrial codes and standards, but design verification may be through use of alternate calculations or computer codes.

B. The procurement of items need not be from the Approved Suppliers List. QA program requirements for the supplier shall be based upon the inspection and test requirements of the procured item.

C. Traceability of materials is not required; however, specified welds require completion by qualified, certified welders.

D. Quality Assurance verification activities shall be performed by personnel qualified and certified in accordance with the requirements of the QA program.

E. Only lead auditor personnel require certification in accordance with the QA program.

Category C

A. Items may be purchased from a catalog or "off-the-shelf".

B. When received, the item shall be identified and checked for compliance with the purchase order and for damage.

The "important to safety" classifications are identified on the drawings (Appendix E).

Additional system components other than those delineated above, such as the ISFSI basemat, the remaining transfer equipment, the auxiliary equipment, and consumables (including the dry film lubricant) are not considered important-to-safety and will be controlled in accordance with good industrial practices.

If a utility elects to perform construction, and has an NRC approved QA program (10CFR50) that is equivalent to or exceeds TN West's program, then the utility QA program is considered an acceptable substitute.

Table 11.2-1
Attributes to be Verified for Quality Category B Components of Horizontal Storage Module [1]

Item	Component	Attribute				
		Compressive Strength	Air Content	Slump	Concrete Density	Yield Strength
Base Unit	Concrete	X	X	X	X	
	Reinforcing Steel					X
Roof Slab	Concrete	X	X	X	X	
	Reinforcing Steel					X
Canister Support Structure	Rail					X
	Structural Steel					X
Accessories	Door				X	
	Shield Wall Supports					X
	Shield Wall Tie Plates					X
	Axial Retainer				X	X
Shield Wall	Concrete	X	X	X	X	
	Reinforcing Steel					X
	Bolts, Nuts, Washers					X

Notes: 1. Refer to Appendix E.2 for Quality Categories of all HSM components.

Table 11.2-2
Attributes to be Verified for Quality Category B Components of Onsite Transfer Cask[(1)]

Item	Component	Attribute				
		Yield Strength	Ultimate Strength	% Elon-gation	Chemical Analysis	Gamma Scan
Cask Structural Shell Assembly	Top Flange	X	X	X	X	
	Cylindrical Shell	X	X	X	X	
	Bottom Support Ring	X	X	X	X	
	Bottom End Plate	X	X	X	X	
	Ram Access Penetration	X	X	X	X	
	Upper Trunnion Sleeve	X	X	X	X	
	Upper Trunnion	X	X	X	X	
Cask Inner and Outer Shell Assy	Inner Liner	X	X	X	X	
	Lead Gamma Shielding				X	X
Cask Main Assembly	Top Cover Plate	X	X	X	X	
	Top Cover Bolts	X	X	X	X	

Notes: 1. Refer to Appendix E.3 for Quality Categories of all On-site Transfer Cask components.

11.3 Description of TN West 10CFR72 Subpart G Quality Assurance Program

11.3.1 Project Organization

The NUHOMS® system has been designed by a dedicated TN West project organization.

QA duties are performed by the NUHOMS® project organization, the QA Manager, and QA Engineer.

The organization structure for the NUHOMS® project is presented in Figure 11.1-1. A description of TN West's organizational structure, functional responsibilities, levels of authority, and lines of internal and external (client and supplier) communication may be found in the TN West Quality Assurance Manual.

Project QA controls are determined by the Project Manager and approved by the QA Manager. All Project Plans, regardless of the indicated applicability of QA requirements, are reviewed by the QA Manager to assure that QA controls are commensurate with the specific activity, item complexity, importance to safety and client-imposed contractual requirements.

Project personnel are indoctrinated, trained, and qualified in accordance with the TN West QA Manual.

11.3.2 Quality Assurance Program

TN West has established and implemented a QA program for the control of quality in the design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair and modification of shipping containers for nuclear products. Training and/or evaluation of personnel qualifications are required for all QA functions in accordance with written procedures. The QA program assures that all quality requirements, engineering specifications and specific provisions of any package design approval are met. Those characteristics critical to safety are emphasized.

The TN West Quality Assurance Manager regularly evaluates the TN West QA program for adherence to the 18 point criteria in scope, implementation and effectiveness. Further, the TN West President requires that the Quality Assurance Program, including the QA Manual Policies and Procedures, be implemented and enforced on all applicable projects at TN West.

11.3.3 Design Control

Important-to-safety and safety related NUHOMS® design activities including the performance of design verifications shall be implemented in accordance with the TN West Quality Assurance Manual.

Errors and deficiencies in the design, including the design process, are documented in the form of Corrective Action Reports.

Typically, valid industry standards and specifications are used for the selection of suitable materials, parts, equipment and processes for important-to-safety and safety related structures, systems, or components. Standard, or off-the-shelf items, and items previously approved for a different application are reviewed for suitability prior to selection.

11.3.4 Procurement Document Control

Procurement documents are prepared in accordance with the TN West Quality Assurance Manual which delineates the actions to be accomplished in the preparation, review, approval, and control of procurement documents. Review and approval of procurement documents by the QA Manager are documented on the procurement documents prior to release to assure the adequacy of quality requirements stated therein. This review determines that quality requirements are correctly stated, inspectable, and controllable; that there are adequate acceptance and rejection criteria; and that the procurement document has been prepared, reviewed, and approved in accordance with QA program requirements.

The procurement documents shall identify the documentation required to be submitted for information, review, or approval by TN West or TN West's client. The time of submittal shall also be established. When TN West requires the supplier to maintain specific quality assurance records, the retention times and disposition requirements shall be prescribed.

11.3.5 Procedures, Instructions, and Drawings

Activities affecting quality are prescribed and accomplished in accordance with approved, written procedures instructions, or drawings as required by the TN West QA Manual.

11.3.6 Document Control

The issuance, distribution, and receipt of documents, which prescribe activities affecting quality, are controlled in accordance with the TN West Quality Assurance Manual. Controlled documents include, but are not limited to, the TN West design specifications and criteria documents, drawings, instructions, and test procedures.

The individuals or groups responsible for reviewing, approving, and issuing documents and revisions thereto are identified in the "Responsibilities" sections of the TN West QA Manual.

11.3.7 Control of Purchased Items and Services

The control of purchased items and services shall be implemented in accordance with the TN West Quality Assurance Manual.

Surveillance of subcontracted activities is planned and performed in accordance with written procedures to assure conformance to the purchase order. These procedures provide for instructions that specify the characteristics to be witnessed, inspected or verified, and accepted; the method of surveillance and the extent of documentation required; and those responsible for implementing these instructions.

TN West suppliers shall furnish documentation that identifies any procurement requirements which have not been met, together with a description of those nonconformances dispositioned as "use-as-is" or "repair."

Documentation from TN West suppliers which demonstrates compliance with procurement requirements (such as material test reports, NDE results, performance test results, etc.) is periodically evaluated by audits, independent inspections, or tests as necessary to assure its validity.

11.3.8 Identification and Control of Materials, Parts, and Components

Materials, parts, and components shall be identified and controlled in accordance with the TN West Quality Assurance Manual. Hardware identification requirements are determined during generation of design drawings and specifications such that the location and method of identification do not affect the form, fit, function, or quality of the item being identified.

11.3.9 Control of Special Processes

The control of special processes, such as nondestructive examination, chemical cleaning, welding, and heat treating shall be performed in accordance with the TN West Quality Assurance Manual.

11.3.10 Inspection

Receipt inspections, in-process and final inspections of TN Westfabricated, constructed, or erected items, systems, components, or structures shall be performed in accordance with the TN West Quality Assurance Manual.

11.3.11 Test Control

Test control shall be accomplished in accordance with the TN West Quality Assurance Manual.

11.3.12 Control of Measuring and Test Equipment

The TN West QA Manual defines the requirements for calibration of measuring and testing equipment. Calibration is against certified measurement standards which have known relationships to national standards, where such standards exist. Where such standards do not exist, the basis for calibration shall be documented.

11.3.13 Handling, Storage and Shipping

Handling, storage, and shipping shall be conducted in accordance with the TN West Quality Assurance Manual. Special handling, preservation, storage, cleaning, packaging, and shipping requirements are established and accomplished by qualified individuals in accordance with predetermined work and inspection instructions.

11.3.14 Inspection and Test Status

The use of inspection and test status tags shall be accomplished in accordance with the TN West Quality Assurance Manual.

11.3.15 Control of Nonconforming Items

The TN West Quality Assurance Manual defines the requirements and assigns the responsibilities for the control, identification, segregation, documentation, and close-out of nonconforming items to prevent their inadvertent installation or use in fabrication, construction, or erection.

Nonconformance reports identify the item description and quantity, the disposition of the nonconformance, the inspection requirements, and signature approval of the disposition. They are retained in the Project files and are periodically analyzed to show quality trends and help identify root causes of nonconformances. Significant results are reported to responsible management for review and assessment.

Nonconforming items are segregated from acceptable items and tagged to prevent inadvertent use until properly dispositioned and closed out.

Nonconforming items dispositioned "use-as-is" or “repair” are reported to the client.

11.3.16 Corrective Action

Corrective action for significant conditions adverse to quality shall be taken in accordance with the TN West Quality Assurance Manual.

11.3.17 Records

The TN West Quality Assurance Manual defines the scope of the records program such that sufficient records are maintained to provide documentary evidence of the quality of items and the activities affecting quality.

11.3.18 Audits and Surveillances

A comprehensive system of planned and documented audits, including audits of suppliers and site construction activities, verifies compliance with all aspects of the TN West Quality Assurance Program and determines the effectiveness of the program.

Audits are performed by certified lead auditors and are planned, performed, and documented in accordance with the TN West Quality Assurance Manual.

Unannounced QA surveillances may be performed on activities affecting quality by the TN West Quality Assurance Manager, or his designee, on an as-needed basis to further assure compliance with QA requirements.

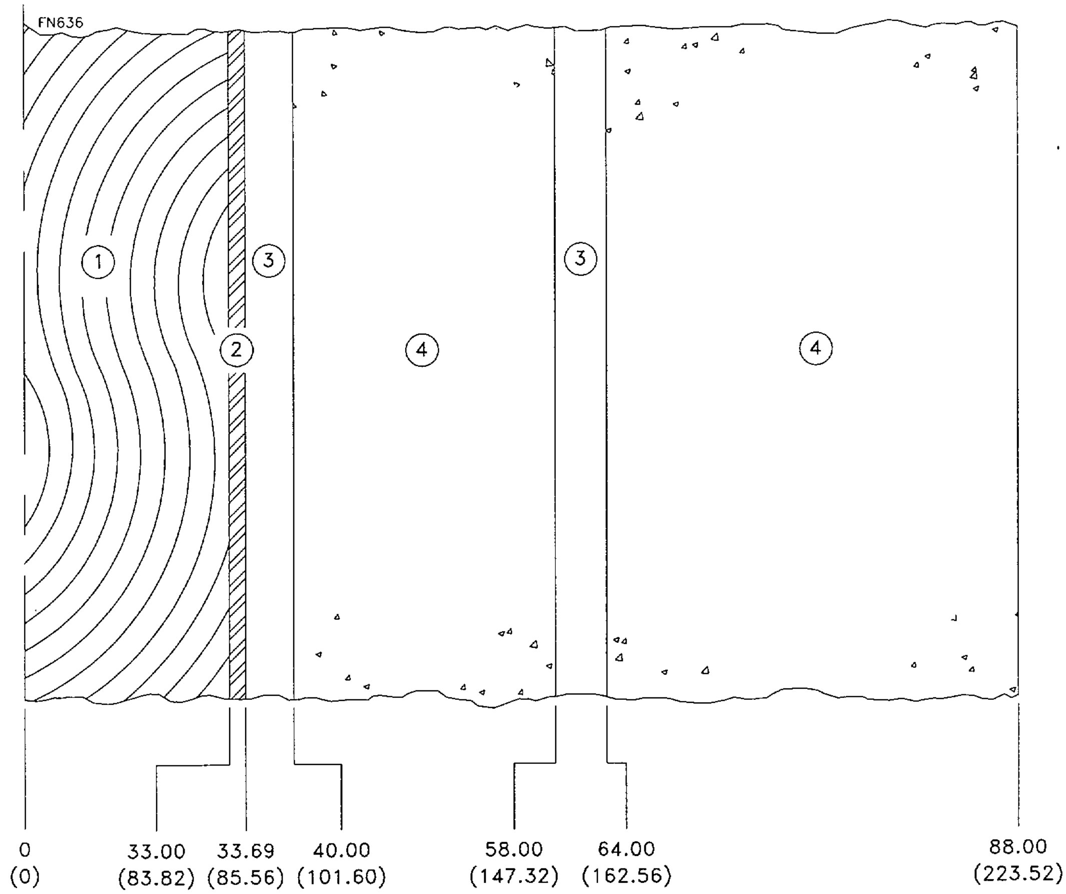
11.4 Conditions of Approval Records

As required by 10CFR72, Subpart L, TN West will establish and maintain records for each storage component fabricated under a certificate of compliance as required by §72.234(d). The records will be available for inspection as required by §72.234(e). Written procedures and appropriate tests will be established prior to use of the storage components, which will be provided to each NUHOMS® system user as required by §72.234(f)

APPENDIX A

DETAILS OF SHIELDING MODELS FOR THE NUHOMS® SYSTEM

This Appendix contains figures depicting the geometry and material configuration of the shielding models discussed in Chapter 7.

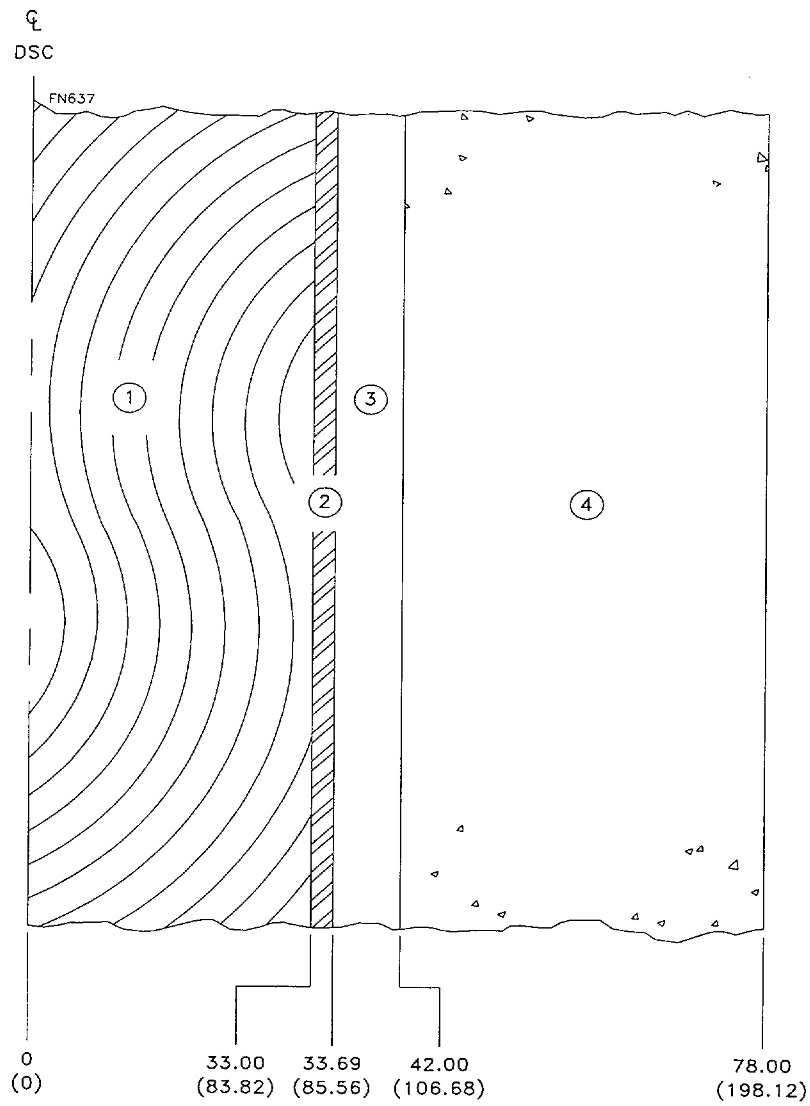


KEY

1. FUEL
2. STAINLESS STEEL (includes DSC shell and heat shield)
3. AIR GAP
4. CONCRETE

NOTE:
ALL DIMENSIONS IN INCHES. DIMENSIONS IN PARENTHESES ARE IN CENTIMETERS.

Figure A.1- 1
ANISN Model of DSC/HSM Wall for Radial Dose Rate

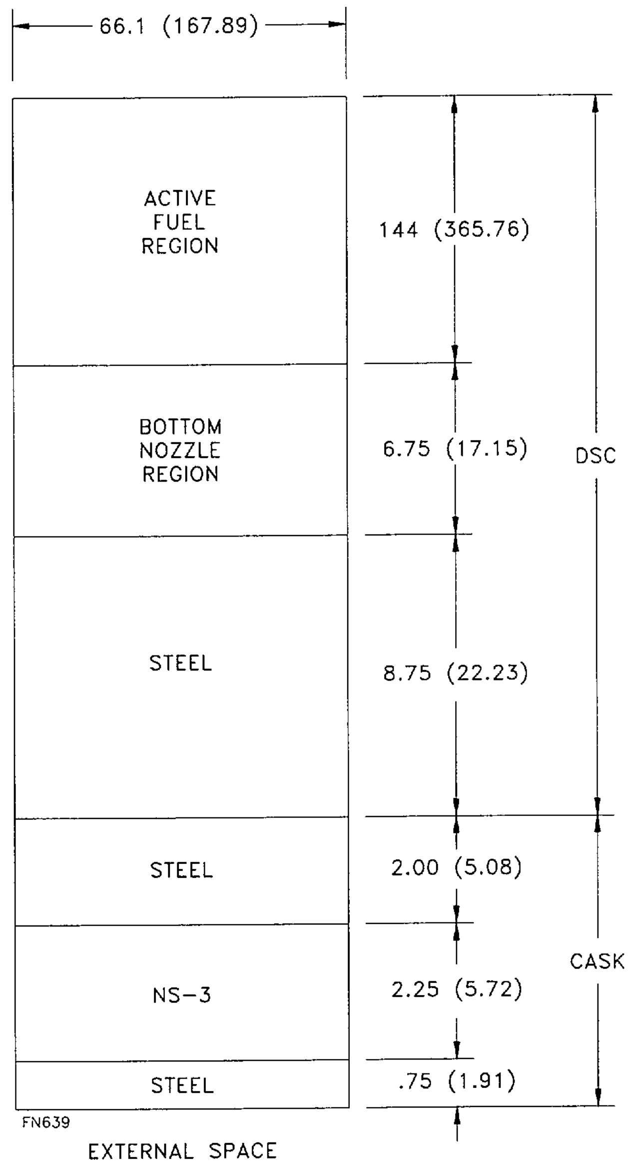


KEY

1. FUEL
2. STAINLESS STEEL (includes DSC shell and heat shield)
3. AIR GAP
4. CONCRETE

NOTE:
ALL DIMENSIONS IN INCHES. DIMENSIONS IN PARENTHESES ARE IN CENTIMETERS.

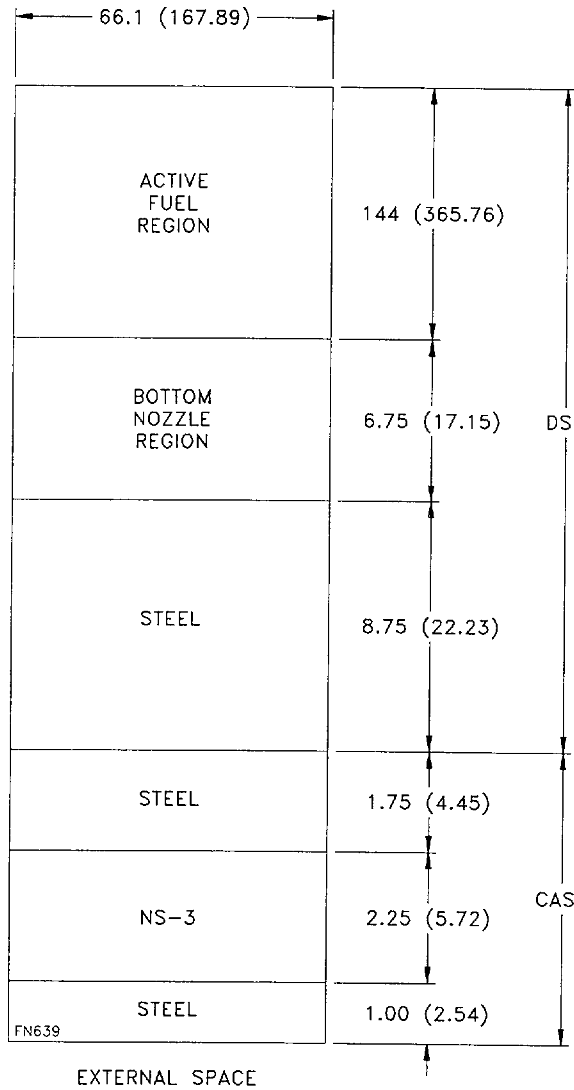
Figure A.1- 2
ANISN Model of DSC/HSM Roof for Radial Dose Rate



NOTE:

1. ALL DIMENSIONS ARE IN INCHES. DIMENSIONS IN PARENTHESES ARE IN CENTIMETERS.

Figure A.1- 3
QAD-CGGP Model of DSC in Cask for Top Axial Gamma Dose Rate



NOTE:

1. ALL DIMENSIONS ARE IN INCHES. DIMENSIONS IN PARENTHESES ARE IN CENTIMETERS.

Figure A.1-4
QAD-CGGP Model of DSC in Cask for Bottom Axial Gamma Dose Rate

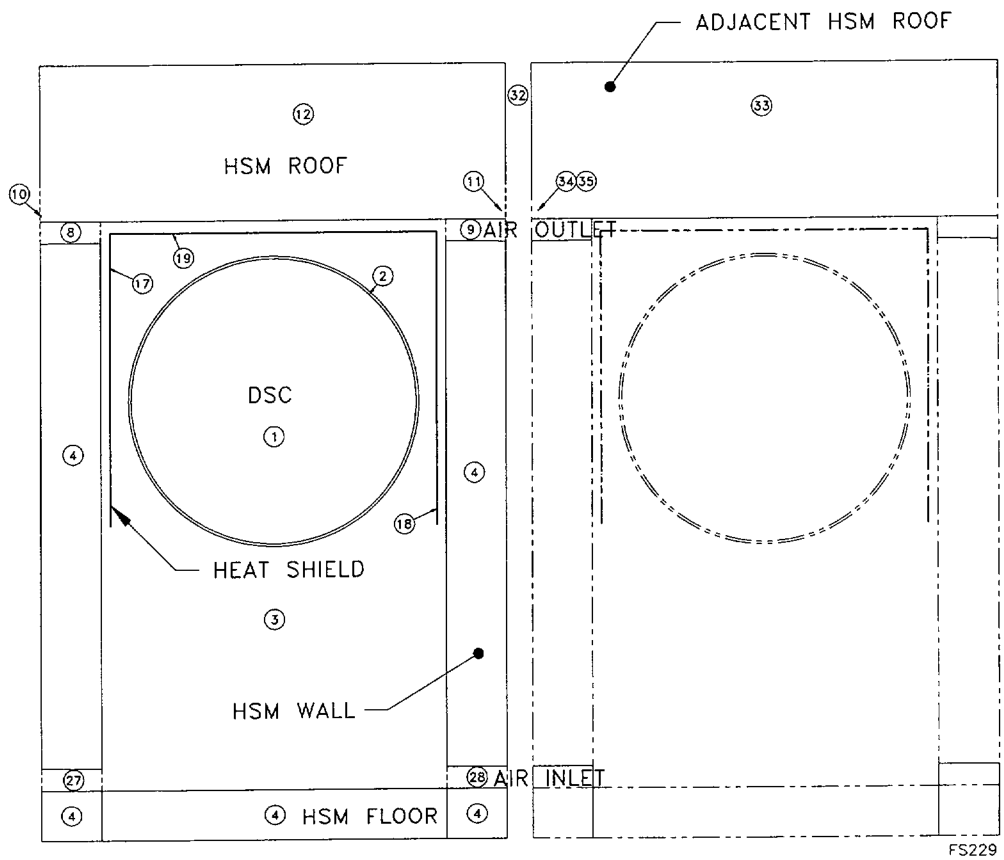


Figure A.1- 5
QAD-CGGP Model of HSM Air Inlets and Outlets for Gamma Dose Rates
(Transverse Cross Section)

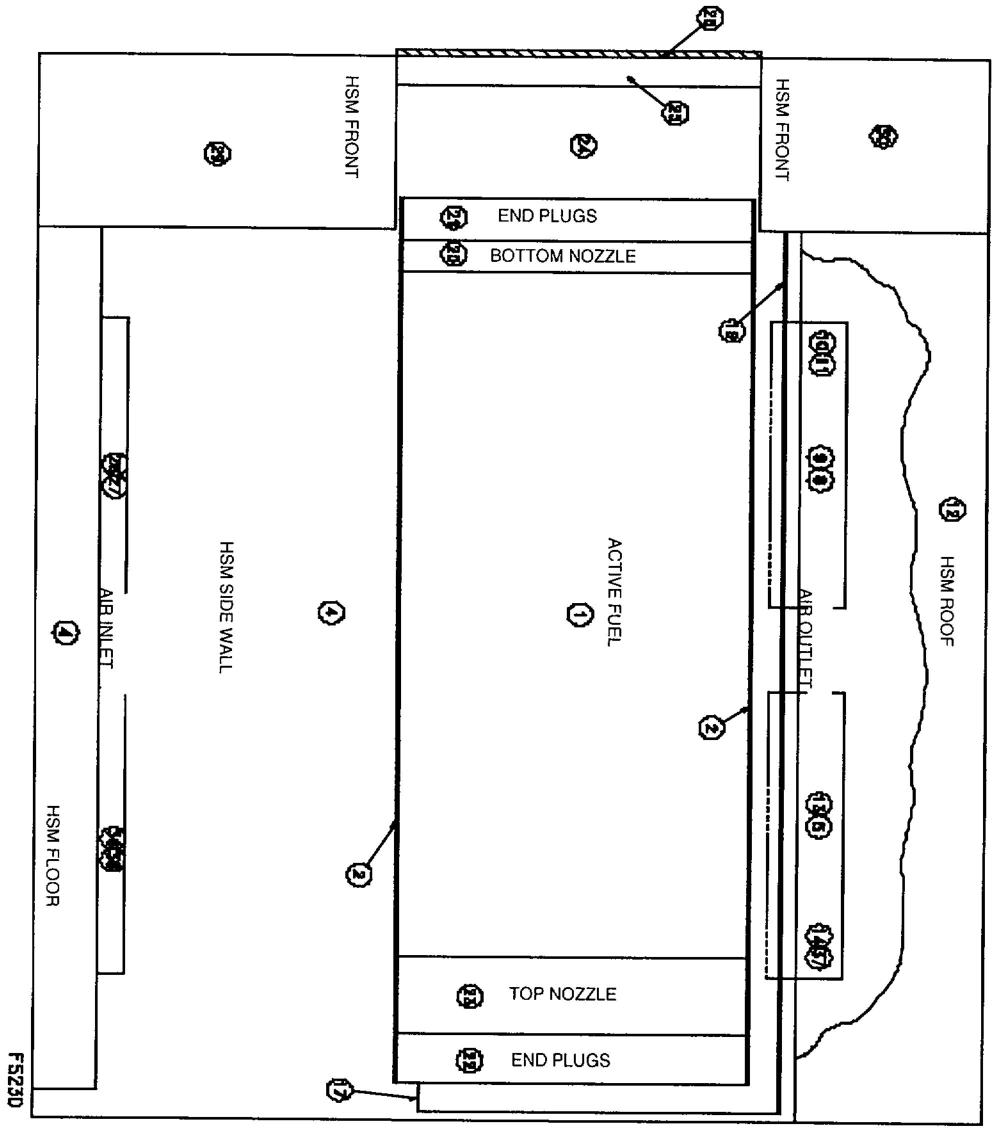
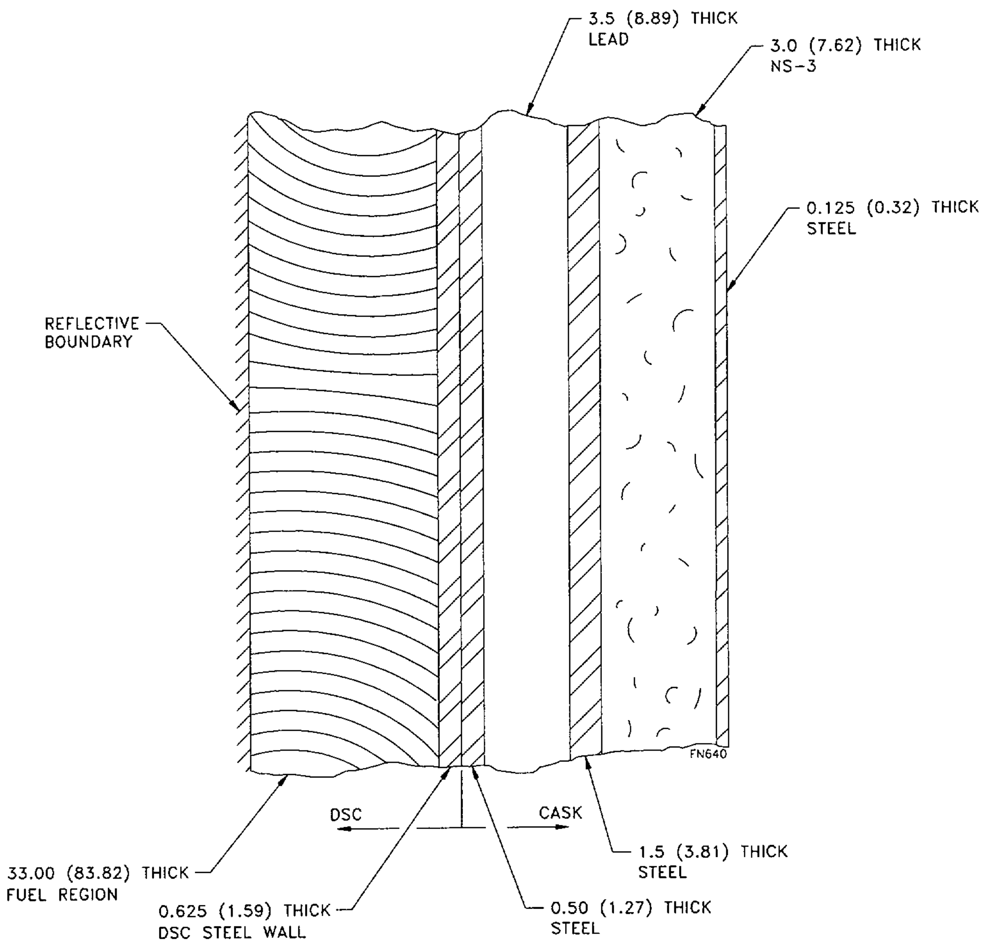


Figure A.1- 6
QAD-CGGP Model of HSM Air Inlets and Outlets for Gamma Dose Rates
(Longitudinal Cross-Section)



NOTE:

1. ALL DIMENSIONS IN INCHES. DIMENSIONS IN PARENTHESES ARE IN CENTIMETERS.

Figure A.1- 7

ANISN Model of DSC/Transfer Cask for Radial Dose Rate

APPENDIX B

DETAILS OF HEAT TRANSFER ANALYSIS OF THE NUHOMS® SYSTEM

This appendix contains the following supporting information:

B.1 Deleted.

B.2 Derivation of the Effective Thermal Conductivity of the Fuel Region of the DSC Model.

B.3 Validation of Fuel Conductivity Values Used for the Standardized NUHOMS® System.

B.4 References

B.1 Deleted

B.2 Effective Thermal Conductivity of the Fuel Regions of the DSC Model

Within the guide sleeve areas (channels for BWR fuel assembly) of the DSC, heat is transferred from the fuel assembly to the walls of the guide sleeve (channels for BWR fuel assembly) by means of radiation and natural convection. To account for these two means of heat transfer in the fuel regions in the DSC HEATING6 model, an equivalent, or effective, thermal conductivity is developed, utilizing existing experimental data.

To evaluate the effective thermal conductivity of the fuel region with helium backfill and vacuum in the DSC the following methodology is used.

For the case of fuel assembly with helium backfill, the thermal conductivity values from the test data at the E-MAD test facility [B.4.2] is used. These thermal conductivity values are from the above ground concrete silo tests for fuel assembly with a decay heat level of 1.05 kW. The canister with fuel assembly was backfilled with helium. The effective thermal conductivity values are shown in Figure B.2-3.

For the case of fuel assembly with internal vacuum, the following methodology is used to develop effective fuel thermal conductivity.

The fuel assembly can be considered as a finite heat generating slab of thickness 2a, surrounded by another slab, the guide sleeve walls of thickness b. Figure B.2-1 presents the temperature distribution in a heat generating slab. The temperature difference between the fuel center and the inside of the guide sleeve wall is equal to [B.4.1]:

$$T_o - T_a = \frac{q'''a^2}{2k_f} \qquad \text{(B.2.1)}$$

Where:

Where:	a	=	Half width of the fuel region (in.)
	k_f	=	Effective thermal conductivity of fuel (Btu/min. in°F)
	q'''	=	Volumetric heat generation fuel (Btu/min. in^3)
	T_o	=	Center fuel temperature (°F)
	T_a	=	Temperature at the guide sleeve wall (°F)

The above equation can be rearranged in the form,

$$k_f = \frac{q'''a^2}{2} \frac{1}{(T_o - T_a)} \qquad \text{(B.2.2)}$$

To develop a k_f for vacuum atmosphere in the DSC, experimental results provided in the Spent Fuel Dry Storage Testing at E-MAD [B.4.2], are utilized. The data provides the temperature distribution for different fuel assemblies with different decay heat loads and environments; air, vacuum, and helium. For the purposes of this analysis, data from fuel assembly B-43 is used to develop the k_f, since its decay heat load of 0.76 kW is the closest to the design base heat load of 1.0 kW. Figure B.2-2 presents the results of these tests.

Table B.2-1 presents the results of measured center temperature for the canister wall maintained at 250°F, 300°F, 400°F, and 500°F. Substituting each of these values in the equation B.2.2 for the T_o and T_a, values of k_f for the vacuum case are developed. Table B.2-4 presents these results. A curve fit of these results is used to produce the effective thermal conductivity as a function of temperature and is presented in Figure B.2-5.

Table B.2-1

Summary of Uniform Canister Temperature Profile Tests for Fuel Assembly B-43

Profile and Canister Backfill	Predicted Decay Heat Level (kW)	Canister Temperature (°F)	Center Thermowell Temperature (°F)
250°F Canister Temp Vacuum	0.730	254	402
300°F Canister Temp Vacuum	0.728	305	432
400°F Canister Temp Vacuum	0.734	398	502
500°F Canister Temp Vacuum	0.756	491	570

Table B.2-2

Deleted

Table B.2-3

Deleted

Table B.2-4
Comparison of Measured Center Fuel Temperature and Calculated Fuel Temperatures - Vacuum Atmosphere

T_a Canister Temperature (°F)	T_o Canister Fuel Temperature (°F)	Calculated k_f (Btu/min. in.°F)	T_o Calculated Center Fuel Temperature (°F)
254	402	2.516E-4	399
305	432	2.770E-4	436
389	502	3.500E-4	502
491	570	4.607E-4	570

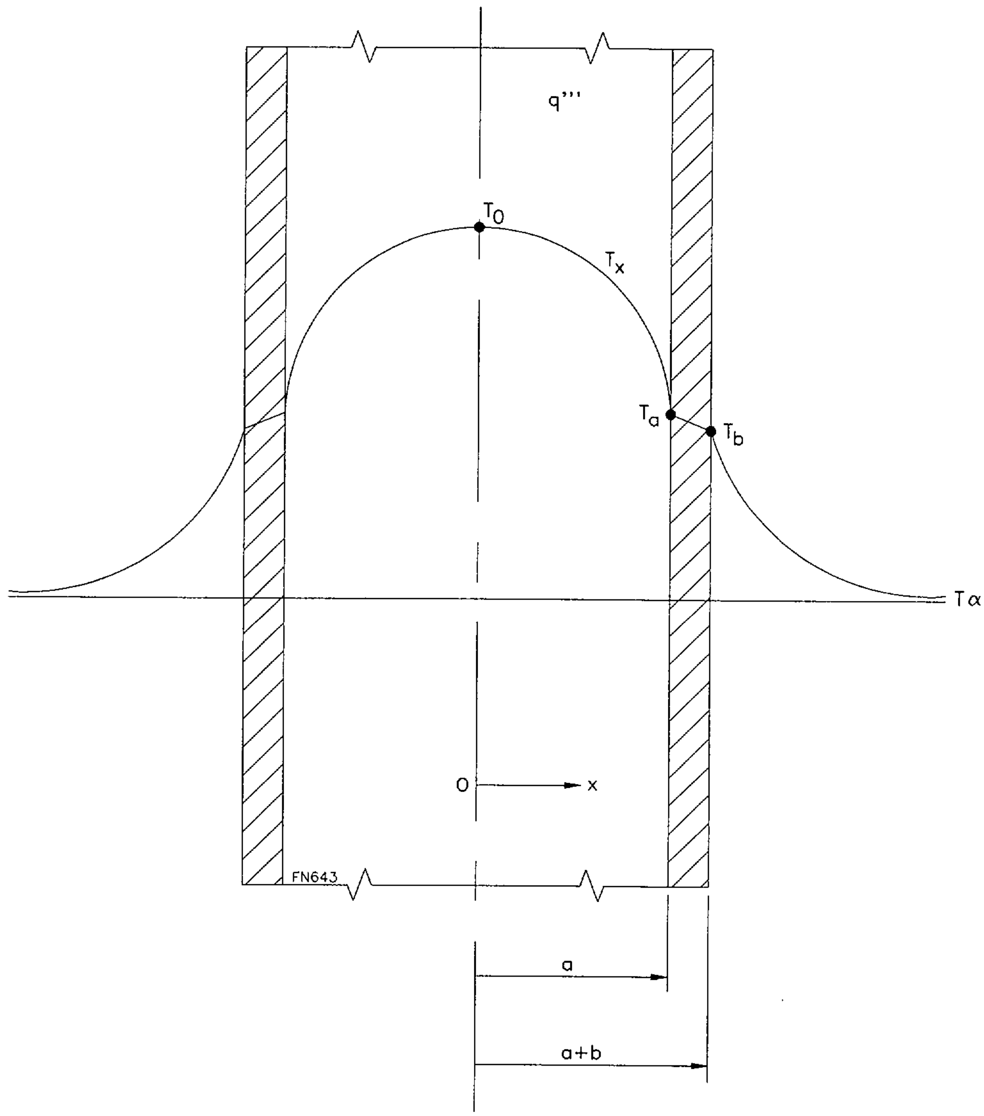
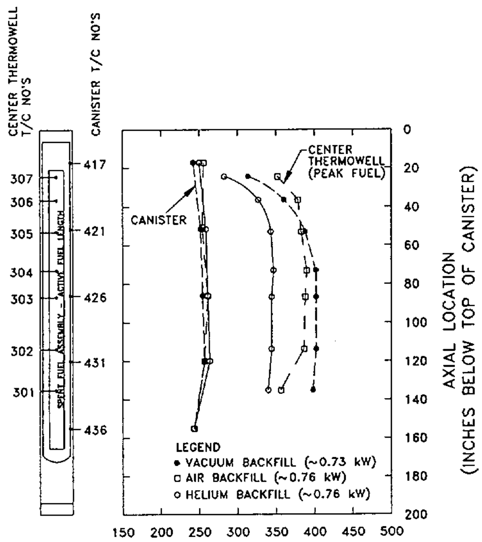
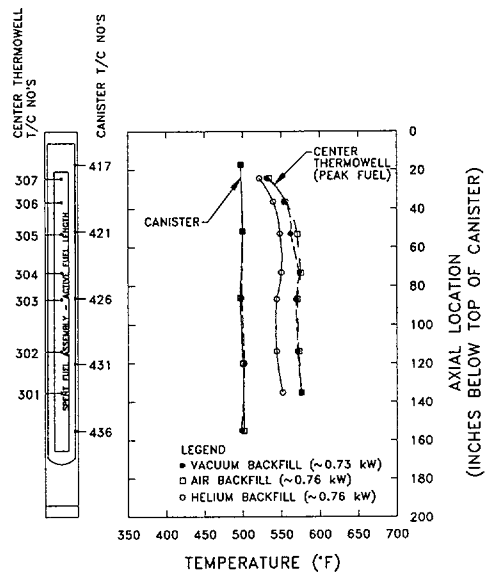


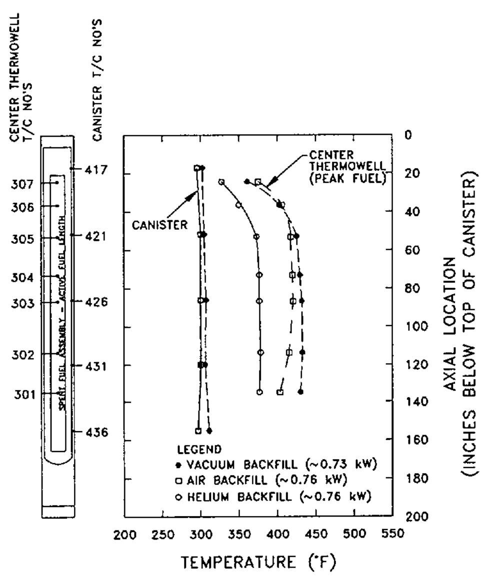
Figure B.2-1
Temperature Distribution in a Finite Heat Generating Slab



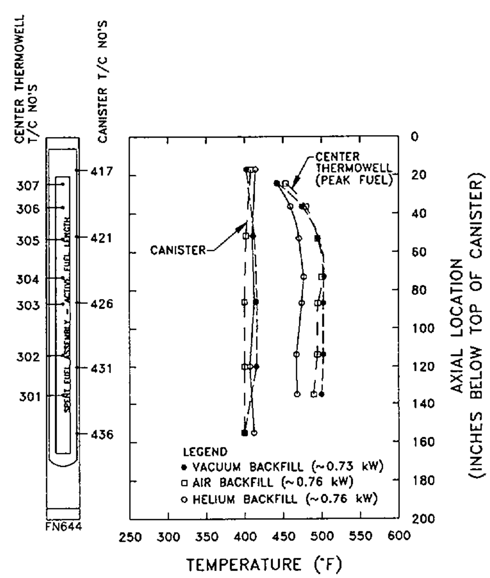
250°F Uniform Canister Temperature Profile Test Temperature Profiles (F/A B43)



500°F Uniform Canister Temperature Profile Test Temperature Profiles (F/A B43)



300°F Uniform Canister Temperature Profile Test Temperature Profiles (F/A B43)



400°F Uniform Canister Temperature Profile Test Temperature Profiles (F/A B43)

Figure B.2-2
Uniform Canister Temperature Profile Graphs

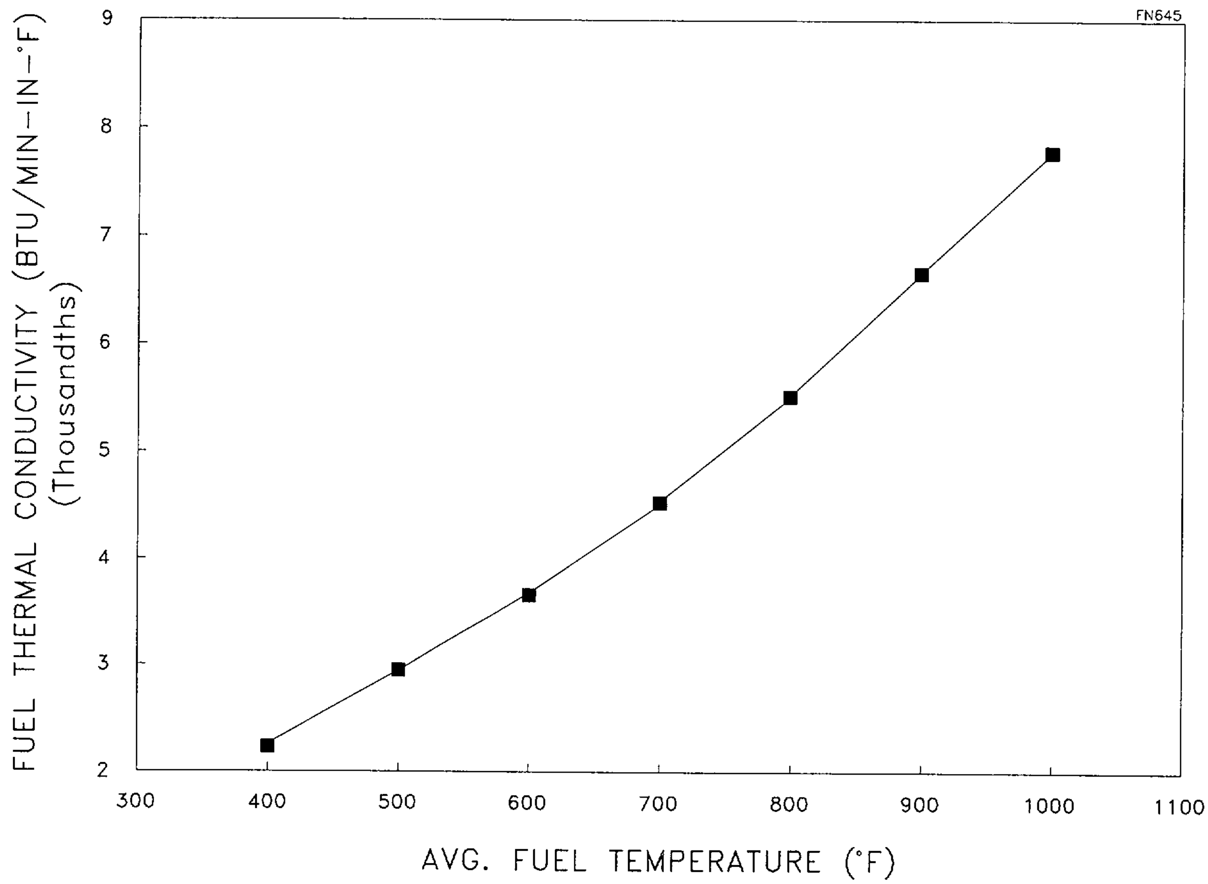


Figure B.2-3
Effective Thermal Conductivity

Figure B.2-4

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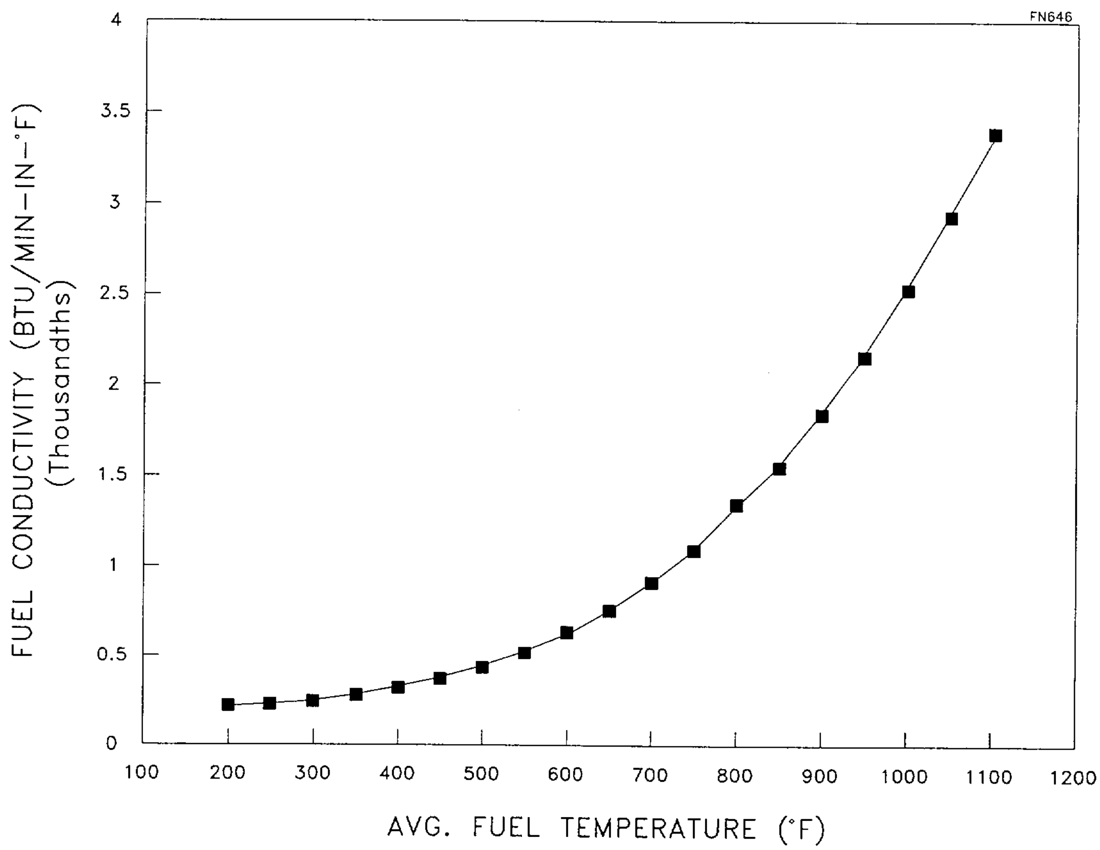

Figure B.2-5
Effective Thermal Conductivity Vacuum Case

Figure B.2-6

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B.3 Validation of Fuel Conductivity Values Used for the Standardized NUHOMS® Design

B.3.1 Introduction

This Section documents validation of the fuel effective conductivity values presented in Section B.2 used for the NUHOMS® design.

The fuel effective conductivities were taken from Table 4.5-2 of Reference B.4.2. In order to validate the fuel conductivity values used, a 3-D ANSYS thermal model of the NUHOMS®-7P design is created and used to compare the methodology used in Section 8.1.3 to calculate maximum fuel cladding temperatures to the actual data reported in Reference B.4.3 for the first NUHOMS® design.

B.3.2 Model Description of NUHOMS®-7P Design

A canister loaded with spent fuel in the center module, designated as HSM-2 case in Reference B.4.3, is modeled. The measured results are reported in Figure 4-10 and Table C-3 of Reference B.4.3.

Table B.3-1 provides the thermal conductivity values used in the analyses. The emissivity of stainless steel used is 0.587 [B.4.5] and zircaloy cladding is 0.80 [B.4.7].

A 180° section of the NUHOMS®-7P design [B.4.8] is modeled as shown in Figure B.3-1. Helium backfill is assumed in the model. Support rods are not modeled. The dimensions and material of construction of the NUHOMS®-7P basket and cylindrical shell were obtained from Reference B.4.8. The spacer discs and guide sleeves are shown in Figure B.3-2.

The heat generation is extracted from Reference B.4.3 for canister 2 during the fuel load test. The values are shown in Figure 3-12 of Reference B.4.3. The heat generations are calculated based on smearing the heat uniformly over the entire fuel region of the model. A sample calculation of heat generation is given in the equation below for the hottest assembly.

$$\dddot{q} = \frac{0.798kW \cdot 1.08 \cdot 3414 \frac{Btu/hr}{kW} \cdot \frac{1hr}{60\min}}{(8.73in)^2 \cdot 144in} = 4.468e-3 \frac{Btu}{\min \cdot in^3}$$

A 1.08 peaking factor is used for the thermal analyses. The heat generations applied to the model are shown in Figure B.3-3 for all the assemblies modeled.

The temperatures of the cylindrical shell are maintained at constant values based on the results of Reference B.4.3. The measured temperature at the top and bottom of the cylindrical shell during the full load were 239.9°F and 162.5°F, respectively. Values between the top and bottom are linearly interpolated.

Radiation is modeled by overlaying surface elements on all the interior guide sleeve and DSC shell surfaces and solving for geometrical view factors using the /AUX12 method in ANSYS. ANSYS then adds the radiation energy equation to the overall set of equations for each node selected in the geometrical view factor calculation.

The conductivity of the guide sleeves is very different through the thickness and along the length because of gaps between the plates. Therefore, the conductivities are derived separately through thickness and along the length and then anisotropic conductivities are used in ANSYS.

The effective conductivity through the thickness of the guide sleeve assembly is based on a series resistance method [B.4.4] given in the equation below.

$$k_{eff} = \frac{t_{tot}}{\frac{t_{st}}{k_{st}} + \frac{t_{boral}}{k_{boral}} + \frac{t_{He}}{k_{He}}}$$

The through-wall effective conductivities of DSC guide sleeves as a function of temperature are given in Table B.3-2.

Along the length of the guide sleeve assemblies and in the axial direction, a parallel resistance method [B.4.4] is more appropriate to model conduction.

$$k_{eff} = \frac{k_{st} \cdot t_{st} + k_{boral} \cdot t_{boral} + k_{He} \cdot t_{He}}{t_{tot}}$$

The effective conductivities of guide sleeves along the length as a function of temperature are given in Table B.3-3.

B.3.3 NUHOMS®-7P Design Thermal Model Results

The results from the model described in Section B.3.2 are shown in Figure B.3-4.

The temperatures of the fuel assemblies are all below 400°F, which means that the effective conductivity at 400°F from Table B.3-1 is used at the lower temperatures by ANSYS to calculate the fuel region temperatures. Given the expected trend of the effective conductivity, that it would be lower at lower temperatures, the use of the value at 400°F yields lower maximum fuel cladding temperatures and is thus conservative in

comparing to the measured results. Using a higher conductivity in the model is conservative in this case because the objective is to calculate higher temperatures than what was measured in order to validate the methodology that has been used. The measured results are given in Figure 4-10 and Table C-3 of Reference B.4.3. Comparisons between measured temperatures and calculated temperatures are presented in Table B.3-4. The locations of the measured temperatures are approximated by inspection of Figure 3-9 of Reference B.4.3. Results from the thermocouples located at the cross section C-C are reported. There are 3 measured results near the axial center of the active fuel at this cross section. By inspection of the drawing [B.4.8] and comparison to Figure 3-9 of Reference B.4.3, it is judged that thermocouples outside the fuel assembly were mounted on the guide tubes at this axial location. The reported calculated temperatures are for the guide tubes, half way between the spacer discs. The thermocouple in the fuel assembly is in the center of the assembly. This conclusion is based on the location of the instrument thimble in the fuel assembly in Figure 3-14 of Reference B.4.3.

Temperature contours of the fuel assembly and guide sleeve for which temperatures are reported in Table B.3-4 are presented in Figure B.3-5.

B.3.4 Helium Backfill Extrapolation to Higher Temperature

The effective conductivity of the fuel which includes conduction, convection and radiation heat transfer is given by:

$$k_{eff} = \frac{F\varepsilon_{eff}\sigma \cdot \left(T_1^4 - T_2^4\right) \cdot \Delta x}{A \cdot \left(T_1 - T_2\right)} + k_{cond} + h_{nc} \cdot \Delta x \cdot \left(T_1 - T_2\right)^{1/3}$$

According to the values given in Table B.3-1, the effective fuel conductivity increases by a factor of 2.44 from 400 to 800°F. The helium gas conductivity increases by a factor of 1.37 over the same temperature range. The radiation contribution to the effective fuel conductivity is expected to increase by a much greater factor over the same temperature range due to its dependence on temperature to the third power.

Therefore, given that these effective conductivity values were derived in Reference B.4.2 to match experimental data, it is reasonable to conclude that the fuel effective conductivity would increase by a factor of 2.44 over the temperature range considered.

B.3.5 Conclusions

The results given in Table B.3-4 show that the methodology, typical of NUHOMS® thermal design calculations, including the fuel effective conductivity values in helium

cover gas presented in Table B.3-1, gives conservative results in predicting fuel assembly and guide sleeve temperatures versus measured NUHOMS®-7P test results.

Table B.3-1
Thermal Conductivities

Temperature (°F)	K (Btu/min-in-°F)
Fuel in Helium(1)	
400	2.22E-3
500	2.92E-3
600	3.61E-3
700	4.44E-3
800	5.42E-3
Fuel in Vacuum(2)	
200	2.099E-4
300	2.417E-4
400	3.107E-4
500	4.339E-4
600	6.301E-4
700	9.191E-4
800	1.322E-3
Fuel Axial Conductivity with Helium(3)	
200	9.750e-4
300	1.004e-3
400	1.034e-3
500	1.071e-3
Boral [B.4.6]	
100	0.0689
500	0.0617

(1) From Figure B.2-3.

(2) From Figure B.2-5.

(3) Fuel axial conductivities are calculated based on a weighted area average using a parallel heat transfer resistance method.

Table B.3-2
Through-Wall Effective Conductivities of Guide Sleeve Assemblies With Helium

Temperature (°F)	K_{eff}, Guide Sleeve (Btu/min-in-°F)
200	6.393e-4
300	7.005e-4
400	7.662e-4
500	8.389e-4
600	9.104e-4
700	9.769e-4
800	1.040e-3

Table B.3-3
Effective Conductivities of Guide Sleeve Assemblies Along Length With Helium

Temperature (°F)	K_{eff}, Guide Sleeve (Btu/min-in-°F)
200	3.443e-2
300	3.387e-2
400	3.334e-2
500	3.278e-2
600	3.218e-2
700	3.162e-2
800	3.099e-2

Table B.3-4
Comparison of Measured and Calculated Temperatures

Location	Measured [B.4.3] (°F)	Calculated (°F)
Guide Sleeve, Top Fuel Cell, Top Center (t/c C-2-08)	298	332
Guide Sleeve, Top Fuel Cell, Bottom Center (t/c C-2-07)	341	361
Fuel Assembly, Top most, center (t/c C-2-16)	357	356[1]

(1) The maximum calculated temperature for the assembly is 361°F.

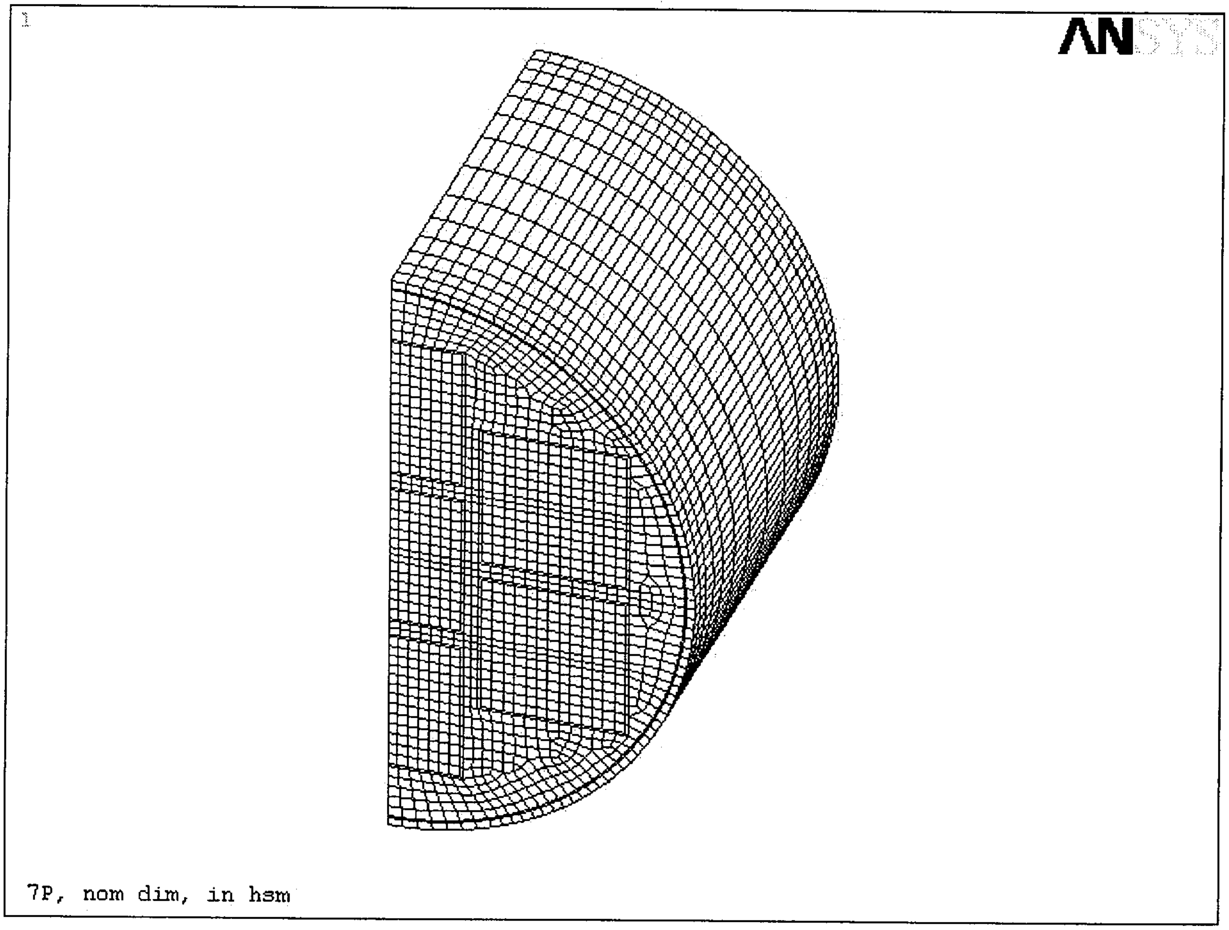

Figure B.3-1
Thermal Model of NUHOMS®-7P Design

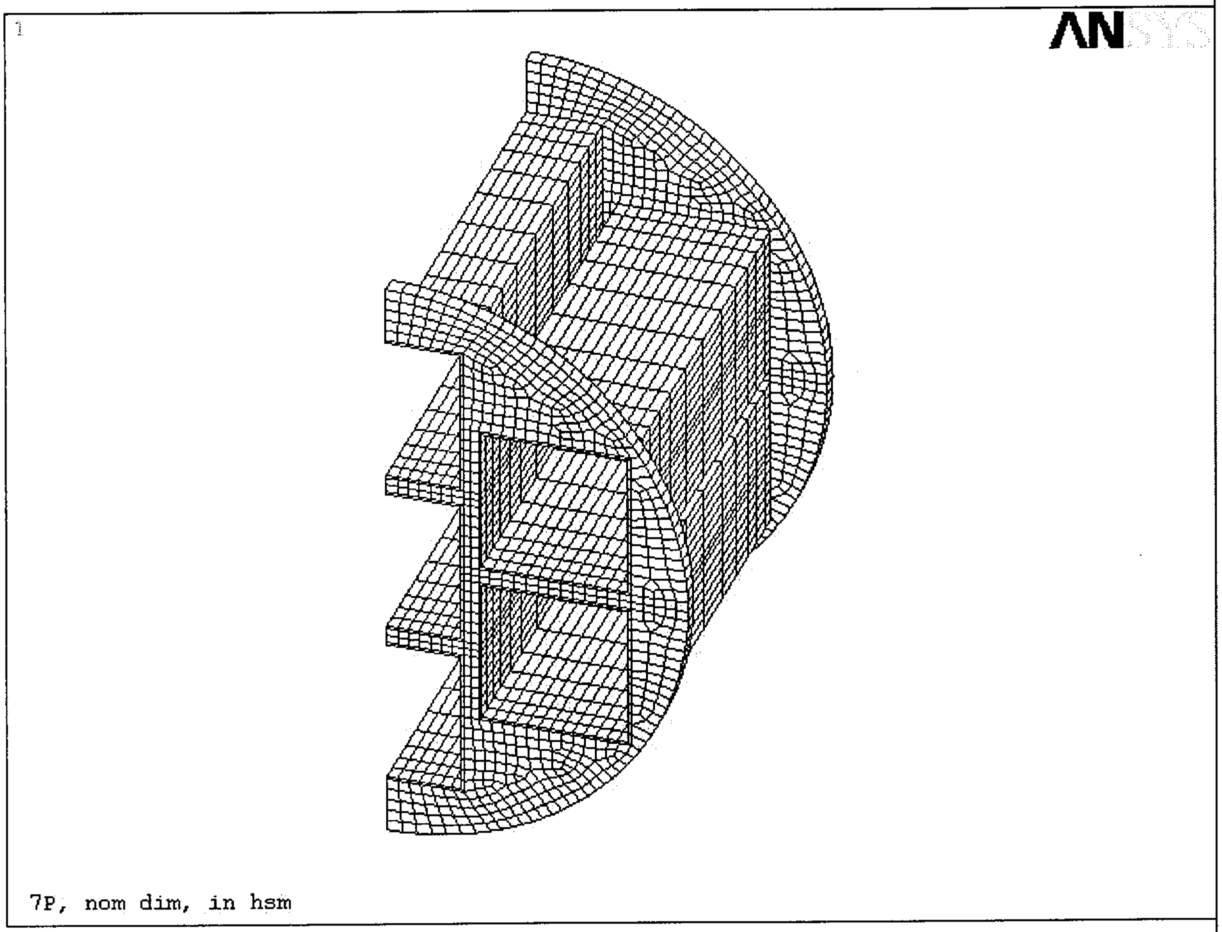

Figure B.3-2
Thermal Model of Spacer Discs and Guide Sleeves for NUHOMS®-7P Design

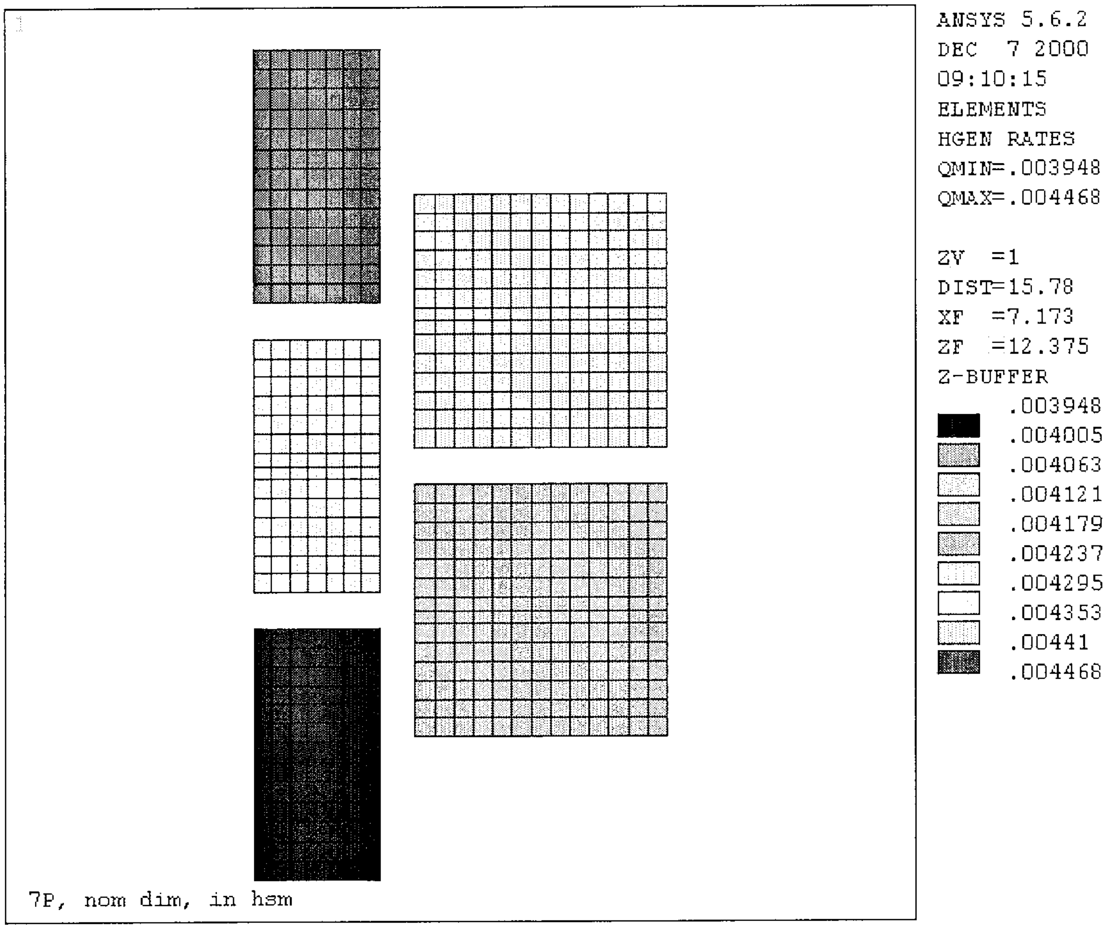

Figure B.3-3
<u>Heat Generations Used in NUHOMS®-7P Model (Btu/min-in^3)</u>

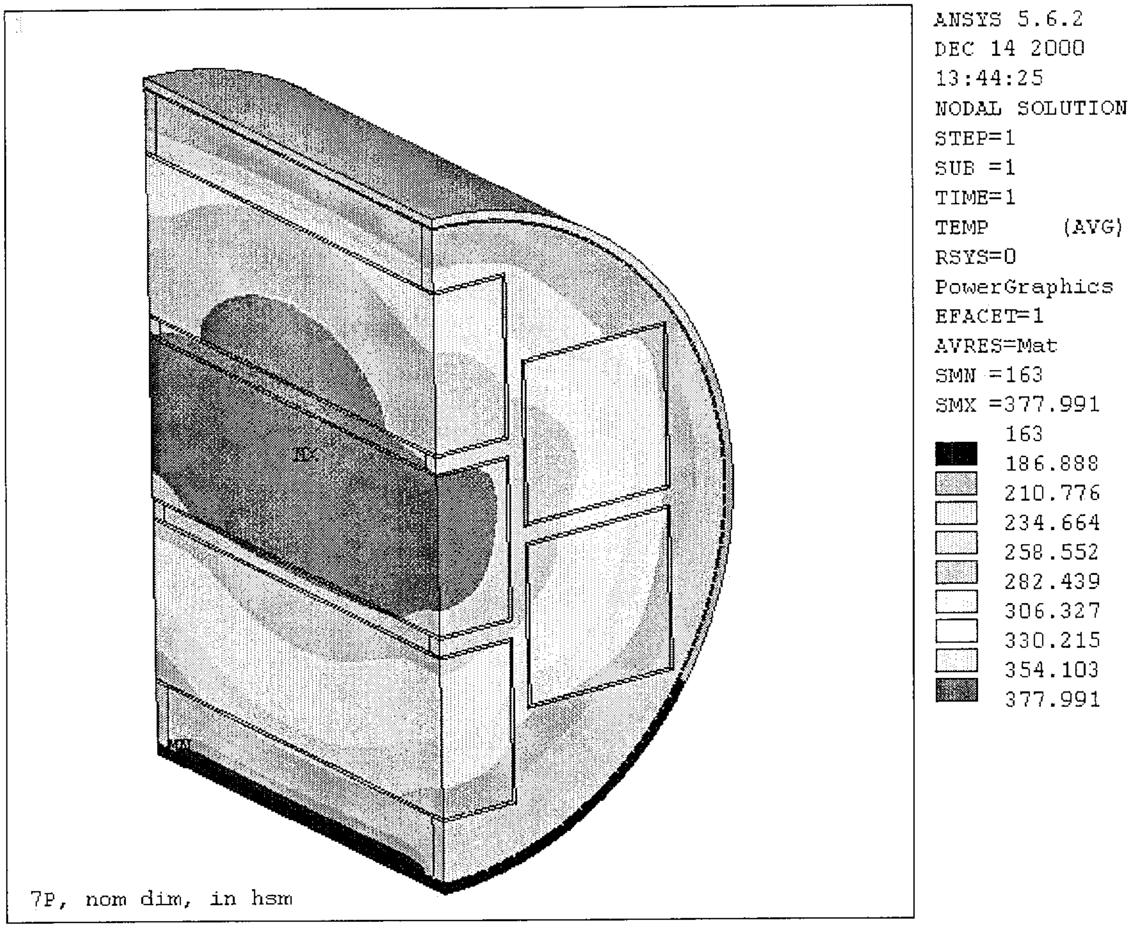

Figure B.3-4
NUHOMS®-7P Thermal Model Results (°F)

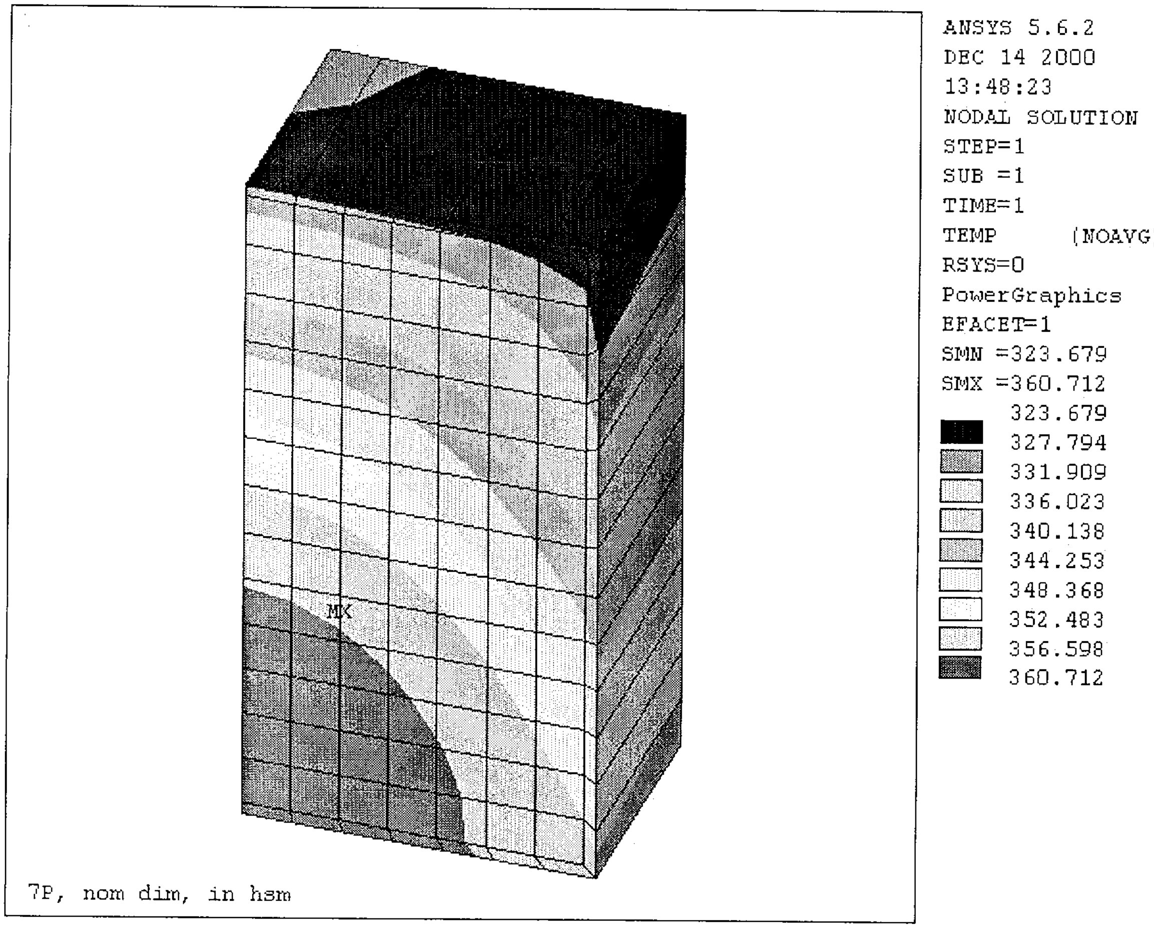

Figure B.3-5
<u>**Fuel Assembly and Guide Sleeve Temperature Results (°F)**</u>

B.4 References

B.4.1 Archie, W. Culp Jr., Principles of *Energy Conversion, McGraw-Hill, New York, NY, 1979.

B.4.2 Westinghouse Electric Corporation, Spent Fuel Dry Storage Testing at E-MAD, (March 1978 - March 1982), PNL-4533, September 1983.

B.4.3 Report, NUHOMS Modular Spent-Fuel Storage System: Performance Testing, Document No. EPRI NP-6941/PNL-7327, September 1990.

B.4.4 Incropera, F. P., D. P. DeWitt, Fundamentals of Heat and Mass Transfer, 3rd Edition, Wiley, 1990.

B.4.5 Bucholz, J. A., Scoping Design Analysis for Optimized Shipping Casks Containing 1-, 2-, 3-, 5-, 7-, or 10-Year old PWR Spent Fuel, Oak Ridge National Laboratory, January, 1983, ORNL/CSD/TM-149.

B.4.6 Standard Specification for BORAL Composite Sheet," Specification Number BPS-9000-04, AAR Advanced Structures, Livonia, Michigan.

B.4.7 McKinnon, M.A. et. al, Testing and Analysis of the TN-24P PWR Spent Fuel Dry Storage Cask Loaded With Consolidated Fuel, February, 1989, Electric Power Research Institute, EPRI Document NP-6191.

B.4.8 NUTECH, Inc., "Topical Report for the NUTECH Horizontal Modular Storage System for Irradiated Nuclear Fuel, " NUH-001, Revision 2A, San Jose, California (Docket M-39).

APPENDIX C

SUPPORTING STRUCTURAL ANALYSES

This appendix contains the following six items:

C.1 Deleted

C.2 Transfer Cask Corner Drop Analysis

C.3 Transfer Cask Side Drop Analysis

C.4 Fatigue Evaluation

C.5 Transfer Cask Structural Analysis NRC Question Resolutions

C.6 References

APPENDIX C.1

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APPENDIX C.2

Transfer Cask Corner Drop Analysis

C.2. Transfer Cask Corner Drop Analysis

C.2.1 Introduction

As described in Section 8.2.5, the transfer cask is designed for a corner drop accident with a 25g equivalent static deceleration. The analysis description provided here is an overview of the methodology used for the Standardized transfer cask. While the input parameters, such as component weights, may differ from the details presented in this analysis, these differences are minor and have negligible impact on the analysis conclusions. Additionally, while the specific details, such as component materials, weights, and dimensions, differ for the OS197, the overall analysis methodology presented here is also applicable to the OS197 and OS197H transfer casks.

The transfer cask corner drop analysis is complicated by the fact that the loading which results from this drop is a non-axisymmetric load applied to an axisymmetric structure. A conservative analysis is performed to derive the impact force for a drop orientation of 30° to the horizontal. The rationale for the choice of this drop orientation is provided in Section 8.2. The impact force acts over a fraction of the circumference and length of the cask. The area over which the impact force acts is determined from geometrical considerations of the cask at impact.

In order to apply the impact force to the cask top and bottom axisymmetric models presented in Section 8.2 and shown in Figure C.2 - 1 and Figure C.2 - 2, the impact force is resolved into Fourier harmonics. Sufficient harmonics are selected to accurately describe the load. The content loading of the cask (DSC + SFAs) is also treated in a similar manner. The analysis is performed using ANSYS STIFF25 harmonic elements. This element is commonly used for problems involving axisymmetric structures with non-axisymmetric loading. The final stresses at various sections of the cask are obtained by summing the contributions of the various harmonics, using the ANSYS POST29 routine.

C.2.2 Development of Impact Forces

At impact, the cask is oriented such that the axis of cask is 30° from the horizontal or 60° from vertical (see Figure C.2 - 3).

The maximum dry loaded weight of the the standardized, OS197, and OS197H transfer casks is approximately 190,000 lbs, 200,000 lbs and 226,000 lbs, respectively. For this analysis, the cask weight is assumed to be 200×10^3 pounds. See Section C.3.7 regarding stress scaling of the OS197 and OS197H transfer casks.

Total impact force = $200 \times 10^3 \times 25g$ $= 5 \times 10^6$ lbs.

Axial component of impact force $(P_i)_A$ $= 5 \times 10^6 \times \text{Cos } 60°$

$= 2.5 \times 10^6$ lbs.

Lateral component of impact force $(P_i)_L$ $= 5 \times 10^6 \times \text{Sin } 60°$

$= 4.3 \times 10^6$ lbs.

To calculate the impact area, the Modified Petry Formula (Reference C-5) is used to calculate depth of penetration into the impacted concrete, assuming that the cask is rigid. The depth of penetration is given by:

$$x = 12\, K_p\, A_p\, \text{Log}_{10}\left[1 + \frac{V_S^2}{215{,}000}\right] \qquad \text{(C.2-1)}$$

Where: x = Depth of penetration into concrete element of infinite thickness (in.)

K_p = Penetration coefficient for reinforced concrete
= 0.0035 for 3000 psi concrete

A_p = Average impact pressures (psf)

$$= \frac{W}{A} = \frac{\textit{Cask weight}}{\textit{Project frontal area of missile}}$$

V_s = Striking velocity of cask (ft./sec.)

$$= \sqrt{2gh} = \sqrt{2 \times 32.2 \times 6.7} = 20.8 \text{ ft./sec.}$$

h = Drop height = 6.7 ft. (80 inches)

Hence: $x = 12 \times 0.0035 \frac{W}{A} \, Log_{10}\left[1 + \frac{20.8^2}{215{,}000}\right]$

W = 200,000 lbs.

Therefore: $x = 12 \times 0.0035 \times \frac{200{,}000}{A} \, Log_{10}\left[1 + \frac{20.8^2}{215{,}000}\right]$

Therefore: $x = \frac{7.33}{A}$

If A is converted to $(in.)^2$ then:

$$x = \frac{7.33 \times 144}{A} = \frac{1056}{A}$$

The value of x must be solved iteratively since the projected frontal area A is a function of x. The value of A is calculated from geometrical considerations of the cask at impact as shown in Figure C.2 - 4.

Section A-A is an elliptical cross-section with the dimensions shown in Figure C.2 - 5. The projected frontal area is a sector of this elliptical surface.

Assuming the shaded area in Figure C.2 - 5 to be half an ellipse, the projected frontal area is estimated as:

$$A = 0.5\,\pi \frac{x}{Sin\,\alpha\ Cos\,\alpha}\sqrt{\frac{x}{Sin\,\alpha}\left[2R - \frac{x}{Sin\,\alpha}\right]} \qquad (C.2\text{-}2)$$

Solving this gives a value of x = 4.0 inches.

C.2.3 Distribution of Impact Force

The impact force is assumed to be distributed as a cosine function along the cask circumference as shown in Figure C.2 - 6.

Therefore: $$P_i = P_{max}\ Cos\left[\frac{\pi}{2\theta_m}\right]\theta \qquad (C.2\text{-}3)$$

Where: P_{max} = Amplitude of loading function

θ_m = Half angle = 28° (from the geometry of the cask at impact shown in Figure C.2 - 4)

P_{max} is determined by equating the area under cosine curve to the impact force.

In the axial direction:

$$(P_i)_A = 2\,P_{max}\,r\int_0^{\theta_m} Cos\ \frac{\pi}{2\theta_m}\,\theta\,d\theta \qquad (C.2\text{-}4)$$

From which: $P_{max} = \frac{(P_i)_A \pi}{4\theta_m R}$

Therefore: $P_{max} = \frac{2500 \times 10^3 \times \pi}{4 \times 0.489 \times 39.5}$

$= 102{,}000$ lbs.

Hence: $(P_i)_A = 102{,}000 \, Cos\left[\frac{\pi}{2\theta_m}\right]\theta$

In the lateral direction:

$$P_{max} = \frac{(P_i)_L \pi}{4\theta_m R}$$

Therefore: $P_{max} = \frac{4{,}300 \times 10^3 \times \pi}{4 \times 0.489 \times 39.5}$

$= 175{,}000$ lbs.

Therefore: $(P_i)_L = 175{,}000 \, Cos\left[\frac{\pi}{2\theta_m}\right]\theta$

Fourier harmonics for the above load distributions are determined assuming an amplitude of 1.0 to calculate the circumferential load distribution. This distribution is shown in Table C.2 - 1.

Fourier harmonics are determined using the ANSYS PREP 6 Routine. The first eight modes of the Fourier series analysis are selected for use and are shown in Table C.2 - 2. Comparison between the input load and the Fourier harmonic approximation is presented in Figure C.2 - 7.

C.2.4 Development of Content Loading

The cask contents loading includes the weight of cask plus the weight of the DSC and SFAs.

C.2.4.1 DSC Plus Internals

Total weight of DSC and internals	=	72,000 lbs.
Weight of cask lid	=	π x 39.5^2 x (0.283 x 3.25 + 0.064 x 2)
	=	5,100 lbs.
Total weight	=	77,100 lbs.
Due to 25g deceleration, total load	=	77,100 x 25g
Load in the axial direction	=	77,100 x 25 x Cos 60°
Pressure acting on cover plate	=	$\frac{77{,}100 \times 25 \times Cos\ 60^\circ}{\pi (34.0)^2}$
	=	265 psi

In the lateral direction, it is conservatively assumed that the DSC loads are applied at the spacer disk locations (eight) and the two end plugs. Assuming the load is distributed equally between all ten locations.

The load per spacer disk	=	$\frac{72{,}000 \times 25 \times Sin\ 60^\circ}{10}$
	=	156,000 lbs.

In the lateral direction, the load is assumed to have a cosine distribution. The contact angle θ_m of 26° is obtained from the DSC side drop analysis.

Hence: $P = P_{max}\ Cos\left(\frac{\pi}{2\theta_m}\right)\theta$

$$P_{max} = \frac{156{,}000 \times \pi}{4 \times 0.454 \times 33.67}$$

$$= 8{,}020 \text{ lbs.}$$

Therefore: $P_L = 8{,}020\ Cos\left(\frac{\pi}{2\theta_m}\right)\theta$

A Fourier harmonic analysis is performed with this distribution to determine the Fourier coefficients to be applied to the axisymmetric model. In the Fourier analysis, an

amplitude of 8,900 pounds is used. The load distribution around the circumference and the results of the harmonic analysis are shown in Table C.2 - 3 and Table C.2 - 4 respectively. The Fourier coefficients are factored by the ratio of 8,020/8,900 = 0.90 to obtain values for the actual amplitude of 8,020 pounds. The Fourier harmonic analysis results are shown in Table C.2 - 4 for the first eight modes used in the structural analysis. Comparison between the input load and the Fourier harmonic approximation is shown in Figure C.2 - 8.

C.2.4.2 Transfer Cask

The total cask weight (less top cover plate) for the drop analysis is conservatively assumed to be 122.9 kips (200 - 77.1).

Load in axial direction = 122.9 x Cos 60° = 61.5 kips

Load in lateral direction = 122.9 x Sin 60° = 106.4 kips

The cask weight is assumed to be applied at 10 locations (eight spacer disks and two end plugs) for 25g loading. The load components are as follows:

A. Axial direction

Load per location $= \frac{61.5 \times 25}{10} = 154\ kips$

B. Lateral direction

Load per location $= \frac{106.4 \times 25}{10} = 266\ kips$

$$P_{max} = \frac{P_i \pi}{4\theta_m R}$$

Assuming that the dead weight of the cask is transferred to the structural shell over the same angle as for the DSC spacer disk (26°) gives:

$$P_{max} = \frac{266 \times 10^3 \times \pi}{4 \times 0.454 \times 39.5}$$

$$= 11{,}600 \text{ lbs.}$$

C.2.5 Application of ANSYS Models

C.2.5.1 Impact Force

The impact force is applied to the cask top and bottom end assembly ANSYS axisymmetric models discussed in Section 8.2 as follows:

A. For both models (top and bottom), the lateral force is applied by multiplying P_{max} by the Fourier coefficients determined using an amplitude of 1.0. This force is divided equally between the first 10 corner nodes as shown in Figure C.2 - 9.

B. Similarly, the axial force is applied by multiplying P_{max} in the axial direction by the appropriate Fourier coefficients and applying them to the first six bottom corner nodes as shown in Figure C.2 - 9.

C.2.5.2 Content Loadings

The cask contents loading (DSC plus SFAs and dead weight of the cask) are applied to the axisymmetric model as follows:

DSC Plus Internals

A. The axial component is applied on a uniform pressure (axisymmetric loading) to the top or bottom cover plates as appropriate.

B. The lateral force is applied at each of the eight spacer disks locations and two end plug locations (total of 10) using the first eight harmonics of the Fourier analysis (see Figure C.2 - 10).

Transfer Cask

A. The axial forces are distributed to the components of the cask structural shell in the ratio of their masses. The components of the cask are:

1. 1/2" Stainless steel liner, mass = 0.141 S = 7%

2. 3-1/2" Lead, mass = 1.438 S = 72%

3. 1-1/2" Carbon steel shell, mass = 0.424 S = 21%

Total force of 154 kips per location (C.2-4.2) were applied to each of the shell nodes as follows:

1.	1/2" Stainless steel liner	10.8 kips
2.	3-1/2" Lead	110.9 kips
3.	1-1/2" Carbon steel shell	32.3 kips
	Total	154.0 kips

Application of the axial force to the analytical model is shown in Figure C.2 - 11.

B. In the lateral direction, loads are applied on the outer nodes of the 1-1/2" structural shell as shown in Figure C.2 - 12.

C.2.6 Boundary Conditions

The boundary conditions imposed on the axisymmetric structure during the stress analysis are dependent on the particular harmonic and are subject to the ANSYS program limitations. Referring to Figure C.2 - 13, the imposed boundary conditions are as follows:

For Mode 0

At A,	u_x	Restrained	At B,	u_x	Free
	u_y	Free		u_y	Restrained
	u_z	Free		u_z	Restrained

For Mode 1

At A,	u_x	Free	At B,	u_x	Free
	u_y	Restrained		u_y	Restrained
	u_z	Free		u_z	Restrained

For Modes 2 through 7

At A,	u_x	Restrained	At B,	u_x	Free
	u_y	Restrained		u_y	Restrained
	u_z	Restrained		u_z	Free

C.2.7 Analysis Results

Stress intensities for the corner drop analysis for various components of the transfer cask are reported in Section 8.2.

Table C.2 - 1
Impact Force Distribution Around Cask Circumference During Corner Drop

θ°	Normalized Load Value
0	1.0
2	0.9937
4	0.9749
6	0.9439
8	0.9010
10	0.8467
12	0.7818
14	0.7071
16	0.6235
18	0.5320
20	0.4339
22	0.3303
24	0.2225
26	0.1196
28	0

Table C.2 - 2
Fourier Harmonics for Corner Drop Impact Force

Mode*	Fourier Coefficient (Amplitude = 1.0)
0	0.099010
1	0.193584
2	0.180709
3	0.160638
4	0.135269
5	0.106915
6	0.078026
7	0.058992

* Due to the symmetric nature of the cosine function, only symmetric modes were selected in the ANSYS PREP6 analysis.

Table C.2 - 3
Content Loading (DSC) Around Circumference

θ°	Load Value
0	8902
2	8837
4	8643
6	8324
8	7882
10	7326
12	6663
14	5903
16	5057
18	4137
20	3157
22	2130
24	1073
26	0

Table C.2 - 4
Fourier Harmonics for Content Loading (DSC)

Mode	Fourier Coefficient (Amplitude = 8,902)	Fourier Coefficient (Amplitude = 8,020)
0	818	737
1	1604	1445
2	1512	1362
3	1367	1232
4	1182	1065
5	970	874
6	748	674
7	532	479

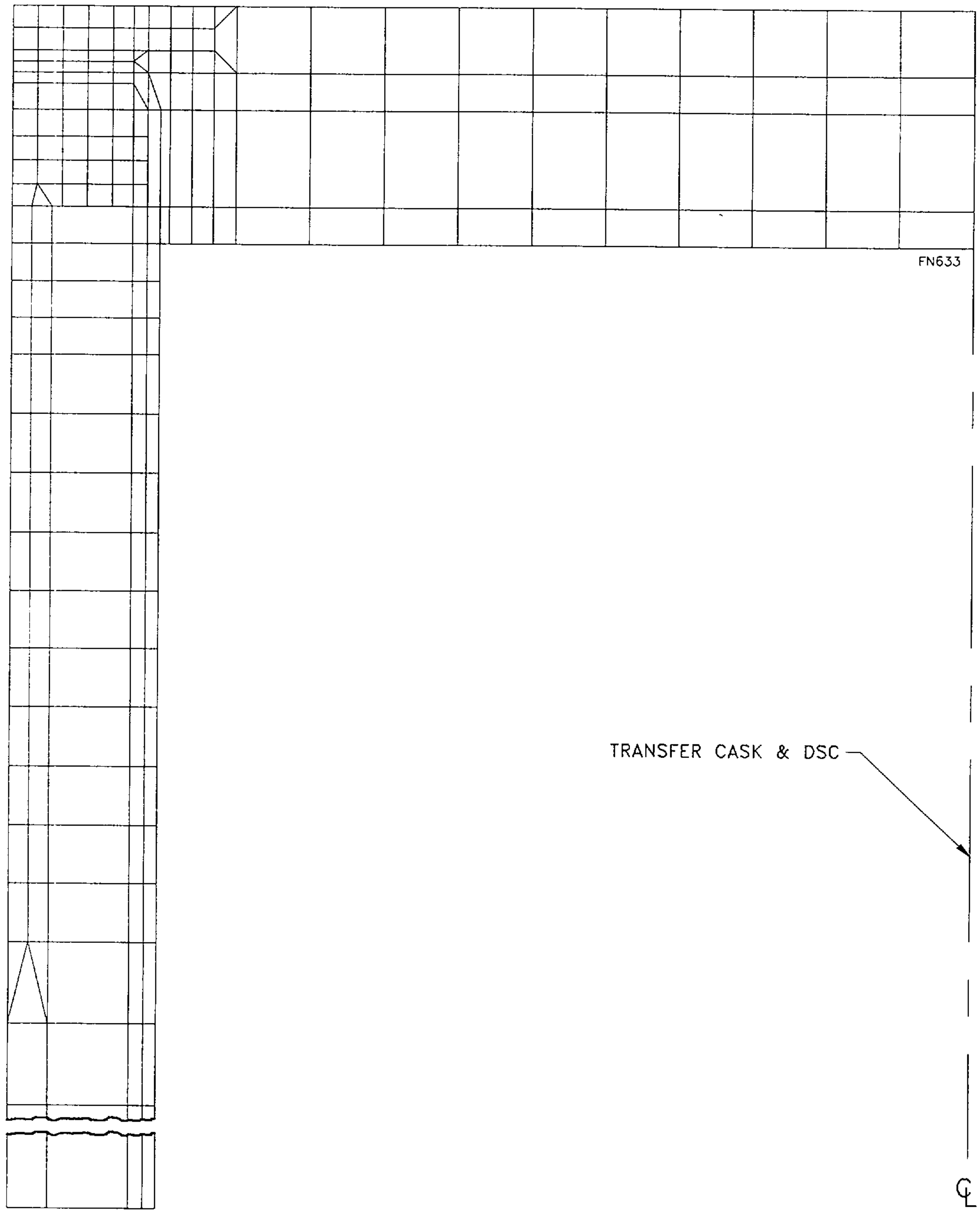


Figure C.2 - 1
Transfer Cask Top Model

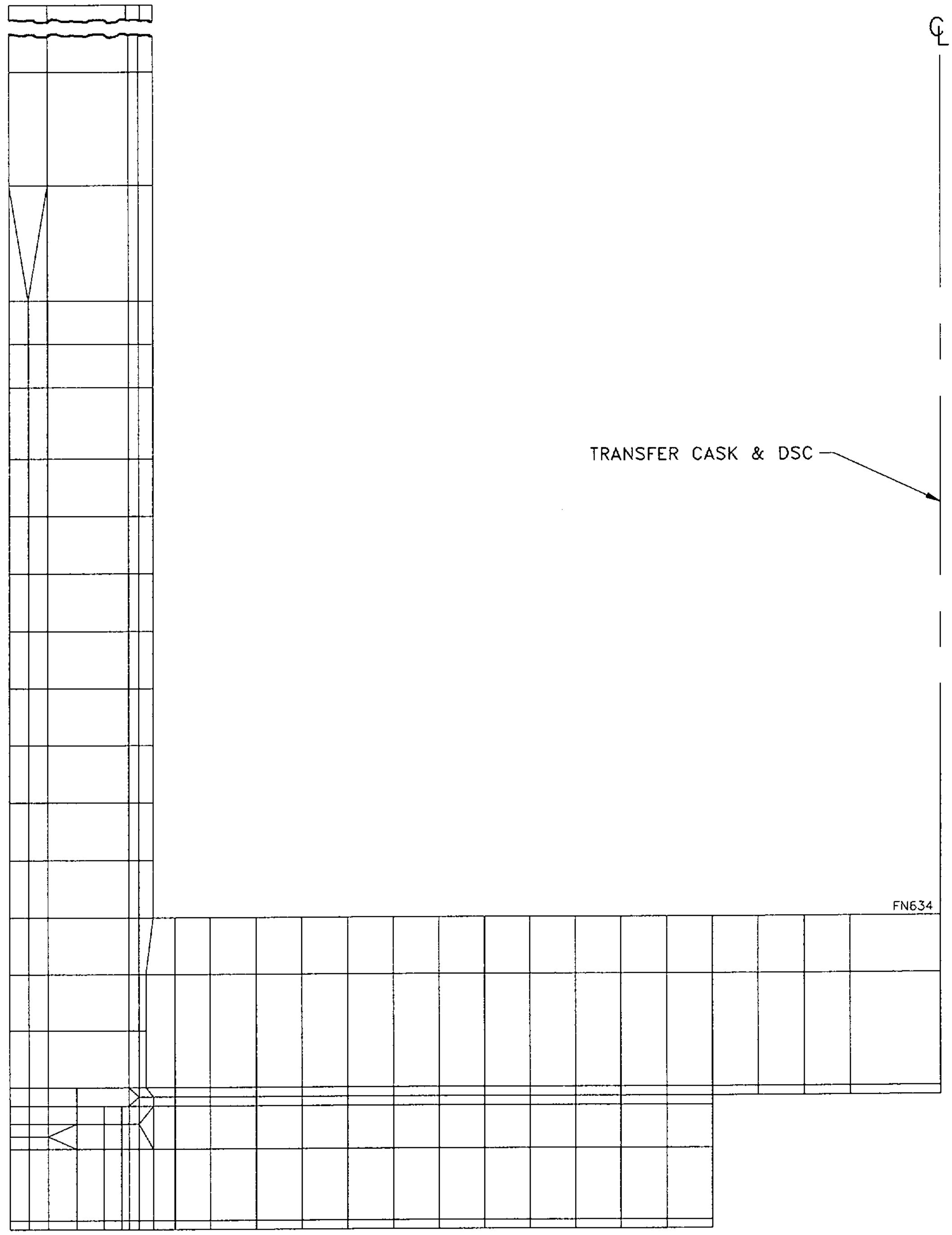


Figure C.2 - 2
Transfer Cask Bottom Model

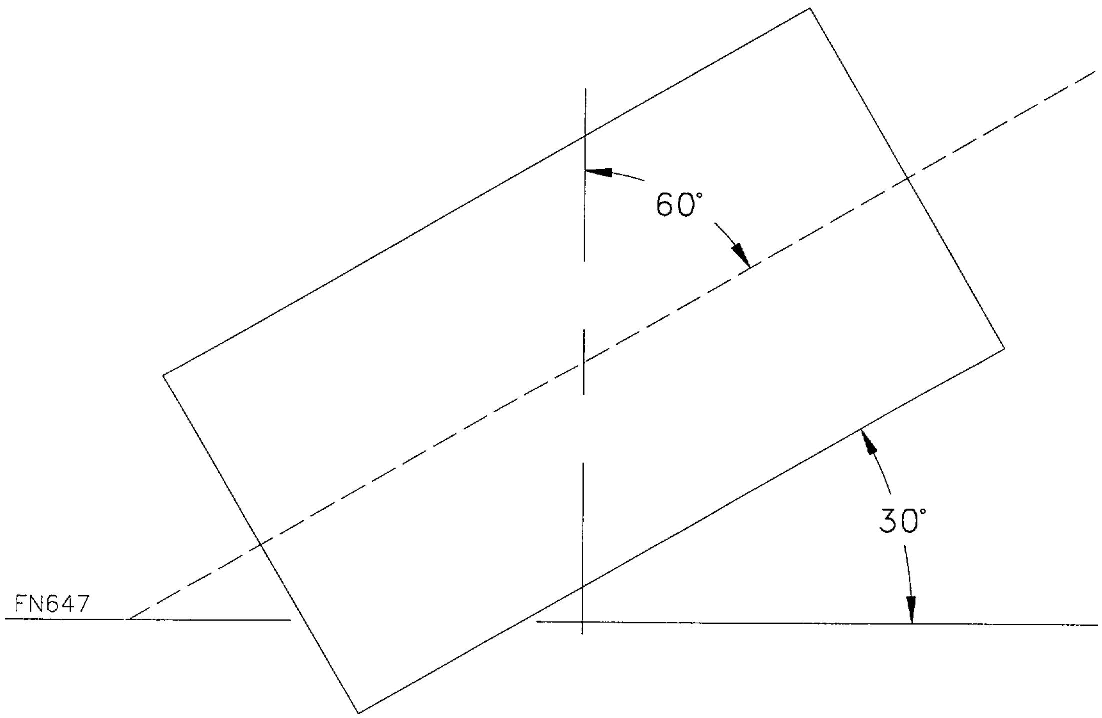


Figure C.2 - 3
Cask Orientation During Corner Drop

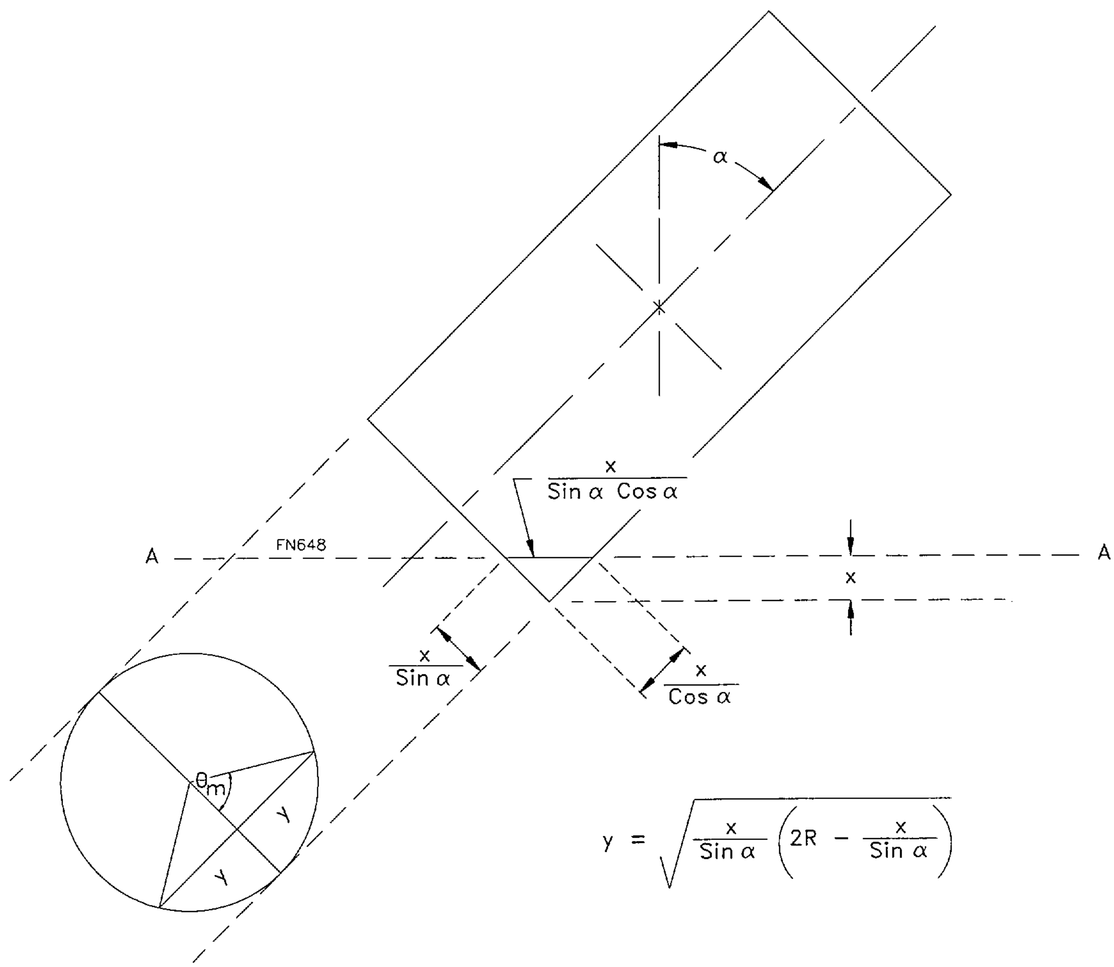
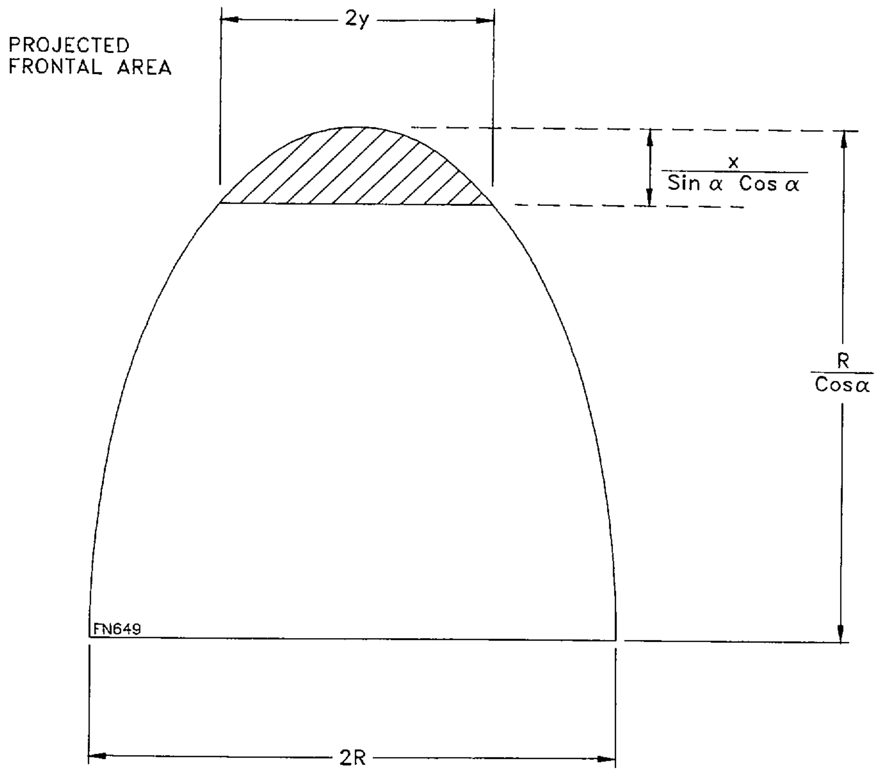


Figure C.2 - 4
Determination of Impact Area



$$y = \sqrt{\frac{x}{\sin\alpha}\left(2R - \frac{x}{\sin\alpha}\right)}$$

Figure C.2 - 5
<u>Projected Frontal Area During Impact</u>

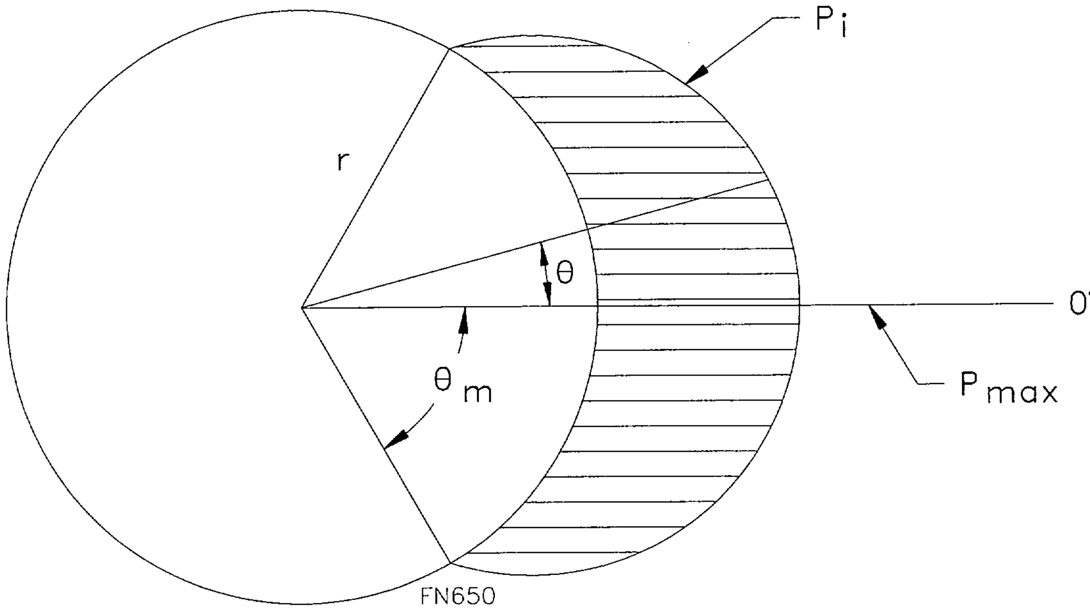


Figure C.2 - 6
Cask Impact Force Distribution

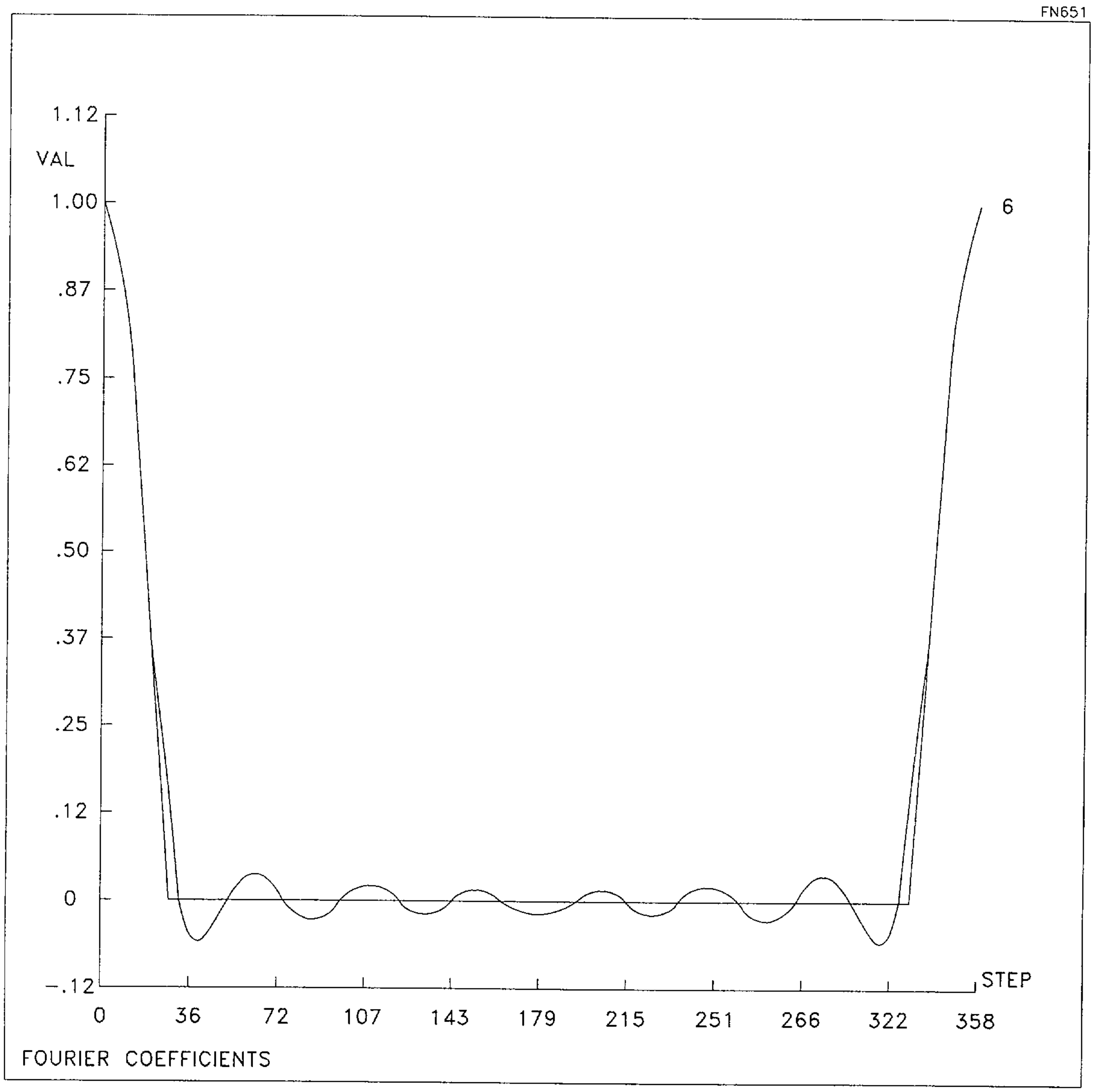


Figure C.2 - 7
Input Load During Impact vs. That Calculated from Fourier Harmonic Analysis for Corner Drop

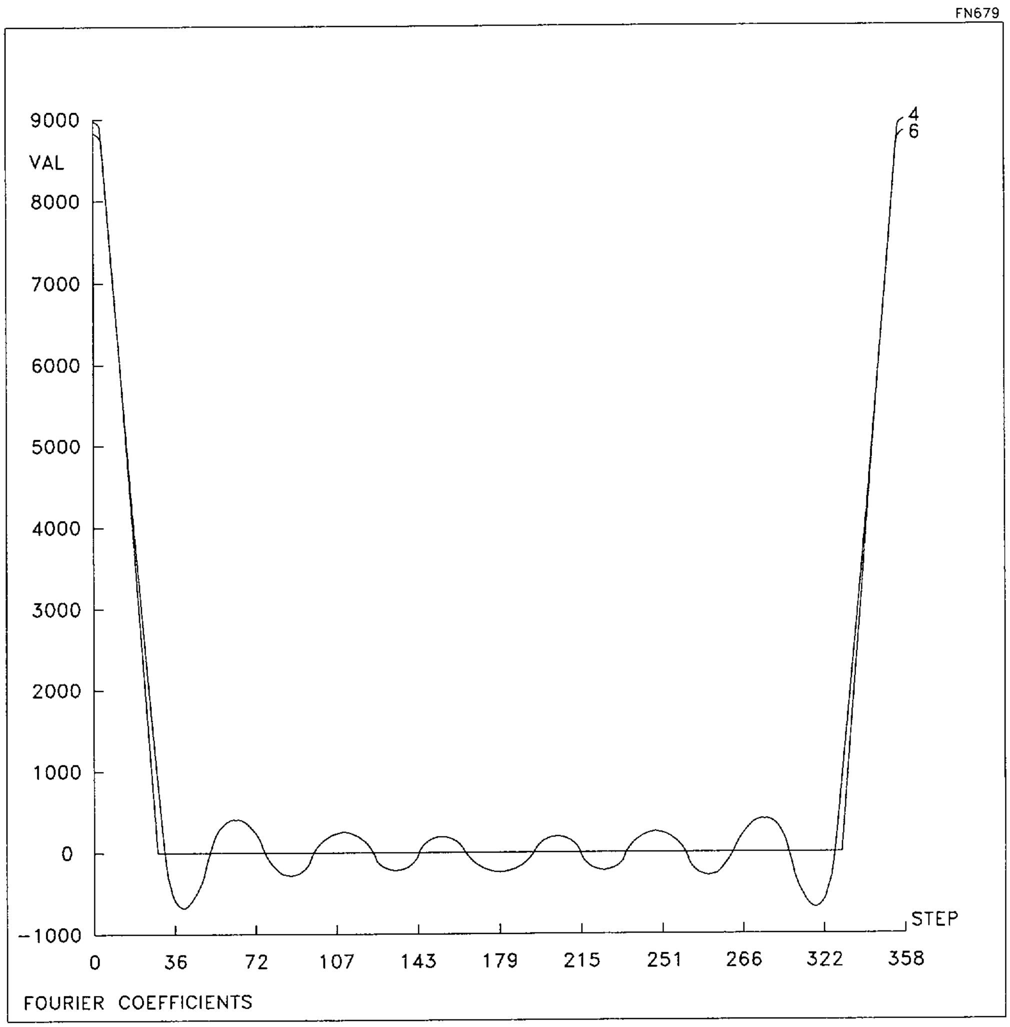


Figure C.2 - 8
Input Canister Content Loading vs. That Calculated from Fourier Harmonic Analysis for Corner Drop

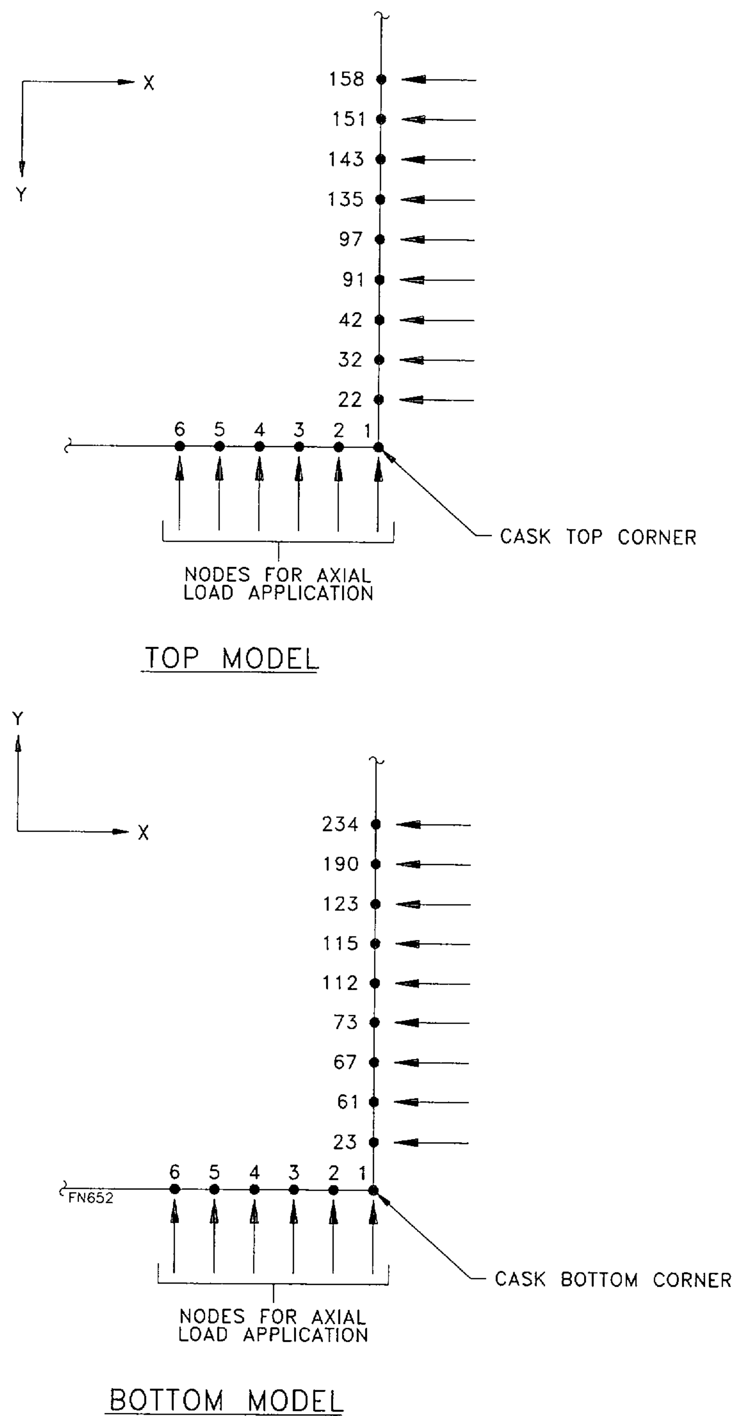


Figure C.2 - 9
Impact Force Application to Axisymmetric Model

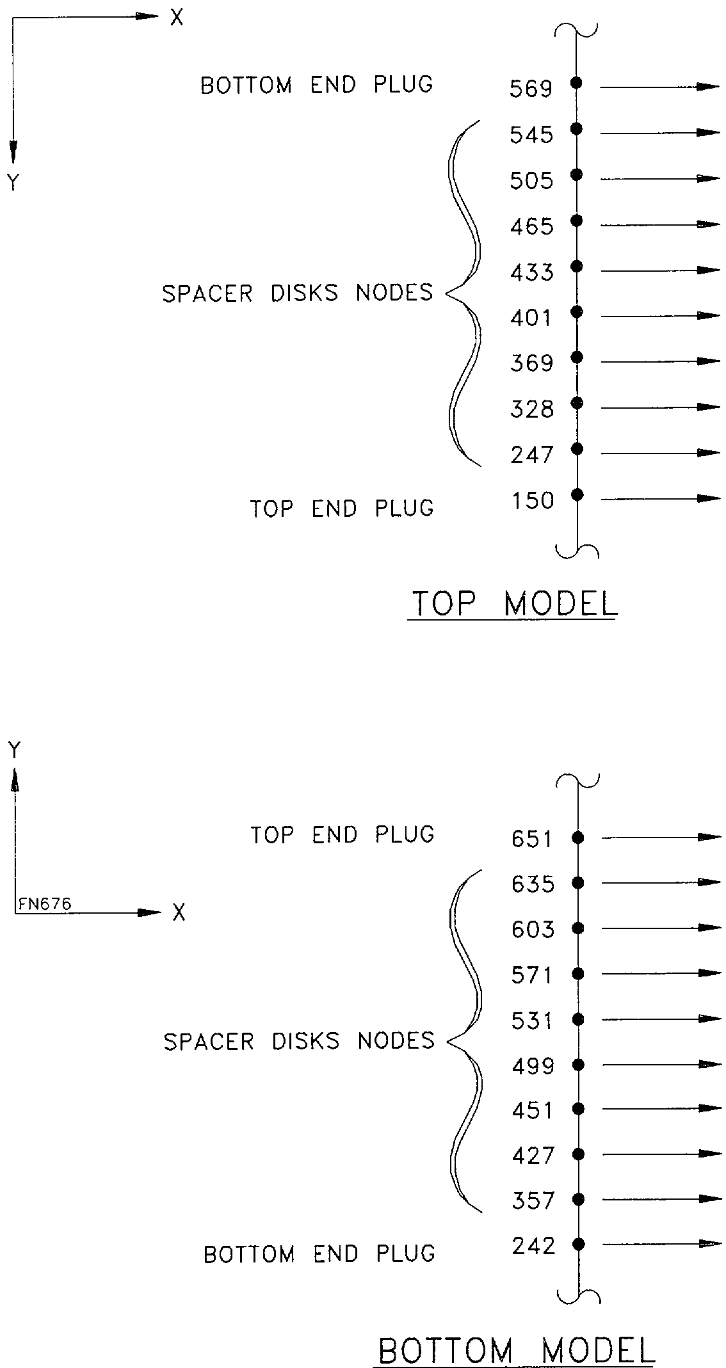


Figure C.2 - 10
Content Loading (Canister and Internals) Application to Axisymmetric Models

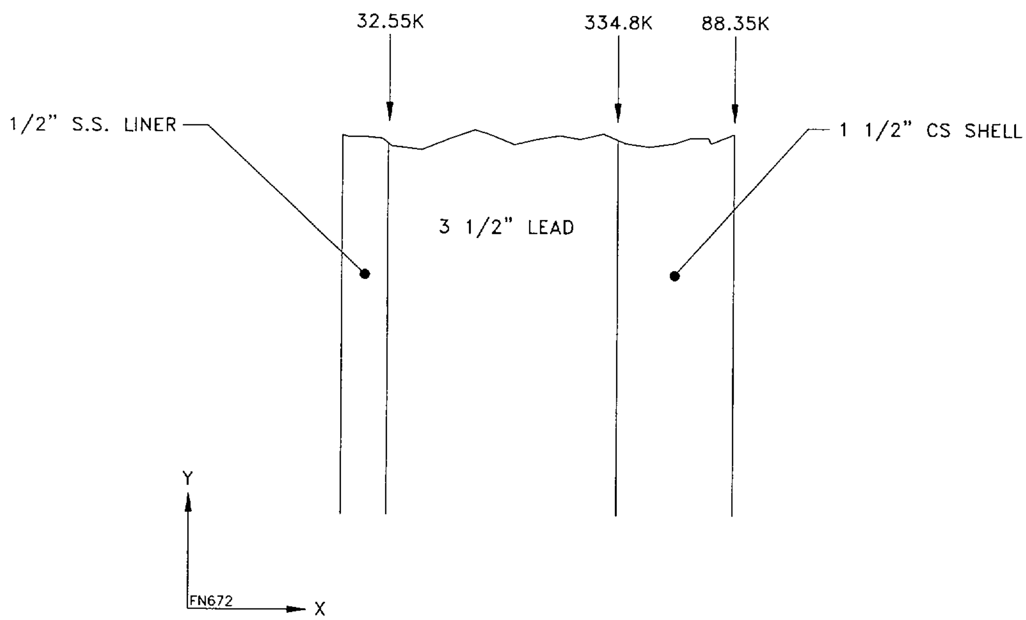
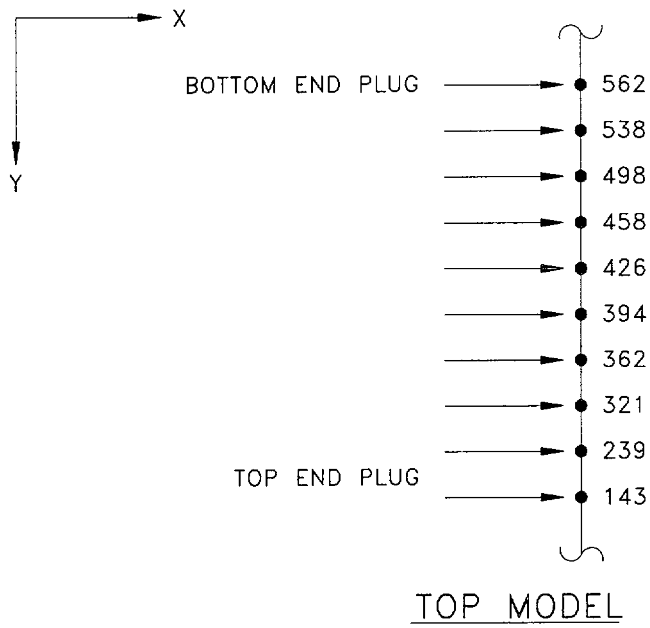


Figure C.2 - 11
Axial Force Application Due to Transfer Cask



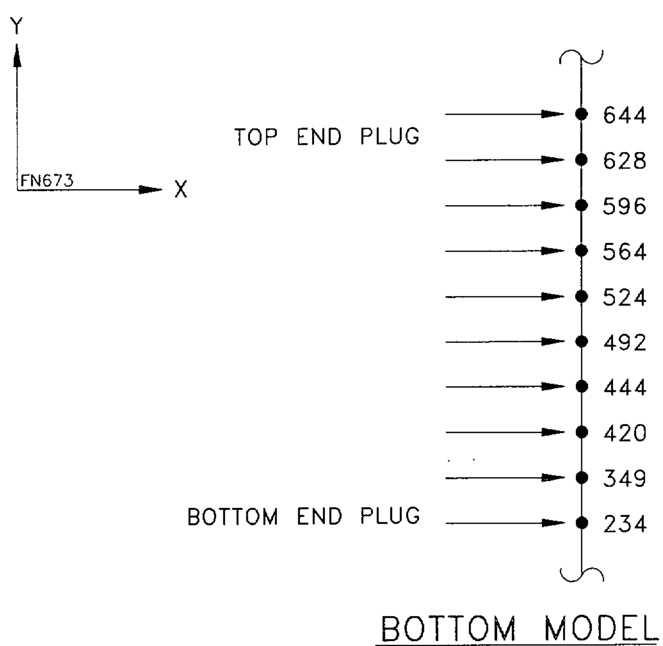


Figure C.2 - 12
Lateral Force Application Due to Transfer Cask Weight

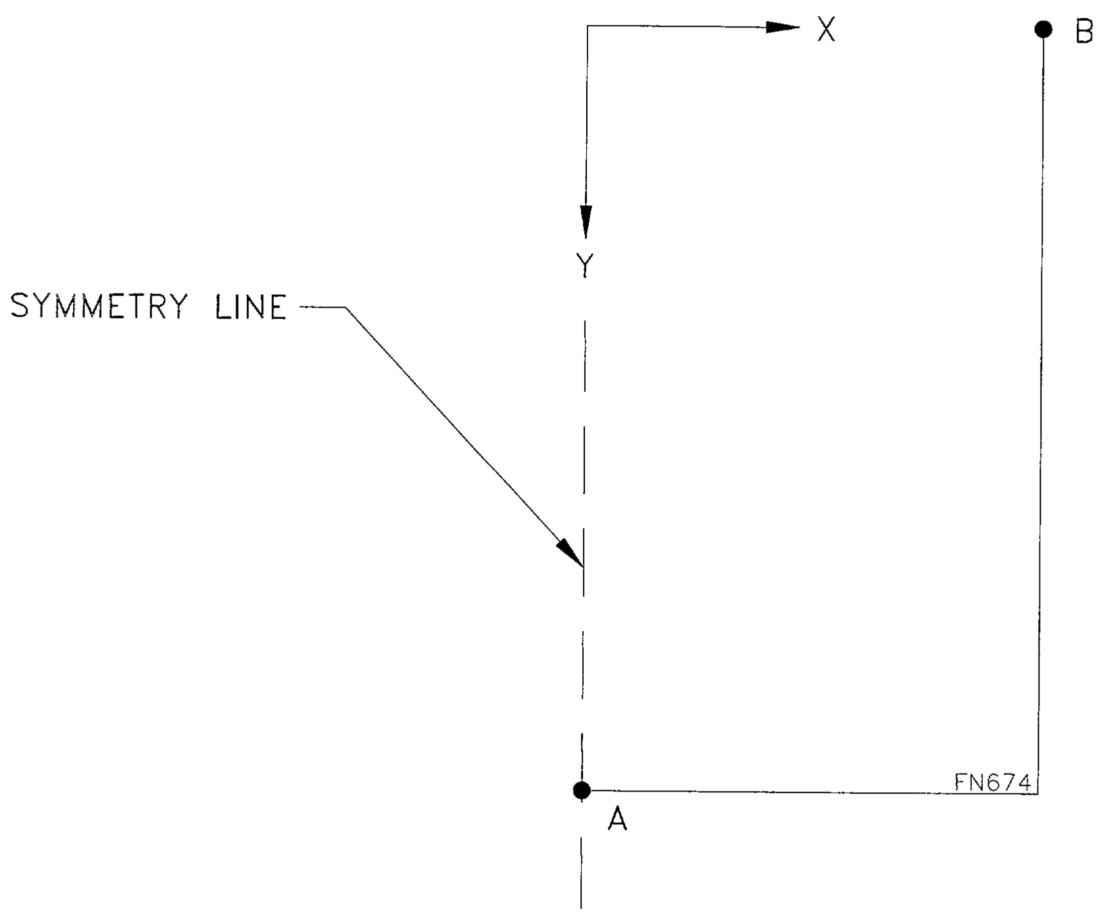


Figure C.2 - 13
Boundary Conditions for Corner Drop Analysis

APPENDIX C.3

C.3 Transfer Cask Side Drop Analysis

C.3.1 Introduction

The Standardized transfer cask side drop analysis followed the same basic approach discussed for the corner drop analysis in Appendix C.2. The cask is analyzed for a deceleration value of 75g. It also involved an axisymmetric structure with a non-axisymmetric loading. In this analysis only the cask top end model shown in Figure C.2-1 is utilized. The impact force and the content loading are calculated and applied harmonically to the model using the ANSYS STIFF45 element.

As discussed in Section 8.2, an additional supplementary analysis was performed for the OS197 transfer cask. This supplementary analysis considers the transfer of the DSC load through the cask rails that are at 18.5° on each side of the 180° azimuth. The bounding stresses from the two analyses are used for the evaluation of the OS197 and OS197H transfer cask and the results presented in Section 8.2. See Section C.3.6 for further description of the supplementary analysis.

C.3.2 Impact Force Calculation

As discussed in Appendix C.2 the maximum weight of the loaded transfer cask is assumed to be 200,000 lbs.

Total impact force P_i for a 75g deceleration:

$$= 200 \times 10^3 \times 75g \text{ lbs.}$$

Therefore: $P_i = 15 \times 10^6$ lbs.

To calculate impact area, the depth of concrete penetration is calculated assuming a rigid transfer cask using the Modified Petry Formula (Reference C-5). Figure C.3-1 shows the assumed cask configuration at impact. The depth of penetration is given by:

$$x = 12K_p \; A_p \; Log_{10}\left[1+\frac{V_s^2}{215{,}000}\right]$$

Where:

x = Depth of penetration (inches)

K_p = Penetration coefficient for reinforced concrete = 0.0035 for 3,000 psi concrete

$$A_p = \frac{W}{A} = \frac{\textit{Missile weight}}{\textit{Projected frontal area of missile}} \, psf$$

V_s = Striking velocity of missile (ft./sec.)

$= \sqrt{2gh}$ h = drop height = 6.7 ft.

$= \sqrt{2 \times 32.3 \times 6.7}$

= 20.8 ft./sec.

Therefore: x $= 12 \times 0.0035 \times \frac{200{,}000}{A} Log_{10}\left[1 - \frac{(20.8)^2}{215{,}000}\right]$

$= \frac{7.33}{A}$

If A has units of in.^{2} then:

x $= \frac{7.33 \times 144}{A} = \frac{1056}{A}$

The projected impact area:

A = 2b x L

Where: 2b = Chord length (refer to Figure C.3-2)

L = Length of cask = 198.5 in.

b $= \sqrt{x(2R - x)}$

$= \sqrt{x(79 - x)}$

Therefore: x $= \frac{1056}{198.5 \times 2\sqrt{x(79 - x)}}$

Solving iteratively, x = 0.45 in.

Therefore: b $= \sqrt{0.45(79 - 0.45)}$

= 5.9 in.

Therefore: θ_m $= Tan^{-1}\left[\frac{b}{R}\right] = Tan^{-1}\left[\frac{5.9}{39.5}\right] = 8.6°$

For analysis purposes, take $\theta_m = 10°$

C.3.3 Distribution of Impact Force

Similar to the corner drop, it was assumed that the impact force has a cosine distribution of the form:

$$P = P_{max} \, Cos\left(\frac{\pi}{2\theta_m}\right)\theta$$

Where: $$P_{max} = \frac{P_i \, \pi}{4\,\theta_m\, R}$$

When: P_i = Impact force = 15×10^6 lbs.

θ_m = 10° = 0.1745 rad.

R = Radius of cask = 39.5 in.

Therefore: $$P_{max} = \frac{15 \times 10^6 \times \pi}{4 \times 0.1745 \times 39.5}$$

Therefore: $$P = 1.709 \times 10^6 \times Cos\left(\frac{90}{10}\right)\theta$$

To calculate the equivalent pressure, divide P by cask length L.

Therefore: $$p = P_{max} \, Cos\left(\frac{90}{10}\right)\theta$$

Where: $$p_{max} = \frac{P_{max}}{198.5} = 8{,}600$$

Therefore: $$P = 8{,}600 \, Cos\,(9\theta)$$

The Fourier harmonics are determined for a load distribution from $\theta = 0°$ to $\theta = 10°$ using an amplitude of 1.0. The Fourier harmonics are then multiplied by P_{max} to determine load application to axisymmetric model. The load distribution around the circumference is shown in Table C.3-1.

Fourier harmonic analyses are performed using ANSYS PREP 6 routine.

The first twelve Fourier harmonics used in the analysis are shown in Table C.3-2. A comparison between the input load and that calculated based on the first twelve Fourier coefficients is shown in Figure C.3-3.

C.3.4 Content Loading

The cask contents loading (DSC plus internals) for the side drop consists of the lateral loading at the spacer disks and end plug locations. Loads are obtained by factoring the lateral loads (in terms of Fourier harmonics) for the corner drop analysis by 1/Sin 60° = 1.154.

The weight of the transfer is also applied in the same harmonic fashion as for the corner drop analysis except the loads are applied at the interior nodes of the 1-1/2" structural shell (Nodes 144, 241, 322, 363, 395, 427, 459, 499, 539, and 563). Also lateral loads (in terms of Fourier coefficients) are factored by 1/Sin 60° = 1.154.

C.3.5 Boundary Conditions

For the side drop analysis, the cask top end model used in the corner drop analysis is used. The boundary conditions are the same as detailed for the corner drop analysis in Appendix C.2.

C.3.6 Supplementary Analysis for the OS197 and OS197H Transfer Casks

A half-symmetry finite element model (see Figure 8.2-10a) is developed for the analysis of the OS197 and OS197H casks. The cask inner liner and structural shell are modeled using 3-D quadrilateral shell elements having three translational and three rotational degrees of freedom per node. The lead gamma shield is modeled using 3-D brick elements having three translational degrees of freedom per node.

The lead gamma shield is assumed to transfer only normal loads at the interface with the inner liner and structural shell. It is also assumed that there is no shear transfer between the lead gamma shield and the cask shells. The coincident nodes on the inner liner, gamma shield, and structural shell are coupled in the radial direction only to model the interface between the lead gamma shield and the cask shells.

The load acting on the inner surface of the cask inner liner due to the accelerated mass of the DSC, fuel, and spacer is modeled as a uniform pressure acting over the inner liner elements in the region of the cask rails (centered at 18.5° on each side of the 180° azimuth.) It is assumed the spacer assembly will have a minimal impact on the load distribution. The elements over which the pressure load is applied span an arc of 7.5°. Therefore, the magnitude of the uniform pressure load is:

$$P = 75W/2\theta RL$$

where;

W	=	Weight of the dry loaded 24P DSC & Spacer
	=	79,230 lbs. (use 80,000 pounds)
θ	=	0.1309 radians (7.5°)
R	=	34.25 inches, Mean radius of inner liner
L	=	196.75 inches, Length of cask cavity

Therefore,

$$P = (75)(80,000)/[2(0.1309)(34.25)(196.75)] = 3,401 \text{ psi}$$

A uniform pressure of 3,250 psi was applied to the inner surface of those inner liner elements within the 7.5° half angle of contact. The computer model results were scaled up by 5.3% to obtain the stress results corresponding to the higher loading of 3,401 psi to accommodate a payload of 80,000 lbs.

In addition to the contents loading, a 75g side drop vertical acceleration load is also applied to the model.

Symmetry boundary conditions are applied to the nodes lying on the cask half symmetry plane and along the plane passing through the cask mid-length. The nodes at the end of the cask shells and gamma shielding (Z=0) are restrained from translating in the radial (UX) direction and from rotating about the radial (ROTX), circumferential (ROTY), and longitudinal (ROTZ) axes. The nodes at the end of the cask shells and gamma shielding are conservatively allowed to translate freely in the longitudinal direction, ignoring any coupling effect due to the cask end plates.

C.3.7 Analysis Results

Stress intensities for the side drop analyses for various components of the Standardized, OS197, and OS197H transfer casks are reported in Section 8.2.

To qualify the OS197 transfer cask for a payload weight of 90,000 lbs, the maximum stresses for each component obtained from the vertical, horizontal, and corner drop analyses were conservatively scaled by the increase in payload weight (90,000 lb / 80,000 lb = 1.125). To qualify the OS197H transfer cask, the maximum stresses were scaled similarly (116,000 lbs / 80,000 lbs = 1.45).

Because of fabrication concerns, the inner liner of the OS197 transfer cask is allowed to vary to a minimum of 0.38 inches. When considering a payload of 116,000 lbs for the OS197H transfer cask, the shell allowable minimum thickness is calculated to be 0.44 inches.

Table C.3 - 1
Impact Force Distribution Around Cask Circumference During Side Drop

θ^{o}	p
0	1.0
2	0.9511
4	0.8090
6	0.5878
8	0.3090
10	0.0

Table C.3 - 2
Fourier Harmonics for Impact Load During Cask Side Drop

Mode	Fourier Coefficient (Amplitude = 1.0)
0	0.0350767
1	0.0699583
2	0.0693754
3	0.0684117
4	0.0670785
5	0.0653915
6	0.0633706
7	0.0610392
8	0.0584244
9	0.0555562
10	0.0524673
11	0.0491923

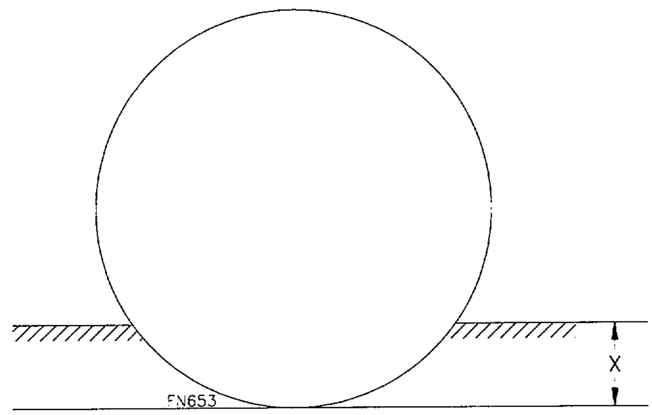


Figure C.3 - 1
Cask Configuration During A Side Drop

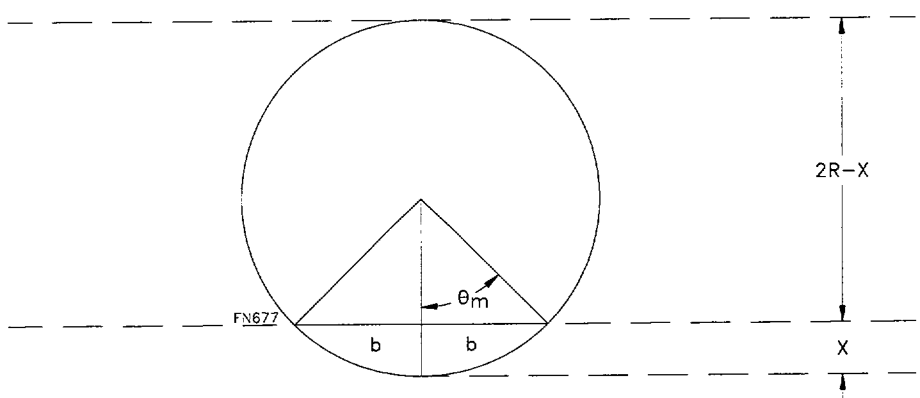


Figure C.3 - 2
Calculation of Projected Frontal Area During Side Drop

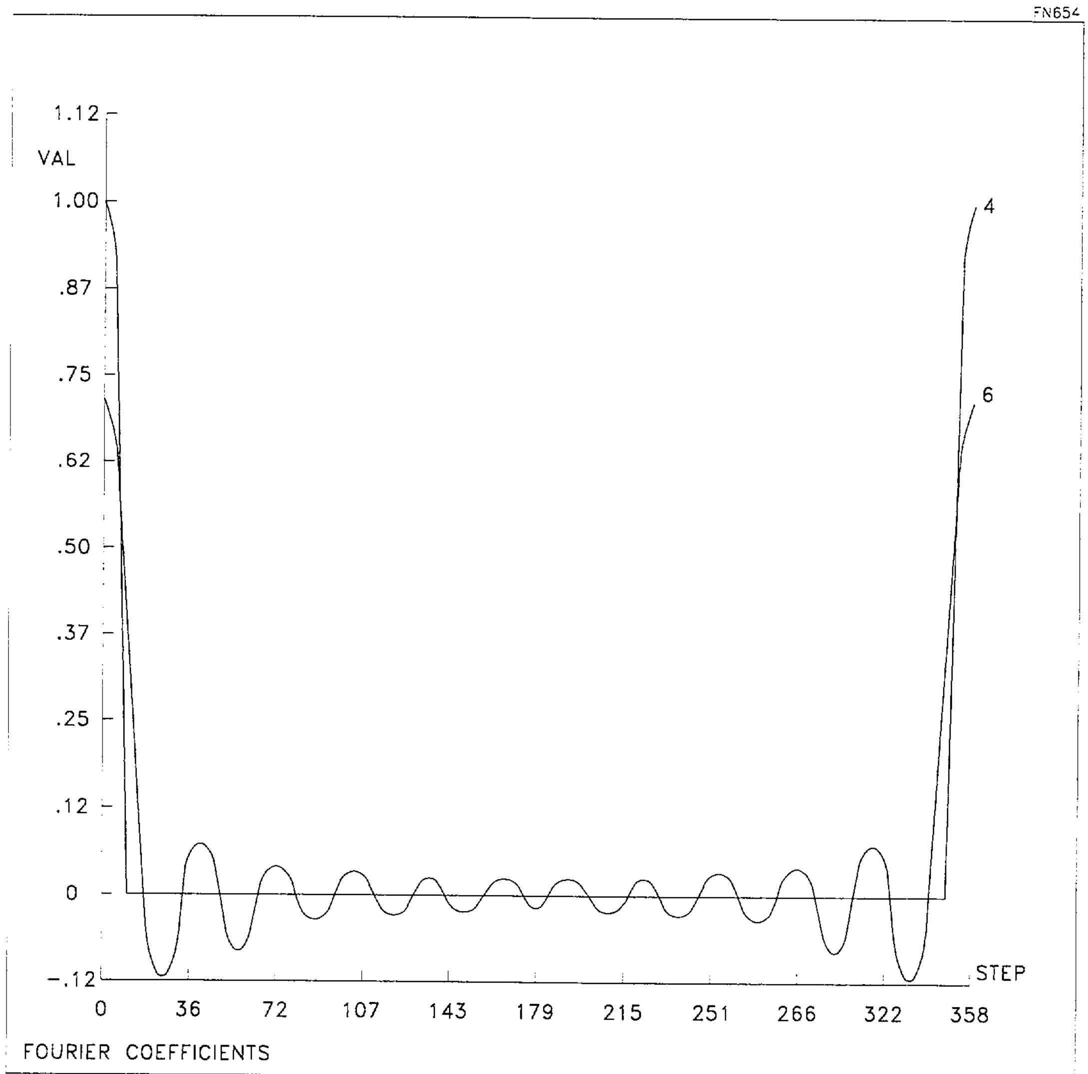


Figure C.3 - 3
Input Load vs. That Calculated From Fourier Harmonic Analysis

APPENDIX C.4

C.4 Fatigue Evaluation

C.4.1 DSC Fatigue Analysis

C.4.2 Transfer Cask Fatigue Analysis

C.4.1 DSC Fatigue Analysis

Fatigue effects on the DSC are addressed using the criteria contained in NB-3222.4 of the ASME Code (Reference C-3). Fatigue effects need not be specifically evaluated provided the criteria contained in NB-3222.4(d) are met. A summary of the six criteria and their application to the DSC are presented in the paragraphs which follow:

A. The first criterion states that the DSC is adequate for fatigue effects provided that the total number of atmospheric-to-operating pressure cycles during normal operation (including startup and shutdown) does not exceed the number of cycles on the applicable fatigue curve corresponding to an S_a value of three times the S_m value of the material at operating temperatures. This condition is satisfied for the DSC since the pressure is not cycled during its design life. The pressure established at the time that the DSC is sealed following fuel loading and DSC closure operations is maintained during normal storage in the HSM.

B. The second criterion states that DSC is adequate for fatigue effects provided that the specified full range of pressure fluctuations during normal operation does not exceed the quantity (1/3) x design pressure x (S_a/S_m), where S_a is the value obtained from the applicable fatigue curve for the total specified number of significant pressure fluctuations, and S_m is the allowable stress intensity for the material at operating temperatures. Significant pressure fluctuations are those for which the total excursion exceeds (1/3) x design pressure x (S/S_m), where S equals the value of S_a for 10^6 cycles. For a DSC maximum normal operating pressure of 6.9 psig, an S_m value of 18,700 psi, and an S value of 28,200 psi, the total range for a significant pressure fluctuation is 3.5 psig. This small pressure fluctuation may occur during normal storage as a result of seasonal ambient temperature changes. Ambient temperature cycles significant enough to cause a measurable pressure fluctuation are assumed to occur five times per year for 50 years. The number of fluctuations with this pressure range is expected to be 250 for the DSC. The value of S_a associated with this number of cycles is 186 ksi. Hence the value of (1/3) x design pressure x (S_a/S_m) is equal to 22.9 psig. Clearly this value will not be exceeded during the pressure fluctuation of the DSC. Therefore the second criterion is satisfied for the DSC.

C. The third criterion states that the DSC is adequate for fatigue effects provided that the temperature differences between any two adjacent points on the DSC during normal operation do not exceed $S_a/2E\alpha$, where S_a is the value obtained from the applicable fatigue curve for the specified number of startup-shutdown cycles, α is the instantaneous coefficient of thermal expansion at the mean value of the temperatures at the two points, and E is the modulus of elasticity at the mean value of the temperatures at the two points. For an operational cycle of the DSC, thermal gradients occur during fuel loading, DSC closure, transport to the HSM, and transfer of the DSC to the HSM. This half-cycle is approximately reversed

for DSC unloading operations. However, this normal operational cycle occurs only once in the 50 year design service life of a DSC. Since there is only one startup-shutdown cycle associated with the DSC, the value of S_a is very large (>800 ksi). Hence the value of $S_m/2E\alpha$ is very large (>1500°F). This is far greater than the temperature difference between any two adjacent points on the canister. Thus, the third criterion is satisfied for the DSC.

D. The fourth criterion states that the DSC is adequate for fatigue effects provided that the temperature difference between any two adjacent points on the DSC does not change during normal operation by more than the quantity $S_a/2E\alpha$, where S_a is the value obtained from the applicable fatigue curve for the total specified number of significant temperature-difference fluctuations. Small fluctuations in the DSC thermal gradients during normal storage in the HSM occur as a result of seasonal ambient temperature changes. Ambient temperature cycles significant enough to cause a measurable thermal gradient fluctuation are assumed to occur five times per year for 50 years. The DSC stresses resulting for thermal gradient fluctuations are small since the structural capacity of the DSC is designed for extreme accident loads such as cask drop loads which are postulated to be a one time occurrence. A temperature difference fluctuation is considered to be significant if its total algebraic range exceeds the quantity $S/2E\alpha$, where S is the value of S_a obtained from the applicable fatigue curve for 10^6 cycles. Taking the value of S = 28,200 psi, E = 26.6 x 10^6 psi and $\alpha = 9.8 \times 10^{-6}$ in./in./°F, the value of $S/2E\alpha$ = 54°F. The most significant fluctuation in normal operating temperature occurs during a change in ambient temperature from 0°F to 100°F. This fluctuation results in an estimated change of temperature difference of 20°F. The effects of this temperature difference is not significant, therefore the fourth condition is satisfied for the DSC.

E. The fifth criterion states that for components fabricated from materials of differing moduli of elasticity or coefficients of thermal expansion, the total algebraic range of temperature fluctuation experienced by the component during normal operation must not exceed the magnitude $S_a/2(E_1\alpha_1 - E_2\alpha_2)$, where S_a is the value obtained from the applicable fatigue curve for the total specified number of significant temperature fluctuations, E_1 and E_2 are the moduli of elasticity, and α_1 and α_1 are the values of the instantaneous coefficients of thermal expansion at the mean temperature value involved for the two materials of construction. A temperature fluctuation is considered to be significant if its total excursion exceeds the quantity $S/2(E_1\alpha_1 - E_2\alpha_2)$, where S is the value of S_a obtained from the applicable fatigue curve for 10^6 cycles. If the two materials used have different applicable design fatigue curves, the lower value of S_a shall be used. Since the structural material used to construct the DSC is homogeneous (all materials are stainless steel), this fifth condition is not applicable.

F. The sixth criterion states that the DSC is adequate for fatigue effects provided that the specified full range of mechanical loads do not result in a stress range which exceeds the S_a value obtained from the applicable fatigue curve for the total specified number of significant load fluctuations. If the total specified number of significant load fluctuations exceeds 10^6, the S_a value at $N = 10^6$ may be used. A load fluctuation is considered to be significant if the total excursion of stresses exceed the value of S_a obtained from the applicable fatigue curve for 10^6 cycles. The only mechanical loads which affect the DSC are those associated with handling loads and a seismic event. One handling load cycle and a major seismic event are postulated during the design life of the DSC. The DSC stresses resulting from these mechanical load fluctuations are small since the structural capacity of the DSC is designed for extreme accident loads such as a postulated cask drop. The number of significant cycles associated with mechanical load fluctuations are conservatively assumed to be 1,000. The value of S_a associated with this number of cycles is 120 ksi. Since the maximum stress range intensity permitted by the code is 3.0 S_m, or 56.1 ksi for SA-240, Type 304 stainless steel at 400°F, this sixth condition is satisfied for the DSC.

The evaluation presented in the preceding paragraphs demonstrates that the six criteria contained in NB-3222.4(d) are satisfied for all components of the DSC.

C.4.2 Transfer Cask Fatigue Analysis

Fatigue effects on the transfer cask are addressed using the criteria contained in NC-3219.2 of the ASME Code (Reference C-3). Fatigue effects need not be specifically evaluated provided the criteria contained in NC-3219.2 (Condition A or Condition B) are met. In this evaluation the six criteria contained in Condition B are addressed. A summary of the six criteria and their application to the transfer cask are presented in the paragraphs which follow:

A. The first criterion states that the transfer cask is adequate for fatigue effects provided that the total number of atmospheric-to-operating pressure cycles during normal operation does not exceed the number of cycles on the applicable fatigue curve corresponding to an S_a value of three times the S_m value of the material at operating temperatures. The transfer cask is not a pressure retaining boundary, hence this first criterion is not applicable.

B. The second criterion states that transfer cask is adequate for fatigue effects provided that the specified full range of pressure fluctuations during normal operation does not exceed the quantity (1/30 x design pressure x (S_a/S_m), where S_a is the value obtained from the applicable fatigue curve for the total specified number of significant pressure fluctuations, and S_m is the allowable stress intensity for the material at operating temperatures. Significant pressure fluctuations are those for which the total excursion exceeds (1/3) x design pressure x (S/S_m), where S equals the value of S_a for 10^6 cycles. Since the transfer cask is not pressure retaining, this second criterion is not applicable.

C. The third criterion states that the transfer cask is adequate for fatigue effects provided that the temperature differences between any two adjacent points on the transfer cask during normal operation do not exceed $S_a/2E\alpha$, where S_a is the value obtained from the applicable fatigue curve for the specified number of startup-shutdown cycles, α is the instantaneous coefficient of thermal expansion at the mean value of the temperatures at the two points, and E is the modulus of elasticity at the mean value of the temperatures at the two points. The temperature difference is a maximum for a point on the inner surface of the cask and the corresponding point on the outer surface of the cask, through the cask wall thickness. It is conservatively postulated that the transfer cask will be used approximately 1,200 times during its designed life to transfer DSCs to and from the HSMs. The S_a associated with this number of cycles is 75 ksi. Therefore the quantity $S_a/2E\alpha$ = 168°F. The maximum temperature difference between any two adjacent points on the transfer cask is conservatively calculated as 70°F. Therefore this criterion is satisfied for the transfer cask.

D. The fourth criterion states that the transfer cask is adequate for fatigue effects provided that the temperature difference between any two adjacent points on the transfer cask does not change during normal operation by more than the quantity $S_a/2E\alpha$, where S_a is the value obtained from the applicable fatigue curve for the total specified number of significant temperature-difference fluctuations. A temperature-difference fluctuation is considered to be significant if its total algebraic range exceeds the quantity $S/2E\alpha$, where S is the value of S_a obtained from the applicable fatigue curve for 10^6 cycles. Taking the value of S = 20,000 psi, E = 27.7 x 10^6 psi and $\alpha = 7.6 \times 10^{-6}$ in./in./°F, the value of $S/2E\alpha$ = 47.5°F. The most significant fluctuation in temperature occurs during a change in ambient temperature from 0°F to 100°F. This results in a transfer cask temperature change difference of 40°F. During a normal use cycle, the transfer cask is subjected to temperature fluctuations relative to the prevailing ambient temperature at the start of a use cycle. A normal transfer cask thermal use cycle for DSC loading and transfer to the HSM would results in a temperature fluctuation from the following operational conditions:

1. At the start of the use cycle, the cask will have a temperature equal to the prevailing normal ambient temperature.

2. A temperature fluctuation due to placement of the cask in the plant's fuel pool at the prevailing plant fuel pool temperature would result.

3. A temperature fluctuation due to removal of the cask from the plant's fuel pool with the decay heat power of the SFAs in water transferred to the cask would result.

4. A temperature fluctuation due to draining of the DSC/cask with the decay heat power of the SFAs in air transferred to the cask would result.

5. A temperature fluctuation due to drying of the DSC with the decay heat power of the SFAs in a vacuum transferred to the cask would result.

6. A temperature fluctuation due to backfilling of the DSC with the decay heat power of the SFAs in helium transferred to the cask would result.

7. Temperature fluctuations may result from transport of the transfer cask and DSC to the HSM with a solar heat flux and the decay heat power of the SFAs in helium transferred to the cask.

8. At the end of the cycle the cask is returned to a temperature equal to the prevailing ambient temperature.

The maximum total range of temperature fluctuations for this normal operating use cycle is 40°F. The temperature fluctuations for a DSC unloading use cycle would be similar. This temperature fluctuation does not have significant effect on the transfer cask. This fourth criterion, therefore, satisfied for the transfer cask.

E. The fifth criterion states that for components fabricated from materials of differing moduli of elasticity or coefficients of thermal expansion, the total algebraic range of temperature fluctuation experienced by the component during normal operation must not exceed the magnitude $S_a/2(E_1\alpha_1 - E_2\alpha_2)$, where S_a is the value obtained from the applicable fatigue curve for the total specified number of significant temperature fluctuations, E_1 and E_2 are the moduli of elasticity, and α_1 and α_2 are the values of the instantaneous coefficients of thermal expansion at the mean temperature value involved for the two materials of construction. A temperature fluctuation is considered to be significant if its total excursion exceeds the quantity $S/2(E_1\alpha_1 - E_2\alpha_2)$, where S is the value of S_a obtained from the applicable fatigue curve for 10^6 cycles. If the two materials used have different applicable design fatigue curves, the lower value of S_a shall be used. The critical area for the transfer cask is the interface between the trunnion sleeve (SA-533 Class 2) and the trunnion (SA-564 Gr. 630 PH). Assuming 1,200 use cycles, the value of S_a = 75 ksi. The value of $S_a/2(E_1\alpha_1 - E_2\alpha_2)$ at 400°F for these two materials is 561°F. The maximum temperature range experienced by the transfer cask during normal operation is 253°F which is less than 561°F. This fifth criterion is, therefore, satisfied for the transfer cask.

F. The sixth criterion states that the transfer cask is adequate for fatigue effects provided that the specified full range of mechanical loads do not result in stress ranges which exceed the S_a value obtained from the applicable fatigue curve for the total specified number of significant load fluctuations. If the total specified number of significant load fluctuations exceeds 10^6, the S_a value at $N = 10^6$ cycles. During a normal use cycle, the transfer cask is subjected to mechanical load fluctuations including handling and transport load fluctuations as follows:

1. At the start of the use cycle, the cask is lifted from the transport trailer to the plant's fuel/reactor building decon pit.

2. The cask and DSC filled with water is lifted from the decon pit and placed in the plant's fuel pool.

3. The cask and DSC filled with water, and loaded with SFAs is lifted from the fuel pool and placed in the decon pit.

4. The cask and dry DSC loaded with SFAs is lifted from the decon pit and is rotated to a horizontal position onto the support skid and transport trailer.

5. The cask with loaded DSC resting on the support skid is subjected to motion loads and braking loads during transport to the HSM along a predetermined route.

6. The cask is secured to the HSM and the DSC is transferred to the HSM with the hydraulic ram. At the end of this use cycle the cask is returned to its designated storage area or to begin the next use cycle.

The maximum total range of mechanical load fluctuations for this normal use cycle is 30 ksi. The mechanical loads fluctuations for DSC unloading use cycle would be similar. For an assumed 600 use cycles, a conservative number of stress cycles of 5,000 is chosen which has a corresponding value of S_a equal to 50 ksi. This sixth criterion, therefore, is satisfied for the transfer cask.

The evaluation presented in the preceding paragraphs demonstrates that the six criteria contained in NC-3219.2 are satisfied for all components of the transfer cask.

APPENDIX C.5

C.5 Transfer Cask Structural Analysis NRC Question Resolution

NUTECH Letter No. /Date	Subject
WJM-88-127 July 7, 1988	Responses to Initial Topical Report NRC Questions: Chapter 3, Question 15; Additional information to ensure a transfer cask containing a DSC will not be exposed to DBT effects.

NUTECH Letter No. Date	Subject
WJM-88-127 July 7, 1988	Responses to Initial Topical Report NRC Questions: Chapter 3, Question 15; Additional information to ensure a transfer cask containing a DSC will not be exposed to DBT effects. It should be noted that 10CFR72.72 has subsequently been revised and renumbered and that protection from tornado missiles is now required.

CHAPTER 3

QUESTION: 15 Page 3.2-3 and Page 8.2-3. Provide additional information to demonstrate that administrative controls will ensure that a transfer cask containing a DSC will not be exposed to DBT effects. For example, during the DSC transfer operation, what is the maximum time for completion of movement to the HSM, insertion, and sealing or otherwise protecting the transfer cask from exposure? (describe); what is the minimum warning time that is provided by Weather Service tornado advisories?; and relatively how many tornadoes occur in areas and at times where tornado advisories have not been issued? If these cannot be shown to leave an acceptably minimal likelihood of loaded transfer cask tornado exposure (per para 3., p. 3-1, Reg. Guide 3.48), then approval of the NUHOMS®-24P transfer cask, DSC, and transfer system must be contingent on site-specific applications. (Note: Discussion with a representative of the National Weather Service (NWS), Service Evaluation Branch, Mr. Paul Polger (303)472-7970, indicates that severe local storms (which include tornadoes, hail over 3/4", or winds of 50 knots) occur in areas covered by a severe storm "watch" less than half the time on average and that severe local storm "warnings" issued on sighting or cloud formation detection cover only about 3/5ths of the storms. One third of all tornadoes occur in areas which are not even included in the slight, moderate, or high risk areas of the NWS one day outlook for severe storms.) The NWS data suggest that administrative watches, warnings, or the NWS national outlooks may not provide the required degree of assurance against DBT for nuclear material in transit, and that analysis of the transfer cask, DSC, and transport means for safety under a DBT may be required. If administrative controls include cessation of operations when the site is within the general region identified as being at "risk" by the NWS, then satisfactory justification and descriptions must be submitted. If avoidance of tornado effects is to be based on on-site meteorology, then convincing data showing that satisfactorily low probabilities of an underacted occurrence within the DSC transit and transfer times must be submitted.

RESPONSE: The possibility of a tornado damaging a cask/DSC in transit to the HSM is a low probability event. The low probability of this occurrence can be demonstrated by examining a site specific probability assessment performed at Duke Power Company's Oconee Nuclear Station located in Seneca, South Carolina.

This assessment concluded that the probability of a tornado occurring at the Oconee site and generating a missile that impacts the cask is less than $1X10^{-7}$ per transfer trip. This is based on site-specific tornado frequencies derived from 35 years of National Severe Storm Forecasting Center data and assumes a conservative exposure time to DBT effects of 24 hours.

The general design criteria for ISFSIs currently specified in 10CFR72, Subpart F, Section 72.72 requires that components important to safety be designed for the effects of tornadoes, excluding design for tornado missiles. The criteria specified by ANSI 57.9-1984, Section 6.17.12 requires only design for wind effects as specified by ANSI 58.1 with no requirements for design for tornado effects. In accordance with this criteria, the NUHOMS®-24P transfer cask is being designed for tornado wind effects, but need not be designed for tornado missile effects.

As will be demonstrated, the effects of tornado winds with a maximum wind speed of 360 mph are not as severe as by those already evaluated for a design basis cask drop accident. Therefore, compliance with 10CFR72 can be readily demonstrated. With this criteria as a design basis for the NUHOMS®-24P transfer cask, there is no need for administrative controls on wind speeds during cask/DSC transfer and the question of tornado prediction reliability need not be pursued. Therefore, the TR is being amended to include design of the transfer cask for tornado wind effects and ANSI 58.1 wind effects, and the current TR Section 10.3.4.3 requirements for wind speed measurements are being deleted. For conservatism, the HSM design basis for tornado missile effects will be maintained as currently documented in the TR. For the purpose of demonstrating the inherent design margins of the NUHOMS®-24P transfer cask, a structural evaluation was also performed for design basis tornado (DBT) loads. This analysis was performed in accordance with the requirements of NUREG-0800.

RESPONSE:
(Continued)

The transfer cask was evaluated for the tornado wind speed and missiles specified for the HSM in TR Table 3.2-1. The maximum DBT tornado wind speed of 360 mph produces a design pressure of 304 psf. The 3,967 pound automobile and 276 pound eight inch diameter shell missiles were also considered. The one inch diameter spherical missile effects are enveloped by the eight inch shell missile.

This analysis was performed for the cask secured in the horizontal position on the support skid. The following criteria were used to evaluate the adequacy of the transfer cask for the loads described above.

A. Stability

B. Penetration Resistance

C. Stresses

The main components of the transfer cask considered in this analysis were the structural shell, and the top and bottom cover plates. It was assumed that the neutron shield will be ruptured by a DBT missile strike and therefore, this was not considered in the structural analysis. A brief description of the analysis is described below.

A. Stability Analysis

A stability analysis for the transfer cask mounted on the skid/trailer assembly was performed for the wind pressure loads and the massive missile impact.

For the wind pressure loads, the overturning moment was compared to the stabilizing moment to determine the factor of safety against overturning. A factor of safety of 3.1 was calculated.

RESPONSE:
(Continued)

For the massive missile impact, it was conservatively assumed that the missile impacts the uppermost part of the cask. The angle of rotation (θ) of the cask/skid/trailer arrangement at impact was calculated as 3.0. This calculation was based on the conservation of angular momentum, and also conservation of energy. This angle was compared to the angle (θ_{tip}) necessary for the cask/skid/trailer to tip over. Tip-over occurs when the center of gravity of the cask is directly above the point of rotation. This was calculated as 32.7°. Since $\theta < \theta_{tip}$, tip-over does not occur and the stability of the cask/skid trailer arrangement is maintained.

B. Penetration Analysis

Penetration due to the 276 pound rigid missile was calculated using two formulas obtained from the literature. The added energy absorbing affect of the neutron shield material were omitted from this calculation to give a more conservative result. The first approach, suggested by Nelms (Reference 3.4) is for a lead-backed shell:

$$T = \left[\frac{KE}{2.4\, S_u\, D^{1.6}} \right]^{0.71} = 0.50\, inches$$

Where: T = minimum required steel plate or shell thickness to resist penetration

KE = Kinetic energy - $1/2\ mV^2$

m = Mass of missile = 276/g
0.714 lb. sec^2/in.

v = Velocity of missile
2,218 in./sec.

S_u = Ultimate strength of cask structural shell = 70,000 psi

RESPONSE:
(Continued)

D = Diameter of missile = 8.0 inches

The second formula used was developed by the Ballistic Research Laboratory (Reference 3.5):

$$T = \frac{KE^{2/3}}{672\, D} = 0.52 \; inches$$

Where: KE = Kinetic energy = 1/2 mV^2

m = Mass of missile
= 8.57 lb. sec./ft.

V = Velocity of missile
= 184.8 ft./sec.

D = Diameter of missile = 8.0 inches

Both methods produce a consistent result which shows a predicted penetration of 0.5 inches compared to the minimum structural shell thickness of 1.5 inches. Therefore the DBT missile will not penetrate the cask and the DSC will remain intact.

C. Stress Analysis

Conservative hand calculations were performed to determine the peak stresses in the cask shell, and the top and bottom cover plates due to DBT loads. A summary of the stress results is provided in the attached Table 3.1. The analytical method for each of the load cases shown in this table are briefly described below.

1. Wind Pressure Loads: A uniform line load of 2.18 K/ft. was applied the full length of the cask. The correlation of Roark and Young (Reference 3.6) Table 31, Case 9c was conservatively used to calculate membrane and bending stresses. The analyses of the three inch top and two inch bottom cover plates were performed using Case 10, Table 24 of Roark and Young. The top cover plate was assumed pinned at the edges while fixed edge supports were assumed for the bottom cover plate.

RESPONSE:
(Continued)

2. Massive Missile Impact: Based on the conservation of angular momentum, the total force on impact was calculated to be 257 kips. This force was applied as a line load to the cask shell and as a pressure load to the top and bottom cover plates. The analysis method followed this described above for the wind pressure loads.

3. Penetration Resistance Missile: The impact force due to the eight inch diameter, 276 pound missile was calculated from the conservation of momentum as 63.4 kips. Case 9a, Table 31 of Reference 3.6, was used to calculate the membrane and bending stress for the cask shell, while Cases 16 and 17, Table 24 of Reference 3, were used to calculate the stresses in the top and bottom cover plates respectively.

APPENDIX C.6

C.6 References

C.6.1 References

C-1 American National Standard for Radioactive Materials, "Special Lifting Devices for Shipping Canisters Weighing 10,000 lbs. (4,500 Kg) or More," ANSI N14.6-1986, American National Standard Institute, New York, N.Y. (1987).

C-2 U.S. Nuclear Regulatory Commission, "Control of Heavy Loads at Nuclear Power Plants," NUREG-0612, July 1980.

C-3 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NC, and Appendices, 1983 Edition.

C-4 Welding Research Council, Bulletin No. 297, "Local Stresses in Cylindrical Shells Due to External Loadings on Nozzles - Supplement to WRC Bulletin No. 107," August 1984.

C-5 Topical Report, "Design of Structures for Missile Impact, "BC-TOP-9A," Revision 2, September 1974, Bechtel Power Corporation.

APPENDIX D

A REVIEW OF CONCRETE BEHAVIOR
UNDER SUSTAINED ELEVATED TEMPERATURES

D.1. Review of Concrete Behavior Under Sustained Elevated Temperatures

The effects of elevated short and long term temperatures on concrete structures have been a subject of much research in the U.S.A. and European communities, and findings of these studies and tests are reported in a number of publications. A number of these publications and test reports, particularly those in references D.1 through D.10 were searched for characteristics of concrete under sustained elevated temperatures. Concrete characteristics as it relates to its physical/chemical reactions and subsequent effect on the mechanical properties are established and are documented herewith.

Changes in concrete properties under elevated temperatures and under atmospheric pressure are primarily attributable to the loss of free water. In ordinary saturated concrete 2% to 10% of its volume is occupied by evaporable free water. Upon heating, a portion or all of this water could be removed. Lankard et al. (D.4) identified five types of evaporable water which differ in the degree of attraction to the solid materials present as follows:

1. Water in capillary pores
2. Water in gel pores
3. Water adsorbed on crystal surfaces
4. Adsorbed water confined between adjacent crystal surfaces
5. Zeolitic intracrystalline water

When concrete is subjected to elevated temperatures the free water would be removed in approximately the order listed above, i.e., capillary and large pore water would be the first to come off, gel waters next and so on. At a temperature of 175°F some of the capillary water will be lost, however, hydration of cement will continue. R. D. Allen (D.5) reports that the capillary water is evaporated and released by heating to 100°C (212°F). However the loss of adsorbed water occurs over a broader temperature range, with all evaporable water having driven off by 300°C (572°F). At this temperature changes are seen in the microstructures.

Degradation or deterioration of concrete as it relates to greater crack formation and subsequent spalling is generally attributed to the loss of chemically combined or nonevaporable water. Lankard et al., reports that the results of tests on unsealed concrete specimens indicate: "An increase in chemically combined water content of the cement phase at 175°F and 10, 20, 40 percent loss of this water at 250, 375, and 500°F respectively." The loss of chemically combined water will cause dehydration of concrete. R. D. Allen concludes that the principle dehydration reactions are:

1. Decomposition of cement gel into dicalcium silicate, beta wallastanite and water,
2. decomposition of calcium hydroxide into lime and water.

The actual effect of this dehydration reaction is weakening of the bond between cement gel phases, which in turn affects its mechanical strength, and may cause microcrack formation and shrinkage of the cement. It is interesting to note that these dehydration reactions with reduced strength phases are reversible if water is reintroduced into the concrete.

From the above observation and given the fact that the NUHOMS® HSM concrete will not reach temperatures beyond 186°F for the maximum summer average ambient temperature of 100°F, it can be concluded that no adverse effect as it relates to degradation or deterioration of concrete can be anticipated under normal storage conditions. The adequacy of the HSM concrete is further substantiated by the fact that the maximum concrete temperature of 150°F for the lifetime average ambient temperature of 70°F is within the ACI 349-85 Code, Paragraph A.4.1 long term temperature, limit of 150°F. Indeed, the maximum HSM concrete temperatures for the 100°F ambient temperature case are below the 150°F temperature limit at all module locations except the local areas near the center of the roof and floor slabs which are well within the ACI 349-85 Code, Paragraph A.4.1 local temperature limit of 200°F.

The physical changes, i.e., loss of evaporable water, and also the chemical changes, i.e., dehydration and formation of other hydrated cement phase associated with loss of nonevaporable or chemically combined water, at sustained elevated temperatures will effect concrete mechanical properties. Mechanical properties most affected by elevated temperatures are compressive strength, modulus of elasticities, tensile strength, poisson ratio and creep. As stated earlier, in recent years extensive amounts of test on concrete mechanical properties at elevated short and long term temperatures have been performed and published. The results of the majority of these tests indicate that compressive strength of sample specimens heated up to (and occasionally above) 250°F and exposed to ambient humidities have changed very little, and frequently exhibit an increase in strength when compared to similar samples stored at room temperature.

Based on the results of tests performed, V. V. Bertero and M. Polivka (D.6) report that: "If the free moisture is allowed to escape during heating to 300°F, the mechanical characteristics of the concrete are very little affected by the heat treatment. This is true regardless of the number of cycles or duration of the thermal treatment." Other tests which include long term effects have also indicated a similar conclusion. K. W. Nasser (D.7) concludes from the results of tests performed on 500 specimens at temperature range from 70°F to 205°F, that the gain in strength beyond the age of 14 days is independent of temperature range of 70 to 205°F. The duration of this test was one year. The result of this test is presented in Figure D.1 - 1. In another test performed by

Construction Technology Laboratories, Portland Cement Association (D.8) on Hanford concrete, specimens were tested at temperatures of 250°F, 350°F and 450°F for durations as long as 920 days. The results of these tests further verify the above conclusion. It is interesting to note that even at 450°F the concrete compressive strength did not fall below the original mix designs of 4,500 psi and 3,500 psi. The results of this particular test are presented in Figure D.1-2..

In general, the increase in compressive strength at moderate elevated temperatures (below 250°F) is attributable to the removal of the evaporable water. Other tests performed by M. S. Abrams (D.3), A. Weber et al. (D.10), Kanazu et al. (D.9) and a number of other tests have all indicated similar findings that the concrete compressive strength is very little effected by elevated temperatures up to 250°F. At temperatures above 250°F concrete begins to loose some strength. This is attributed to the chemical changes, i.e., dehydration, that occurs in the cement phase as described earlier.

For the purpose of design, the NUHOMS® HSM concrete strength is very conservatively reduced by 10% at 500°F for all normal, off-normal, and accident load combinations. This reduction is based on the curves presented by Mark Fintel (D.2) as shown in Figure D.1-3. Other mechanical properties that are affected by elevated concrete temperatures are tensile strength and modulus of elasticity. Since the design of NUHOMS® does not rely on the tensile strength of concrete due to the use of reinforcement, any loss of this strength under elevated temperatures does not affect the NUHOMS® design. The reinforcing bar tensile strength, however, is conservatively selected at 500°F for the 125°F off-normal, and accident load combinations.

The modulus of elasticity also decreases with the increased temperature of concrete. Again, the loss of water explains the reduction in modulus of elasticity. According to Lankard, the absence of free water in heated concrete means that in essence an incompressible phase has been removed and the closer approach due to application of an external stress of solid surfaces formally contacting the same volume of water is to be expected. As shown in Figure D.1 - 4 the loss in the modulus of elasticity due to elevated temperatures up to 200°F is expected to be approximately 10% of the original value. The modulus of elasticity determines the flexural rigidity of the structure, and at the same time affects the magnitude of the thermal stresses induced under constrained conditions. A substantial reduction in this property will cause excessive flexural deformation in long span beams. Since the NUHOMS® walls and roof slabs are deep, short span members, the added deflections in these members under 10% loss of modulus of elasticity is considered negligible.

Other mechanical properties such as creep and Poisson ratio are also considered and their effects under elevated temperatures investigated and found to have insignificant impact on the design of the NUHOMS® modules. Although the loss in the concrete's modulus of elasticity reduces the thermal stresses, this loss is not considered in the design of HSMs for sake of conservatism.

In conclusion, given the maximum concrete design temperatures of the NUHOMS® HSMs i.e., 150°F for the 70°F lifetime normal ambient case and less than 200°F for the maximum normal summer ambient case of 100°F, the concrete integrity is unaffected and is in compliance with the ACI 349-85 Code. In addition, the maximum HSM concrete temperature of 222°F for the 125°F short term extreme ambient temperature case are well within the ACI 349-85 Code, Paragraph A.4.2 short term temperature of 350°F. The same can be said for the worst case accident condition with the HSM vents assumed to be blocked with an extreme ambient temperature of 125°F for which the maximum HSM concrete temperatures are less than 350°F, except at localized areas near the center of the roof, wall, and floor slab. At these locations the maximum concrete temperatures are 441°F, 414°F, and 479°F respectively, which are well below the ACI 349-85 Code, Paragraph A.4.2 short term local temperature limit of 650°F. It is also noted that the average temperatures through the thickness of the roof and floor slabs are less than 350°F for this worst case. Therefore, the NUHOMS® HSM design is in full compliance with the ACI 349-85 Code requirements. Nevertheless, the concrete compressive strength and rebar yield stress given in Table 8.1-2 at 500°F were used in calculating the concrete section capacities for the 125° extreme off-normal and accident load cases to provide a conservative result. The conservatism on the concrete properties and temperatures which meet the ACI 349-85 requirements eliminates the need for surveillance inspection of the interior concrete surfaces following DSC emplacement.

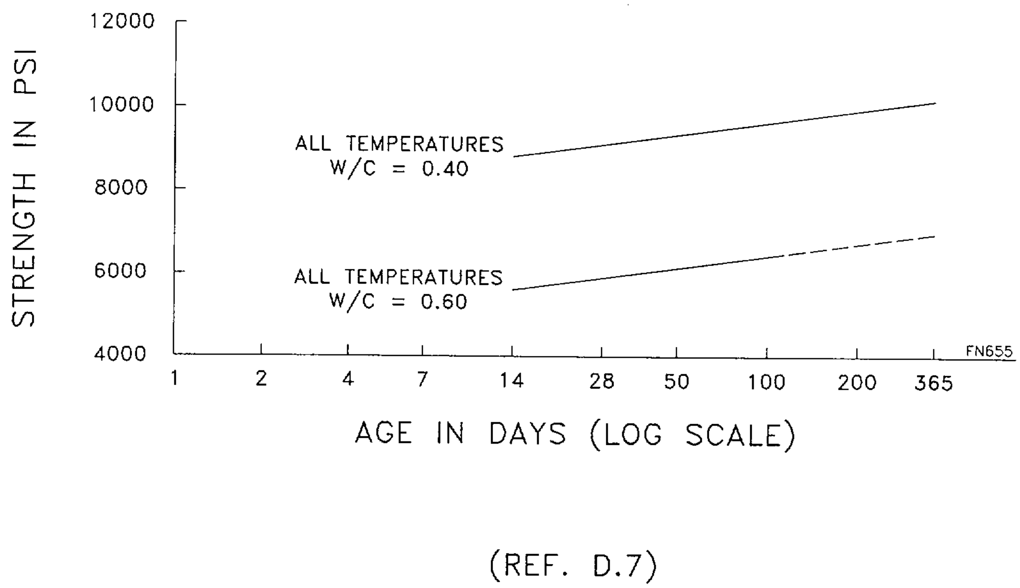
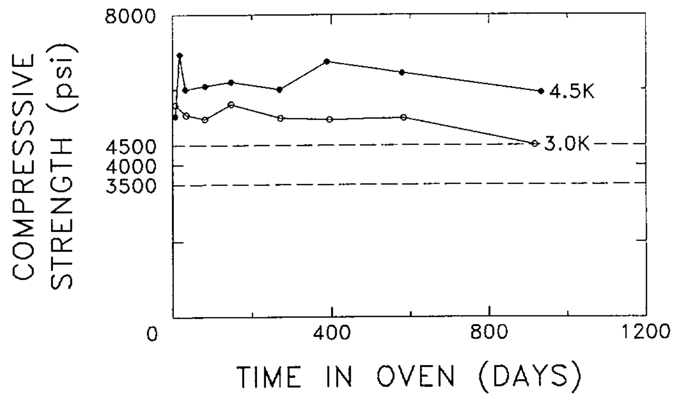
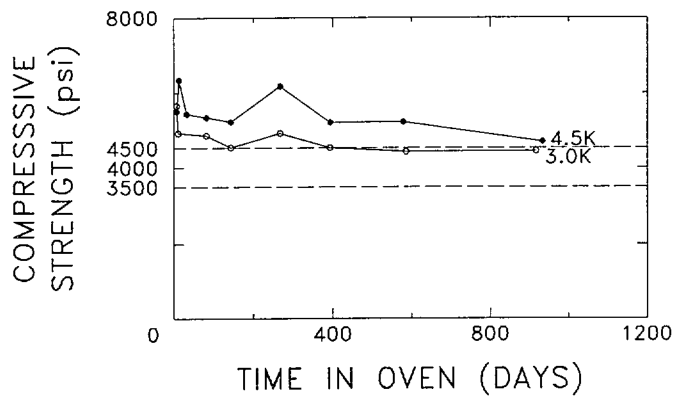


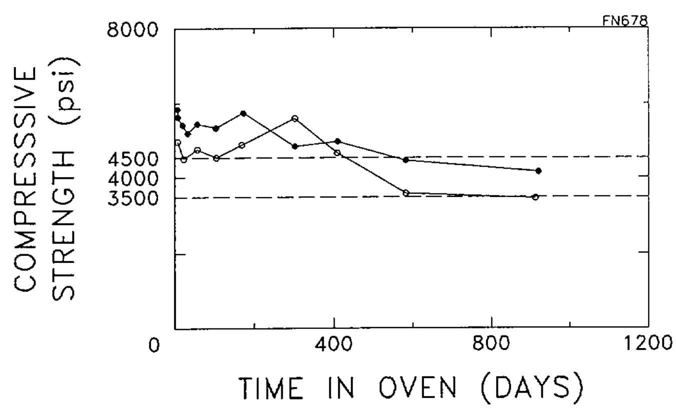
Figure D.1 - 1
Strength Versus Age in Days (Log Scale) for W/C Ratios of 0.40 and 0.60 at all Temperatures up to 205°F



Compressive Strength of Cylinders at 250°F.



Compressive Strength of Cylinders at 350°F.



Compressive Strength of Cylinders at 450°F.

(REF. D.8)

Figure D.1 - 2
Concrete Compressive Strength at Various Temperatures

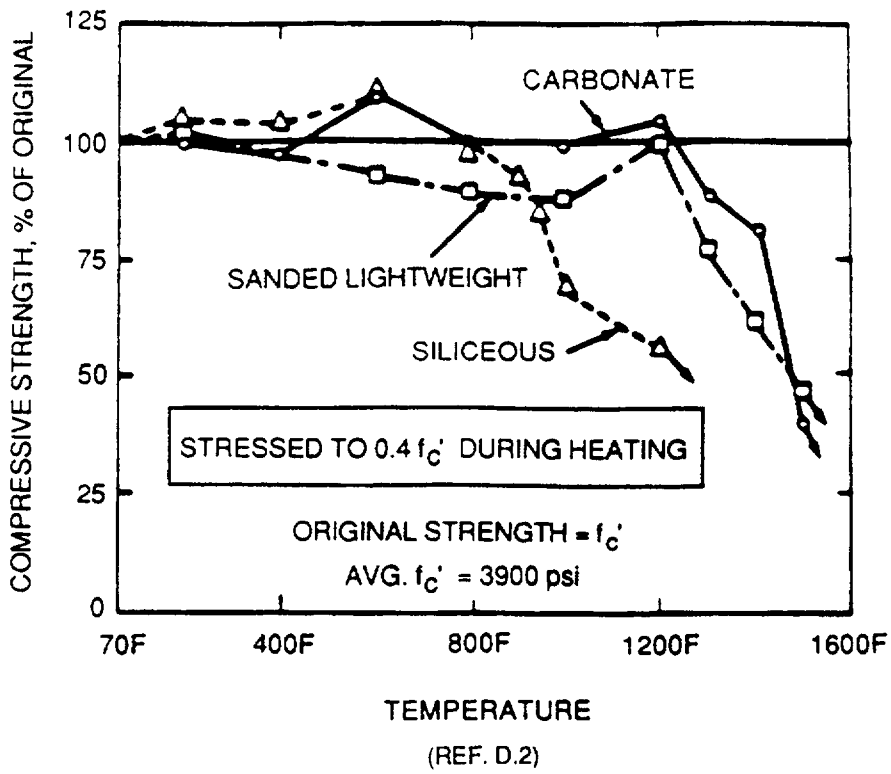


Figure D.1 - 3
Compressive Strength of Concrete at High Temperatures

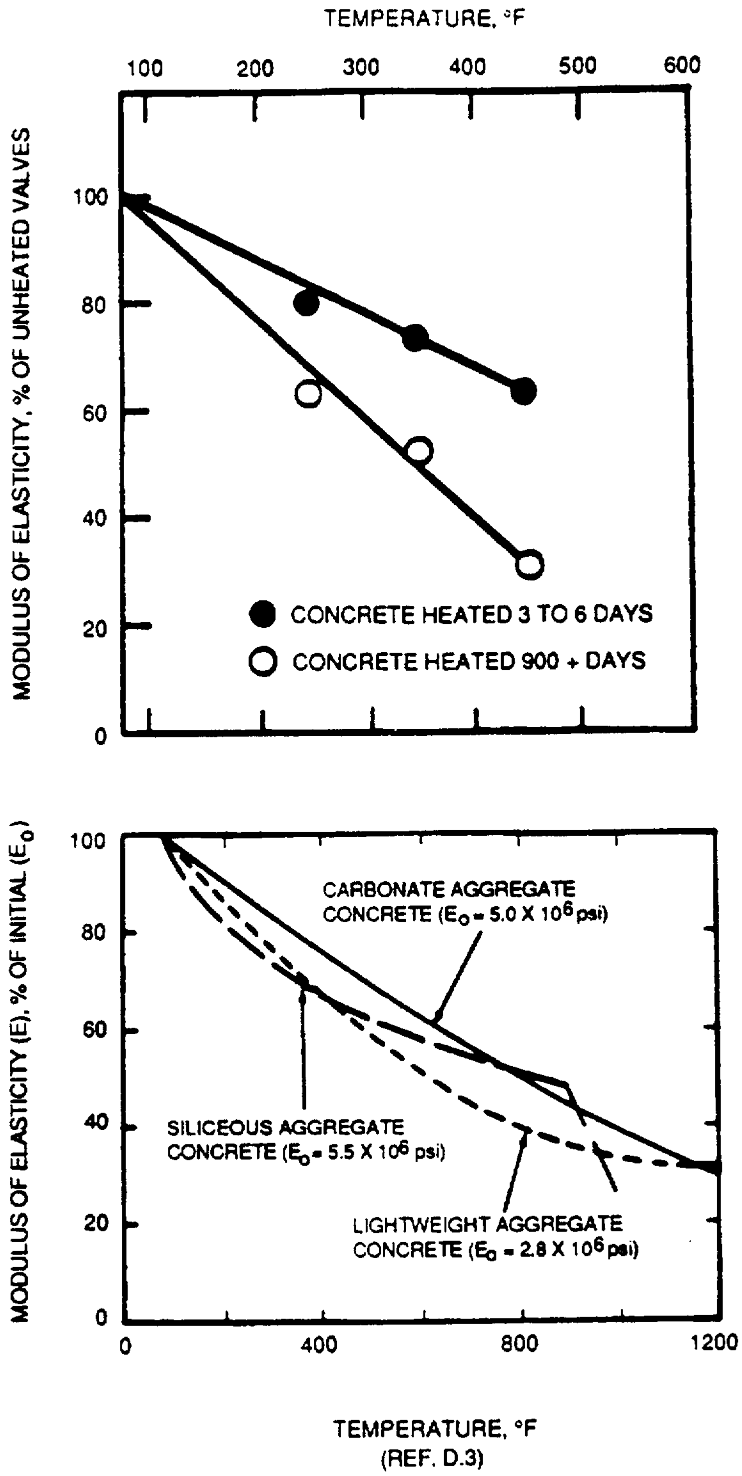


Figure D.1 - 4
Modulus of Elasticity of Concrete at High Temperatures

D.2. References

D.1 N. G. Zoldners: Thermal Properties of Concrete Under Sustained Elevated Temperatures, ACI Publication, paper SP25-1, American Concrete Institute, Detroit, MI (1970).

D.2 M. Fintel, Handbook of Concrete Engineering, Van Nostrand Reinhold Co., New York, N.Y., (1974).

D.3 M. S. Abrams, M. P. Gillen, and D. H. Campbell, Elastic and Strength Properties of Hanford Concrete Mixes at Room and Elevated Temperatures, Construction Technologies Laboratories, Portland Cement Association, Skokie, Il (1979).

D.4 D. R. Lankard et al., Effects of Moisture Content on the Structural Properties of Portland Cement Concrete Exposed to Temperatures Up to 500°F, ACI Special Publication, SP25, American Concrete Institute, Detroit, MI (1970).

D.5 R. D. Allen, High Temperature Properties of Concrete Relevant to Monitored Retrievable Storage Application, Battelle, Pacific Northwest Laboratories (1984).

D.6 V. V. Bertero, M. Polivka, Influence of Thermal Exposures on Mechanical Characteristics of Concrete, ACI Special Publication, SP.34, Concrete for Nuclear Reactors Volume 1, American Concrete Institute, Detroit, MI (1972).

D.7 K. W. Nasser, Creep of Concrete at Low Stress Strength Ratios and Elevated Temperatures, ACI Special Publication SP25, American Concrete Institute, Detroit, MI (1970).

D.8 Rockwell International, Effect of Long-Term Exposure to Elevated Temperature on the Mechanical Properties of Hanford Concrete, Construction Technology Laboratories, Portland Cement Association Report RHO-C-54.

D.9 T. Kanazu, et al, Mechanical Behavior of Concrete and Reinforced Concrete at Elevated Temperature Up to 500°C, Transactions of the 8th International Conference on Structural Mechanics in Reactor Technology (SMiRT), Volume H, North-Holland for CEC (1985).

D.10 A. Weber, G. Becker, Effects of Long Term Exposure on the Behavior of HTR Concrete, Transactions of the 8th International Conference on Structural Mechanics in Reactor Technology, Volume H, North-Holland for CEC (1985).

APPENDIX E

DRAWINGS FOR THE STANDARDIZED NUHOMS® SYSTEM

This appendix contains the following items:

E.1 Drawings for NUHOMS® Dry Shielded Canisters

- E.1.1 Standardized NUHOMS®-24P DSC Drawings
- E.1.2 Standardized NUHOMS®-52B DSC Drawings
- E.1.3 Standardized NUHOMS®-24P Long Cavity DSC Drawings

E.2 Drawings for NUHOMS® Horizontal Storage Module

E.3 Drawings for NUHOMS® On-Site Transfer Cask

The drawings for the NUHOMS®-61BT DSC are contained in Appendix K. The drawings for the NUHOMS®-24PT2S and -24PT2L DSCs are contained in Appendix L.

APPENDIX E.1

DRAWINGS FOR NUHOMS® DRY SHIELDED CANISTERS

Appendix E.1.1

This Appendix contains the following drawings of the standardized NUHOMS®-24P system:

Drawing Number	Title
NUH-03-1020NP-SAR	General License NUHOMS® DSC for PWR Fuel Basket Assembly
NUH-03-1021NP-SAR	General License NUHOMS® DSC for PWR Fuel Shell Assembly
NUH-03-1022NP-SAR	General License NUHOMS® DSC for PWR Fuel Basket-Shell Assembly
NUH-03-1023NP-SAR	General License NUHOMS® DSC for PWR Fuel Main Assembly

Security-Related Information Figure Withheld Under 10 CFR 2.390.

ALL DIMENSIONS ARE APPLICABLE AT GET AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH Y14.5M-1982.

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC FOR PWR FUEL BASKET ASSEMBLY

NUH003.1020-SAR	NUH-03-1020NP-SAR	NONE	1 OF 3	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

ALL DIMENSIONS ARE APPLICABLE AT 68°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

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3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC FOR PWR FUEL BASKET ASSEMBLY

FILE NO.	DWG NO.	SCALE	SHEET	REV NO.
NUH003.1020NP-SAR	NUH-03-1020NP-SAR	NONE	2 OF 3	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

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3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC
FOR PWR FUEL
BASKET ASSEMBLY

NUH003.1020NP-SAR	NUH-03-1020NP-SAR	NONE	3 OF 3	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

ALL DIMENSIONS ARE APPLICABLE AT 68°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

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3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC
FOR PWR FUEL
SHELL ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV. NO.
NUH003.1021NP-SAR	NUH-03-1021NP-SAR	NONE	1 OF 1	0

U.S. Patent No. 4,780,269
Transnuclear, Inc.

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC
FOR PWR FUEL
BASKET-SHELL ASSEMBLY

NUH003.1022NP-SAR	NUH-03-1022NP-SAR	NONE	1 OF 2	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

DO NOT SCALE DRAWING

3rd ANGLE PROJECTION

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC
FOR PWR FUEL
BASKET-SHELL ASSEMBLY

NUH003.1022NP-SAR | NUH-03-1022NP-SAR | NONE | 2 OF 2 | 0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
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TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC
FOR PWR FUEL
MAIN ASSEMBLY

NUH003.1023NP-SAR	NUH-03-1023NP-SAR	NONE	1 OF 3	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC
FOR PWR FUEL
MAIN ASSEMBLY

FILE NO.	DWG NO.	SCALE	SHEET	REV NO.
NUH003.1023MP-SAR	NUH-03-1023MP-SAR	NONE	2 OF 3	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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GENERAL LICENSE NUHOMS® DSC
FOR PWR FUEL
MAIN ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV. NO.
NUH003.1023NP-SAR	NUH-03-1023NP-SAR	NONE	3 OF 3	0

Appendix E.1.2

This Appendix contains the following drawings of the standardized NUHOMS®-52B system:

Drawing Number	Title
NUH-03-1029NP-SAR	General License NUHOMS® DSC for Channeled BWR Fuel Shell Assembly
NUH-03-1030NP-SAR	General License NUHOMS® DSC for Channeled BWR Fuel Basket-Shell Assembly
NUH-03-1031NP-SAR	General License NUHOMS® DSC for Channeled BWR Fuel Main Assembly
NUH-03-1032NP-SAR	General License NUHOMS® DSC for Channeled BWR Fuel, BWR Fuel Basket Assembly

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC FOR CHANNELLED BWR FUEL SHELL ASSEMBLY

NUH-03-1029NP-SAR

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC FOR CHANNELLED BWR FUEL BASKET-SHELL ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV. NO.
NUH003.1030NP-SAR	NUH-03-1030NP-SAR	NONE	1 OF 2	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

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3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC FOR CHANNELLED BWR FUEL BASKET-SHELL ASSEMBLY

NUH003.1030NP-SAR	NUH-03-1030NP-SAR	NONE	2 OF 2	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

ALL DIMENSIONS ARE APPLICABLE AT GET AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

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3RD ANGLE PROJECTION

DO NOT SCALE DRAWING

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC FOR CHANNELLED BWR FUEL MAIN ASSEMBLY

FILE NO.	DWG NO.	SCALE	SHEET	REV. NO.
NUH003.1031NP-SAR	NUH-03-1031NP-SAR	NONE	1 OF 3	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH Y14.5M-1982.

3rd ANGLE PROJECTION

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U.S. Patent No. 4,780,269
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TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC FOR CHANNELLED BWR FUEL MAIN ASSEMBLY

NUH003.1031NP-SAR	NUH-03-1031NP-SAR	NONE	2 OF 3	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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3rd ANGLE PROJECTION

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TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS DSC FOR CHANNELLED BWR FUEL MAIN ASSEMBLY

File No.	Dwg No.	Scale	Sheet	Rev. No.
NUH003.1031NP-SAR	NUH-03-1031NP-SAR	NONE	3 OF 3	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH Y14.5M-1982.

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC
FOR CHANNELLED BWR FUEL
BWR FUEL BASKET ASSY

FILE NO.	DWG NO.	SCALE	SHEET	REV NO.
NUH003.1032NP-SAR	NUH-03-1032NP-SAR	NONE	1 OF 3	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
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ALL DIMENSIONS ARE APPLICABLE AT SET AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.	TRANSNUCLEAR WEST
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH Y14.5M-1982.	
3rd ANGLE PROJECTION	GENERAL LICENSE NUHOMS® DSC FOR CHANNELLED BWR FUEL BWR FUEL BASKET ASSY
DO NOT SCALE DRAWING	NUH003.1032NP-SAR · NUH-03-1032NP-SAR · SCALE NONE · SHEET 2 OF 3 · REV 0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS® DSC
FOR CHANNELLED BWR FUEL
BWR FUEL BASKET ASSY

FILE NO.	DWG NO.	SCALE	SHEET	REV NO.
NUH003.1032NP-SAR	NUH-03-1032NP-SAR	NONE	3 OF 3	0

Appendix E.1.3

This Appendix contains the following drawings of the standardized NUHOMS®-24P Long Cavity system:

Drawing Number	Title
NUH-03-1050NP-SAR	General License NUHOMS® 24P Long Cavity DSC Basket Assembly
NUH-03-1051NP-SAR	General License NUHOMS® 24P Long Cavity DSC Shell Assembly
NUH-03-1052NP-SAR	General License NUHOMS® 24P Long Cavity DSC Basket-Shell Assembly
NUH-03-1053NP-SAR	General License NUHOMS® 24P Long Cavity DSC Main Assembly

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

ALL DIMENSIONS ARE APPLICABLE AT 68°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS®
24P LONG CAVITY DSC
-BASKET ASSEMBLY

NUH003.1050NP-SAR	NUH-03-1050NP-SAR	NONE	1 OF 3	0

Security-Related Information Figure
Withheld Under 10 CFR 2.390.

ALL DIMENSIONS ARE APPLICABLE AT GBT AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS®
24P LONG CAVITY DSC
-BASKET ASSEMBLY

NUH003.1050NP-SAR	NUH-03-1050NP-SAR	NONE	2 OF 3	0

Security-Related Information Figure
Withheld Under 10 CFR 2.390.

ALL DIMENSIONS ARE APPLICABLE AT 68°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS®
24P LONG CAVITY DSC
-BASKET ASSEMBLY

FILE NO.	DWG NO.	SCALE	SHEET	REV NO.
NUH003.1050NP-SAR	NUH-03-1050NP-SAR	NONE	3 OF 3	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

ALL DIMENSIONS ARE APPLICABLE AT GET AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS®
24P LONG CAVITY DSC
-SHELL ASSEMBLY

FILE NO.	DWG NO.	SCALE	SHEET	REV NO.
NUH003.1051NP-SAR	NUH-03-1051NP-SAR	NONE	1 OF 2	0

U.S. Patent No. 4,780,269
Transnuclear, Inc.

Security-Related Information Figure Withheld Under 10 CFR 2.390.

ALL DIMENSIONS ARE APPLICABLE AT 68°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS®
24P LONG CAVITY DSC
-SHELL ASSEMBLY

NUH003.1051NP-SAR	NUH-03-1051NP-SAR	NONE	2 OF 2	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

ALL DIMENSIONS ARE APPLICABLE AT SET AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.	TRANSNUCLEAR WEST
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.	GENERAL LICENSE NUHOMS® 24P LONG CAVITY DSC BASKET–SHELL ASSEMBLY
3rd ANGLE PROJECTION	NUH003.1052NP-SAR | NUH-03-1052NP-SAR | NONE | 1 OF 2 | 0
DO NOT SCALE DRAWING	

U.S. Patent No. 4,780,269
Transnuclear, Inc.

Security-Related Information Figure Withheld Under 10 CFR 2.390.

ALL DIMENSIONS ARE APPLICABLE AT 68°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS®
24P LONG CAVITY DSC
BASKET-SHELL ASSEMBLY

NUH003.1052NP-SAR	NUH-03-1052NP-SAR	NONE	2 OF 2	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

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DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS®
24P LONG CAVITY DSC
-MAIN ASSEMBLY

FILE NO.	DWG NO.	SCALE	SHEET	REV NO.
NUH003.1053NP-SAR	NUH-03-1053NP-SAR	NONE	1 OF 3	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

ALL DIMENSIONS ARE APPLICABLE AT 68°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS®
24P LONG CAVITY DSC
-MAIN ASSEMBLY

NUH003.1053MP-SAR	NUH-03-1053MP-SAR	NONE	2 OF 3	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

ALL DIMENSIONS ARE APPLICABLE AT 68°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

GENERAL LICENSE NUHOMS®
24P LONG CAVITY DSC
-MAIN ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV. NO.
NUH003.1053HP-SAR	NUH-03-1053HP-SAR	NONE	3 OF 3	0

APPENDIX E.2

DRAWINGS FOR NUHOMS® HORIZONTAL STORAGE MODULE

Appendix E.2

This Appendix contains the following drawings for the standardized NUHOMS® horizontal storage module:

Drawing Number	Title
NUH-03-6008NP-SAR	Standardized NUHOMS® ISFSI Horizontal Storage Module ISFSI General Arrangement
NUH-03-6009NP-SAR	Standardized NUHOMS® ISFSI Horizontal Storage Module Main Assembly
NUH-03-6016NP-SAR	Standardized NUHOMS® ISFSI Horizontal Storage Module DSC Support Structure

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

ALL DIMENSIONS ARE APPLICABLE AT 68°F AND ALL TOLERANCING APPLIES AFTER WELDING, FINAL MACHINING, AND CONCRETE CASTING UNLESS NOTED OTHERWISE

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE.

FRACTIONS	DECIMALS	ANGLES
±1/8"	.XX ± N/A .XXX ± N/A	± N/A

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

STANDARDIZED NUHOMS® ISFSI
HORIZONTAL STORAGE MODULE
ISFSI GENERAL ARRANGEMENT

NUH-03-6008NP-SAR | NONE | 1 OF 3 | 0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

ALL DIMENSIONS ARE APPLICABLE AT ANY AND ALL TOLERANCING APPLIES AFTER WELDING, FINAL MACHINING, AND CONCRETE CASTING UNLESS NOTED OTHERWISE

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE.

FRACTIONS	DECIMALS	ANGLES
±1/8"	.XX ± N/A .XXX ± N/A	± N/A

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

STANDARDIZED NUHOMS® ISFSI
HORIZONTAL STORAGE MODULE
ISFSI GENERAL ARRANGEMENT

DWG NO.	SCALE	SHEET	REV
NUH-03-6008NP-SAR	NONE	2 OF 3	0

E (34 X 44)

Security-Related Information Figure Withheld Under 10 CFR 2.390.

NUH-03-6008NP-SAR 3 OF 3

ALL DIMENSIONS ARE APPLICABLE AT 60°F AND ALL TOLERANCING APPLIES AFTER WELDING, FINAL MACHINING, AND CONCRETE CASTING UNLESS NOTED OTHERWISE	TRANSNUCLEAR WEST
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE	STANDARDIZED NUHOMS® ISFSI HORIZONTAL STORAGE MODULE ISFSI GENERAL ARRANGEMENT
3rd ANGLE PROJECTION	
DO NOT SCALE DRAWING	NUH-03-6008NP-SAR NONE 3 OF 3 0

U.S. Patent No. 4,780,269
Transnuclear, Inc.

Security-Related Information Figure Withheld Under 10 CFR 2.390.

ALL DIMENSIONS ARE APPLICABLE AT 68°F AND ALL TOLERANCING APPLIES AFTER WELDING, FINAL MACHINING, AND CONCRETE CASTING UNLESS NOTED OTHERWISE

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE.

FRACTIONS	DECIMALS	ANGLES
±1/8"	.XX ± N/A .XXX ± N/A	± 1°

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

STANDARDIZED NUHOMS® ISFSI
HORIZONTAL STORAGE MODULE
MAIN ASSEMBLY

DWG NO	SCALE	SHEET	REV NO
NUH-03-6009NP-SAR	NONE	1 OF 1	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

ALL DIMENSIONS ARE APPLICABLE AT 68°F AND ALL TOLERANCING APPLIES AFTER WELDING, FINAL MACHINING, AND CONCRETE CASTING UNLESS NOTED OTHERWISE

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE.

FRACTIONS	DECIMALS	ANGLES
±1/16"	.XX ± N/A .XXX ± N/A	± 3°

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

STANDARDIZED NUHOMS® ISFSI
HORIZONTAL STORAGE MODULE
DSC SUPPORT STRUCTURE

DWG. NO.	SCALE	SHEET	REV. NO.
NUH-03-6016NP-SAR	NONE	1 OF 1	0

APPENDIX E.3

DRAWINGS FOR NUHOMS® ON-SITE TRANSFER CASK

Appendix E.3

This Appendix contains the following drawings for the standardized NUHOMS® On-site Transfer Cask:

Drawing Number	Title
NUH-03-8000NP-SAR	General License NUHOMS® ISFSI On-Site Transfer Cask Overview
NUH-03-8001NP-SAR	General License NUHOMS® ISFSI On-Site Transfer Cask Structural Shell Assembly

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

SAFETY ANALYSIS REPORT
GENERAL LICENSE NUHOMS® ISFSI
ONSITE TRANSFER CASK OVERVIEW

NUH003.8000.SAR	NUH-03-8000NP-SAR	NONE	1 OF 1	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

SAFETY ANALYSIS REPORT
GENERAL LICENSE NUHOMS® ISFSI
ONSITE TRANSFER CASK
STRUCTURAL SHELL ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV. NO.
NUH003.8001.SAR	NUH-03-8001NP-SAR	NONE	1 OF 4	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

TRANSNUCLEAR WEST

SAFETY ANALYSIS REPORT
GENERAL LICENSE NUHOMS® ISFSI
ONSITE TRANSFER CASK
STRUCTURAL SHELL ASSEMBLY

NUH003.8001.SAR | NUH-03-8001NP-SAR | NONE | 2 OF 4 | 0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

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3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

SAFETY ANALYSIS REPORT
GENERAL LICENSE NUHOMS® ISFSI
ONSITE TRANSFER CASK
STRUCTURAL SHELL ASSEMBLY

NUH003.8001.SAR	NUH-03-8001NP-SAR	NONE	3 OF 4	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269
Transnuclear, Inc.

ALL DIMENSIONS ARE APPLICABLE AT 60°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

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3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

SAFETY ANALYSIS REPORT
GENERAL LICENSE NUHOMS® ISFSI
ONSITE TRANSFER CASK
STRUCTURAL SHELL ASSEMBLY

NUH003.0001.SAR	NUH-03-8001NP-SAR	NONE	4 OF 4	0