10 CFR PART 72 SCREEN

Screen No. 09-024

Facility Name: TMI-2 ISFSI Change No.: EDF-9208

Activity Description: EDF-9208 presents and discusses potential impacts on the design of the Horizontal Storage Modules (HSM) of performing concrete assessment activities. Surface cracking has been noted on the HSM from the time they were loaded and a formal assessment is scheduled for spring 2009. This concrete assessment will require the taking of samples of the concrete from the HSMs for testing. Samples will be taken by core drilling and removing the core. The core drilling will require the installation of anchor bolts by drilling small holes in the HSMs

After the core is removed, the core drill holes and the anchor bolt holes will be backfilled with a dry pack grout mix. This grout has been specified to meet the strength of the original concrete and have the same density. Only one core will be removed at a time, the previous core will be backfilled before the next core is removed.

The HSMs are Important to Safety. The safety functions they provide are structural, radiation shielding, and heat transfer. EDF-9208 concludes that these functions of the HSM will not be adversely affected by the core drilling.

Use of this form must be in accordance with MCP-2925. Sufficient activity description, justifications, and documents reviewed must be provided to permit an independent reviewer to reach the same conclusions. The discussions in Appendix A should be used to develop any justifications documented below.

1. License Condition or Technical Specification: (Complete this section for all Part 72 screens.)

1a. Does the activity require any change, even editorial, to the license or technical specifications? ☐ Yes ☒ No

1b. Does the activity require an exemption to any NRC regulations? ☐ Yes ☒ No

1c. Is the activity a change to or require a change to FSV SAR Section 7.7, 9.3, or Chapter 11; or TMI-2 SAR Section 7.6, 9.3, or Chapter 11; or ISFF SAR Section 7.6.1.4, 9.3, or Chapter 11? ☐ Yes ☒ No

Justification: Core drilling and grouting the HSMs will not require changes to the license, technical specifications, or SAR sections 7.6, 9.3 or 11. No exemption to the regulations will be required.

Documents Reviewed: TMI-2 ISFSI License, Technical Specifications, and SAR.

If the answer to 1a or 1b is "Yes" the activity may not be implemented until NRC approval is obtained. If the answer to 1c is "Yes" a ***72.44 Evaluation*** in accordance with MCP-2925 is required before the activity may be completed.

2. Facility Change: If the activity is a physical change (addition, modification, or removal) within a facility or to any equipment or structure, or to any design document (drawing, calculation, analysis, specification, design input or assumption, etc.), then complete this section. Also complete this section for changes to the SAR. Otherwise indicate **N/A** at the end of this section.

2a. Does the activity adversely affect a design function of equipment or structures described in the SAR or TS Bases? ☐ Yes ☒ No

2b. Does the activity adversely affect a method of performing or controlling a design function of equipment or structures described in the SAR or TS Bases? ☐ Yes ☒ No

2c. Does the activity adversely affect an evaluation which demonstrates the design functions of equipment or structures described in the SAR or TS Bases? ☐ Yes ☒ No

2d. Does the activity result in a change to the Technical Specification Bases? ☐ Yes ☒ No

Justification (include effects that are not adverse): The design functions of structural strength, radiation shielding, and heat transfer will not be affected by removing and replacing these concrete cores. The dry pack grout used to replace the cores and fill the holes meets or exceeds the original design specifications. EDF-9208 determines that there is not a structural, shielding or heat transfer concern while a core is removed and work package instructions require that the core holes be backfilled prior to removal of the next core. So, this activity does not adversely affect a design function of the HSM as described in the SAR and TS Bases.

This activity does not affect a method of controlling a design function, any evaluation, and does not require a change to the Technical Specifications Bases.

10 CFR PART 72 SCREEN

Documents Reviewed: TMI-2 SAR, Technical Specifications and Bases, EDF-9208

If any answer in Section 2 is "Yes" then a ***72.48 Evaluation*** in accordance with MCP-2925 is required before the activity may be completed.

3. Procedure Change: If the activity is a change to facility operation, maintenance, transport, test, or experiment procedures, then complete this section. Also complete this section for changes to the SAR. Otherwise indicate **N/A** at the end of this section.

Is the activity a modification to, addition to, or removal from any procedure that adversely affects the operation and control of equipment or structures as described in the SAR or TS Bases? ☐ Yes ☐ No

Justification (include effects that are not adverse): NA

Documents Reviewed: NA

If this answer is "Yes" then a ***72.48 Evaluation*** in accordance with MCP-2925 is required before the activity can be completed.

Conclusion:

If all the questions on this form are answered "No", then the signatures on this form will complete the 10 CFR Part 72 regulatory screen and the activity may proceed.

Assumptions & Limitations:

The dry pack grout meets or exceeds the requirements for the original concrete a far as strength and density.
Only one core hole will be open at a time, each hole will be backfilled prior to beginning the next core drilling operation.

APPROVALS (Signature signifies that screener/reviewer has confirmed with requester that change package was complete and accurate before performing/reviewing the screen.)

Print/Type Name	Signature	Date
Harry L Lord Completed By Qualified Screener Print/Type Name	Harry L. Lord Qualified Screener Signature	6 May 2009 Date
Gregory G Hall Independent Review By Qualified Evaluator Print/Type Name	GGHall Qualified Evaluator Signature	5/6/09 Date

ENGINEERING DESIGN FILE

EDF No.: 8465 EDF Rev. No.: 0 Project File No.: ICARE-102744

1. Title: Evaluation of Concrete Efflorescence and Cracks of TMI HSMs (ICARE-102744)
2. Index Codes:
   Building/Type CPP-1774 SSC ID HSM-1 through 30 Site Area 200/INTEC

3 Commercial Level? ☐ Yes ☒ No

*4. NPH Performance Category: ________ or ☒ N/A SSC Safety Category: SS or ☒ N/A

*5. (a) Affects Safety Basis: ☐ Yes ☒ No (b) Affects a SNF Facility: ☒ Yes ☐ No

6. Summary:

This report investigates the nature and significance of the observed conditions found on several of the concrete Horizontal Storage Modules (HSMs) at the INTEC Interim Storage Facility (CPP-1774). The conditions observed are white solid deposits, crazing, and cracks.

The scope of the EDF is limited to evaluation of the 30 HSMs at CPP 1774. The conditions evaluated are limited to efflorescence, crazing, and cracking.

Efflorescence, the solid whitish crystalline material observed on the HSMs, is calcium carbonate, the usual constituent of concrete efflorescence. Such deposits are common to concrete exposed to a wet-dry cycle, and do not represent a significant degradation to the concrete structure.

Crazing, the observed fine line cracking, is caused by shrinkage on the surface of the concrete. These fine cracks are rarely greater than 1/8 inch deep, and do not affect the durability or wear resistance of the concrete. Crazing is caused by poor curing practice, too rapid water evaporation, too wet a concrete mix, and a few other means. If the surface was soft and dusting, it may have been caused by surface carbonation, which does not appear to be the case here.

Cracking, greater than fine line cracking, is somewhat typical to concrete structures. This observed cracking seems to be the result of environmental conditions and volume changes within the concrete mass. The cracks are not associated with structural stress conditions within the concrete structure. As currently observed the condition is more associated with spalling rather than structural cracking. As such, repair techniques tend toward removal of the damaged concrete and concrete replacement, rather than direct repair of the cracked portion.

No actions are required at this time. The existing conditions are cosmetic in nature, and efflorescence removal or crack repair is not recommended. The conditions should be monitored, and if the severity increases, or sufficient quantities of minor cracks are present to justify the risk and cost associated with repairs, concrete repair could be performed. Corrective action could be initiated when significant areas of concrete reinforcing steel cover is reduced by one half (1/2 inch, Ref. 2), reinforcing steel is exposed, or reinforcing steel damage is suspected.

Consideration should be given to providing effective protection against liquid water to reduce the severity of freeze attack, by reducing the exposing of the concrete to water penetration.

431.02
02/20/2009
Rev. 19
(Use with MCP-2374 or MCP-2059)

ENGINEERING DESIGN FILE

EDF No.: 9208 EDF Rev. No.: 0 Project No.: n/a FCF and/or FDC No.: n/a

1. Title: TMI 2 HSM Core Drilling			
2. Index Codes: Building/Type CPP-1774	SSC ID HSM 5, 7, 9, 12, 15, 18, 19, 27, and 29	Site Area INTEC	
3. Formal Calculation? ☒ Yes (MCP-2374) ☐ No (MCP-2059)	Quality Level: 1	QLD Number: 2880	
Formal analyses and calculations require engineering management approval.			
*4. NPH PC or SDC: or ☒ N/A		SSC Safety Category: or ☒ N/A	
*5. (a) Affects Safety Basis: ☒ Yes ☐ No		(b) Affects SNF/HLW: ☒ Yes ☐ No	

6. Summary:

This Engineering Design File (EDF) is written to analyze the effect core drilling, removal of the core, and grouting the core hole will have on the horizontal storage modules (HSM) to perform its safety function. The HSMs are located at the Idaho National Laboratory (INL) Three Mile Island Unit 2 (TMI-2) Independent Spent Fuel Storage Installation (ISFSI) located at Idaho Nuclear Technology and Engineering Complex (INTEC). It is planned to drill and remove a total of twelve concrete core samples from nine HSMs. The HSMs are 5, 7, 9, 12, 15, 18, 19, 27, and 29. HSMs 5, 27, and 29 will have two (2) cores removed while the other HSMs will have one (1) core sample removed. The analysis includes a review of the governing loading and shielding conditions described in the latest chapter revisions of the TMI-2 ISFSI Safety Analysis Report (SAR) and a comparison to reduced concrete sections at the core hole. Acceptance criteria are the reduced concrete sections do not adversely affect the governing loading and shielding conditions. The conclusion is the reduced concrete sections will not adversely affect the governing loading and shielding conditions and the grouted holes will return the HSM to an equivalent condition comparable to the original HSM.

7. Signatures: (See instructions for significance of signatures. Add or delete signatories as needed.)

Name (typed or printed) / Signature and Date	Signatory Role	Organization / Discipline
M. D. Wilberg [signature] 5/5/09	Author	ISFSI Management / 5290 Design Agent
N. B. Smith [signature] for N.B. Smith per telecon/email 5/5/09	Technical Checker	Engineering Analysis & Modeling / 9420 Design Agent
K. E. Lombard [signature] 5/5/09	Approver	Engineering Analysis & Modeling/ 9420 Engineering Management
D. F. Barker Donald J. B[signature] acting for Rick L. Gardner NFM 5-6-09	Reviewer	ISFSI Management / 5290 Requestor (if applicable)
G. G. Hall [signature] 5/5/09	Reviewer	ISFSI Management / 5290 * Design Authority (if applicable)
D. C. Warner	Reviewer	Waste Management/CERCLA / 2512

ENGINEERING DESIGN FILE

EDF No.: 9208 EDF Rev. No.: 0 Project No.: n/a FCF and/or FDC No.: n/a

5/6/09		* Quality Assurance (only if 5(b) is "Yes")
H. L. Lord	Reviewer	ISFSI Management / 5290
Harry E. Lord 5 May 2009		* Nuclear Safety (only if 5(a) is "Yes")
R. K. Elwood	Document Owner	ISFSI Management / 5290
5/6/09		Document Owner

8. Does document contain sensitive unclassified information? ☐ Yes ☒ No

   If Yes, what category: n/a

9. Will document be externally distributed? ☒ Yes ☐ No

10. Registered Professional Engineer's Stamp (if required) ☒ N/A

Registered Professional Engineer Stamp

This Engineering Design File was prepared under the direction of the Registered Professional Engineer as indicated by the stamp and signature provided on this page. The Professional Engineer is registered in the State of Idaho to practice __________ Engineering.

* Not required for commercial level calculations.

Purpose

This Engineering Design File (EDF) is written to analyze the effect core drilling, removal of the core, and grouting the core hole will have on the horizontal storage modules (HSM) to perform its safety function. The HSMs are located at the Idaho National Laboratory (INL) Three Mile Island Unit 2 (TMI-2) Independent Spent Fuel Storage Installation (ISFSI) located at Idaho Nuclear Technology and Engineering Complex (INTEC). The reinforced concrete HSM is a component of the NUHOMS®-12T system. The HSMs are classified as systems, structures, and components "Important to Safety" in the TMI-2 ISFSI Safety Analysis Report (SAR) [1] Chapter 3.

To perform a thorough evaluation of the hardened concrete HSM at the TMI-2 ISFSI core samples will be removed from selected HSMs. It is planned to drill and remove a total of twelve concrete core samples from nine HSMs. The core samples removed will be 4 inches or smaller in diameter and range in length from 12 inches to 20 inches plus or minus 2 inches. The HSMs are 5, 7, 9, 12, 15, 18, 19, 27, and 29. HSMs 5, 27, and 29 will have two (2) cores removed while the other HSMs will have one (1) core sample removed.

The various design conditions are documented in the applicable chapters of the SAR; Chapter 3 - Principal Design Criteria Revision 5, Chapter 4 - Installation Design Revision 6, Chapter 7 - Radiation Protection Revision 5, and Chapter 8 - Analysis of Design Events Revision 5. The HSMs are analyzed as single and arrayed HSMs for the maximum, ultimate, combined and bounding loading conditions. Therefore the conclusion is the same for each HSM.

The following conditions will be analyzed to determine the effect core drilling will have on the ability of the HSM to perform its safety function; (1) the impact to the ultimate moment and shear design capacity of the concrete, (2) the impact to the ultimate moment and shear design capacity of the concrete for a Design Basis Tornado Missile, (3) the impact to the thermal capacity of the concrete, and (4) the impact to the shielding capacity of the concrete.

Assumptions

The roof slab is conservatively looked at as a one way slab that can be analyzed in strips as simple beams with a uniformly distributed load [2]. The walls are considered fixed at the base and free at the top of the wall.

Calculation Inputs

Impact to the Ultimate Moment and Shear Design Capacity of the Concrete

The ultimate strength design method is used to evaluate stresses in the HSM reinforced concrete walls, roof, and floor. The HSM is designed to meet the minimum flexural and shear reinforcement requirements of American Concrete Institute (ACI) Code ACI 349 Code Requirements for Nuclear Safety Related Concrete Structures [3] and is constructed to ACI 318 Building Code Requirements for Structural Concrete [4]. Reinforcement is governed by the off normal thermal load (SAR Section 8.1.1.5). The available ultimate strength design exceeds that required for the factored design loads as shown in Table 1. Table 1 includes the Load Combination number, Governing Loads, and Ultimate Capacities from SAR Table 8.3-4. The reinforcement layout for the prefabricated HSMs is shown in Figure 1.

Table 1. HSM Enveloping Load Combination, Governing Loads, Ultimate Capacities, and Reduced Ultimate Capacity Results

Load Combination	Governing Loads		Ultimate Capacities		Reduced Ultimate Capacity	
	V_{max} (k/ft)	M_{max} (k-in/ft)	V_u (k/ft)	M_u (k-in/ft)	$V_{reduced}$ (k/ft)	$M_{reduced}$ (k-in/ft)
1	60.4	834.2	100.9	1,683.0	84.0	1,402.5
2	20.0	2,193.8	31.0	2,576.0	25.8	2,146.6
3	20.1	1,471.2	31.0	1,683.0	25.8	1,402.5
4	15.8	1,791.9	31.0	2,576.0	25.8	2,146.6
5	59.8	1,197.2	100.9	1,683.0	84.0	1,402.5
6	54.7	1,265.3	100.9	1,683.0	84.0	1,402.5

V_{max} - Maximum Bearing Shear created by the governing load combinations
M_{max} - Maximum Bearing Moment created by the governing load combinations
V_u - Maximum Ultimate Shear Design Capacity of the concrete
M_u - Maximum Ultimate Moment Design Capacity of the concrete
$V_{reduced}$ - Reduced Ultimate Shear Design Capacity of the concrete
$M_{reduced}$ - Reduced Ultimate Moment Design Capacity of the concrete

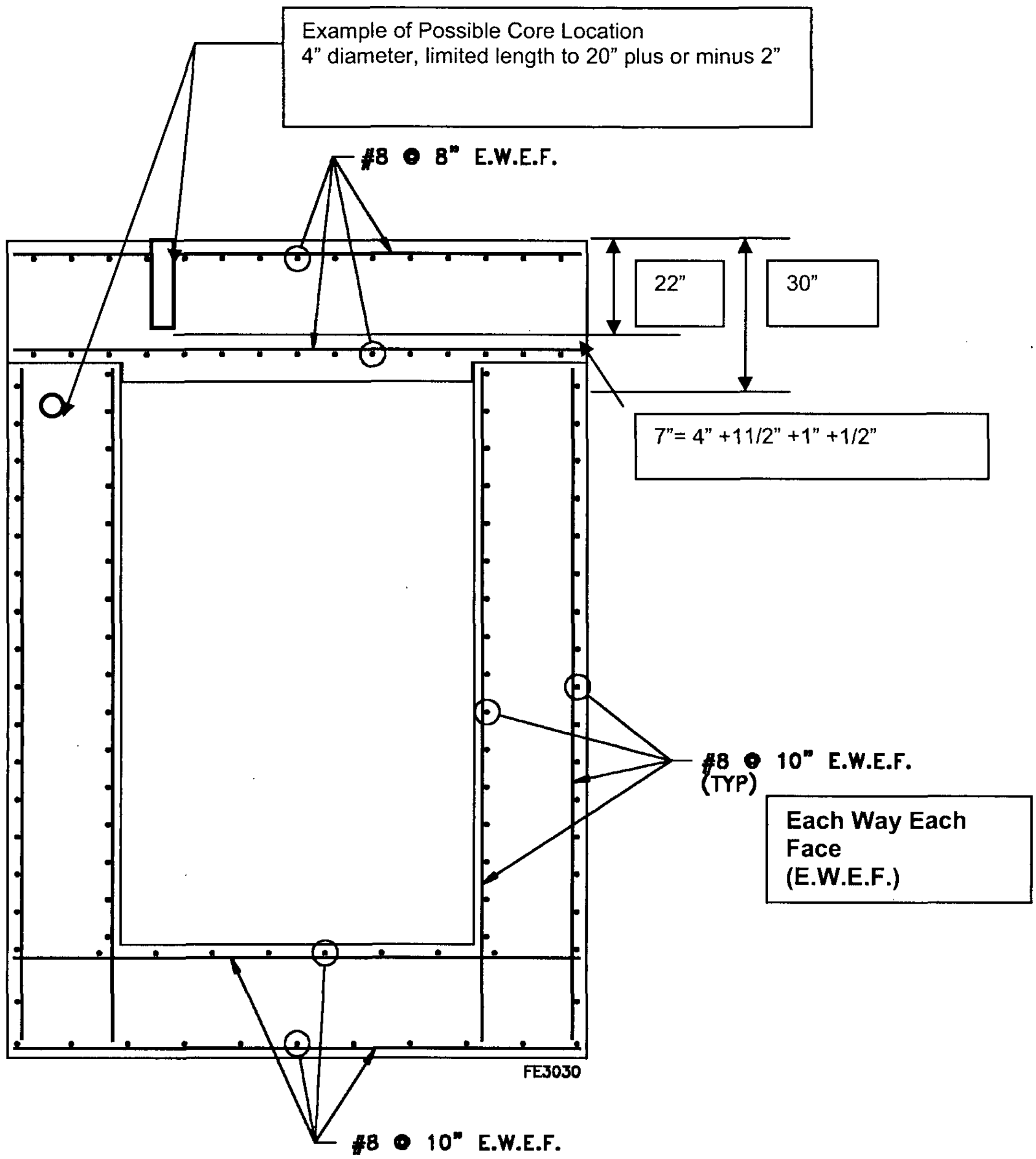

Figure 1. Typical HSM Reinforcement

The roof slab is conservatively looked at as a one way slab that can be analyzed in strips as simple beams with a uniformly distributed load [2]. The maximum moment would act at the center of the slab and the maximum shear would act at the support ends of the slab. Therefore, cores drilled in the middle of the slab would affect ultimate moment capacity and holes drilled at the edges would affect the ultimate shear capacity. When openings are created in concrete slabs the moment and shear forces that could have been carried by the removed concrete transfers to the concrete on either side of the opening. This can conservatively be evaluated by reducing the ultimate moment and shear capacity of the concrete strip on either side of the opening by the area of concrete strip removed. For the 4-inch diameter hole the concrete strips on either side of the hole would be analyzed as 10-inch wide strips instead of 12-inch. This would reduce the effective ultimate shear and moment design capacity to 10/12 (V_u) and 10/12 (M_u). The effective reduction to $V_{reduced}$ and $M_{reduced}$ are shown with the SAR governing loads and ultimate capacities in Table 1.

As can be seen in Table 1 all $V_{reduced}$ values are greater than the V_{max} values. Therefore the hole has no affect. In Load Combinations 2 and 3 the $M_{reduced}$ is less than the M_{max} (2,146.6/2,193.8 and 1,402.5/1,471.2 in.-k./ft. respectively) which could cause concern. All other $M_{reduced}$ values are greater than the M_{max}. Therefore the hole has no affect on those load combinations. If Load Combinations 2 and 3 are examined it is noted that they both contain the Normal Condition Thermal Load T_o. The maximum temperature in the cask occurs after loading and dry-out. This temperature decreases considerably in the first ten years of storage [5]. The fuel has been stored in the TMI-2 ISFSI for 10 years. It can conservatively be estimated that M_{max} is reduced considerably at this time. After the core is removed and the grout installed the HSM will be in an equivalent condition and strength capacity therefore the hole has no affect on these load combinations.

Table 2 [1] summarizes the design criteria for the principal NUHOMS® system components. This table also summarizes the applicable codes and standards utilized for design. The governing calculated V_{max} and M_{max} values for each load combination are tabulated in Table 3. The tabulated results represent the bounding shears and moments for either a single free-standing HSM or the array of HSMs. For comparison, the V_u and M_u capacity of the HSM for the controlling load combinations are also shown in Table 3 [1]. Comparison of the reported M_{max} and V_{max} for each load combination with the corresponding M_u and V_u values shows that the M_u and V_u values of the HSM are greater than the M_{max} and V_{max} for the most critical load combinations.

Table 2. Summary of TMI-2 ISFSI HSM Design Loadings

Design Load Type	SAR Section	Design Parameters	Applicable Codes
Design Basis Tornado	3.2.1	Maximum wind pressure : 123 psf Maximum speed: 200 mph	NRC Reg. Guide 1.76, Region III and ANSI A58.1 1982
DBT Missile	3.2.1	Maximum speed: 70 mph Types: 1800 Kg automobile 276 lbs artillery shell	NUREG-0800, Section 3.5.1.4
Flood	3.2.2	There are no flood loads since HSMs are above flood plain	10 CFR 72.122(b)
Seismic	3.2.3	Horizontal free field zpa: 0.36 g (both directions) Vertical free field zpa: 0.24 g	NRC Reg. Guides 1.60 and 1.61
Snow and Ice	3.2.4	Maximum load: 30 psf (included in live loads)	ANSI A58.1-1982
Dead Loads	8.1.1.5	Dead weight including loaded DSC (concrete density of 150 pcf assumed)	ANSI 57.9-1984
Normal and Off-normal Operating Temperatures	8.1.1.5	DSC with spent fuel rejecting 860 W of decay heat. Normal ambient temperatures: -20 °F to 87 °F; 67 Btu/hr-ft^2 solar insolation. Off-normal ambient temperatures: -50 °F to 103 °F; 105 Btu/hr-ft^2 solar insolation.	ANSI 57.9-1984
Accident Condition Temperatures	8.2.7.2	Same as off-normal conditions	ANSI 57.9-1984
Normal Handling Loads	8.1.1.1	Hydraulic ram load of 70,000 lb. (35,000 lb./rail)	ANSI 57.9-1984
Off-normal Handling Loads	8.1.1.4	Hydraulic ram load of 70,000 lb. (70,000 applied to one rail)	ANSI 57.9-1984
Live Loads	8.1.1.5	Design load: 130 psf (includes snow and ice loads)	ANSI 57.9-1984
Fire and Explosions	3.3.6 8.2.9	Enveloped by other design basis events	10 CFR 72.122(c)

ACI 318 and ACI 349 allow for openings in concrete slabs when certain conditions are met besides the adequate stress conditions shown in Table 1. Both in ACI 318 and 349, Section 13.4.2.3 it states "In the area common to one column strip and one middle strip, not more than one-quarter of the reinforcement in either strip shall be interrupted by openings." The reinforcement in the roof is spaced at 8-inch centers in each direction. The core drill hole will be 4 inches in diameter. The roof is 30 inches deep and the top of steel of moment reinforcement is 23 inches from the roof slab. Core drilling will be limited to 22 inches so the reinforcement will not be interrupted (see Figure 1). Core drilling into the front or back face will not affect moment or shear even if reinforcement is interrupted. Therefore the reduced ultimate moment and shear capacity of the concrete when the core drilling is performed is not a detrimental impact to the HSM. If reinforcement is interrupted at the top surface of the roof along the edges over the walls the bearing capacity of the roof is not reduced. This reinforcement can be interrupted.

Once the core has been removed the hole will be prepared to receive a cementitious dry pack non shrink grout. When cured the grout will be bonded to the existing concrete, will attain a compressive strength greater than the existing concrete 5,000 psi compressive strength and it will achieve a nominal density of 140 pcf. Therefore the concrete of the HSM will be returned to an equivalent condition.

Table 3. HSM Enveloping Load Combination Results

Load Combination (1)	Loading Combination Description	Governing Load (2, 3)		Capacities	
		V_{max} (k/ft)	M_{max} (k-in/ft)	V_u (k/ft)	M_u (k-in/ft)
1	$1.4 D + 1.7 L + 1.7 R_o$	60.4	834.2	100.9	1,683.0
2	$0.75 (1.4 D + 1.7 L + 1.7 T_o + 1.7 W)$	20.0	2,193.8	31.0	2,576.0
3	$0.75 (1.4 D + 1.7 L + 1.7 T_o + 1.7 R_o)$	20.1	1,471.2	31.0	1,683.0
4	$D + L + T_o + E$	15.8	1,791.9	31.0	2,576.0
5	$D + L + T_o + W_t$	59.8	1,197.2	100.9	1,683.0
6	$D + L + T_a + R_a$	54.7	1,265.3	100.9	1,683.0

D - Dead Weight
E - Earthquake Load
L - Live Load
T_o - Normal Condition Thermal Load
T_a - Off-normal or Accident Condition Thermal Load
W_t - Tornado Wind and Missile Loads
R_o - Normal Handling Loads
R_a - Off-Normal Handling Loads
W - Normal Wind Load
V_{max} - Maximum Bearing Shear created by the governing load combinations
M_{max} - Maximum Bearing Moment created by the governing load combinations
V_u - Maximum Ultimate Shear Design Capacity of the concrete
M_u - Maximum Ultimate Moment Design Capacity of the concrete

(1) Load combinations are based on ANSI-57.9, Table 3.2.4.
(2) Governing loads shown are irrespective of locations. Loads reported have minimum margin to design capacity.
(3) Results of Load Combinations 2 through 6 are based on cracked section. Others based on uncracked sections.

<u>Impact to the Ultimate Moment and Shear Design Capacity of the Concrete for a Design Basis Tornado Missile</u>

The following is stated in the SAR Section 8.2.2.2 Accident Analysis, B. HSM Missile Impact Analysis;

> *The side walls and roof slab of the reinforced concrete HSM are 24 and 30 inches thick, respectively. The walls and roof are designed to provide adequate biological shielding and easily meet the minimum acceptable barrier thickness requirements for local damage against tornado generated missiles, as specified for Region III in NUREG-0800, Section 3.5.3, Table 1.*

The tornado missile loads are individually applied to the roof and walls of the HSM analytical model. The resultant tornado missile forces and moments are combined with other loads as required and the results are reported in Table 3. For these analyses, a rigid, penetration-resistant missile consisting of a 125 Kg (276 lb), 8-inch diameter blunt nosed hardened steel object traveling at 35% of the maximum wind speed (103 fps) is conservatively postulated. The method of analysis is based on the modified National Defense Research Committee (NDRC) formula as recommended in Section 3.5.3 of NUREG-0800 and it identifies three specific areas of design for Missile Impact Penetration Resistance Analysis; penetration, perforation, and scabbing. The HSM wall penetration depth for a postulated Design Basis Tornado (DBT) missile, where x is the penetration depth, is 2.7 inches. The perforating thickness or maximum thickness e that the postulated DBT missile will completely penetrate is 8.07 inches. The maximum perforation thickness e is conservative. The minimum thickness s necessary to prevent scabbing of material from the rear face of the target is 16.9 inches; the scabbing thickness. Scabbing effects control the minimum required wall thickness. ACI 349 requires a minimum of 20% additional wall thickness to prevent perforation and scabbing. Therefore the minimum wall thickness required to provide complete protection for the enveloping DBT missile is 1.2s, or 20.3 inches.

The specified minimum wall thickness for the HSM side walls is 24 inches. The roof and front wall are 30 inches, and the back wall is 36 inches. During the process of core drilling there will be a short time when an area 4 inches in diameter in the roof slab will be less than 20.3 inches thick. This area would be open for no more than 2 hours. The core drilling procedure specifies that when the core drilling machine and core are removed the hole will immediately be cleaned, prepared, core and core hole inspected, and filled with a grout mix. Since the grout will make the HSM equivalent to the original HSM the ultimate shear and moment design capacity for a design basis tornado missile will not be reduced.

Impact to the Thermal Capacity of the Concrete

The thermal stresses in concrete have factors of modulus of elasticity and the difference between temperature gradients within the concrete mass. The factors of modulus of elasticity are based upon the weight of the material. The difference in temperature gradients is based upon the nominal temperature difference between the gradients which will change with ambient temperature and time. For the temperature gradients to change in magnitude the ambient temperature needs to change and the existing temperature of the material will change correspondently with time. The density of the material affects how fast the temperature gradients will change. When the core sample is removed the nominal temperature of the concrete will take many hours to change. The core hole will be in existence for less than 2 hours time. The removed concrete will be replaced with a cementitious grout with the same nominal density of 140 pcf as the existing concrete. There will be no significant change in the temperature gradients when the core is removed and the grout is placed in the existing concrete. There will be no thermal capacity impact to the concrete.

Impact to the Shielding Capacity of the Concrete

The HSM side walls and roof slab thicknesses are established on the basis of radiological shielding requirements. Peak and average radiation dose rates for an HSM loaded with a bounding DSC are documented in the TMI-2 SAR and are summarized in Table 4. [6]

Table 4. Peak and average Gamma Dose Rates on HSM Surfaces

HSM Location	Peak Dose Rate (mrem/h)	Average Dose Rate (mrem/h)
Roof/Side Walls	10	6
Front Wall	13	5
Rear Wall	104	8
Module Gap	4	n/a
Uncovered Interior Wall	270	n/a

The peak gamma dose rates at the end of a core-drilled hole are calculated for a number of locations on an HSM as summarized in Table 5. [6]

Table 5. Calculated Peak Gamma Dose Rates at HSM Core-Drilling (22 inch) Locations

Location on HSM	Concrete Thickness (inches)	Gamma Dose Rate at Closed End of Hole (rem/h)	Gamma Dose Rate at Open End of Hole (mrem/h)
Roof Center	8	417	130
Front Wall	8	417	130
Back Wall	14	27	9
Roof Over Front Wall	17	7	2
Roof Over Back Wall	20	2	<1
Roof Over Side Wall	14	27	9
Roof Edge (Horizontally)	20	2	<1
Front Wall into Side Wall	14	27	9
Back Wall into Side Wall	18	4	1

Applying a radioactivity RF of 0.3 to the peak gamma dose rates summarized in Table 4 reduces the gamma dose rates to well below 100 mrem/h at the open ends of the core drilled holes and well below 1 mrem/h at 30 cm from the open ends of the core drilled holes as summarized in Table 6.[6] The calculated radiation levels are well below the 5 mrem/h radiological posting threshold of 10 CFR 20 as stated in the Radiation Protection Plan for NRC-licensed facilities included in PRD-317.

Table 6. Adjusted Peak Gamma Dose Rates at HSM Core Drilled (22 inch) Locations

Location on HSM	Gamma Dose Rate at Open End of Hole (mrem/h)	Gamma Dose Rate at 30 cm from Open End of Hole (mrem/h)
Roof Center	39	<1
Front Wall	39	<1
Back Wall	3	<1
Roof Over Front Wall	<1	<1
Roof Over Back Wall	<1	<1
Roof Over Side Wall	3	<1
Roof Edge (Horizontally)	<1	<1
Front Wall into Side Wall	3	<1
Back Wall into Side Wall	<1	<1

As stated above the core drilled holes will be packed with a grout of nominal density of 140 pcf and the overall nominal dimensions of the HSM will be maintained. There is no detrimental impact to the radiation protection capacity of the HSM as an effect of the core drilling.

Computer Hardware and Software

No computer hardware or software was used for this analysis.

Summary and Conclusions

The following conditions were analyzed to determine the effect core drilling will have on the ability of the HSM to perform its safety function; (1) the impact to the ultimate moment and shear design capacity of the concrete, (2) the impact to the ultimate moment and shear design capacity of the concrete for a Design Basis Tornado Missile, (3) the impact to the thermal capacity of the concrete, and (4) the impact to the shielding capacity of the concrete. The conclusion of this analysis is the reduced concrete sections will not adversely affect the governing loading and shielding conditions and the grouted holes will return the HSM to an equivalent condition comparable to the original HSM.

References

1. TMI-2 ISFSI Safety Analysis Report (SAR), latest chapter revisions

2. Winter, Urquhart, O'Rourke, Nilson, *Design of Concrete Structures*, Seventh Edition, McGraw Hill, New York, N. Y., 1968

3. American Concrete Institute, *Code Requirements for Nuclear Safety Related Concrete Structures and Commentary*, ACI 349-85 and ACI 349R-85, American Concrete Institute, Detroit, MI, 1980.

4. American Concrete Institute, *Building Code Requirements for Reinforced Concrete*, ACI 318-95, American Concrete Institute, Detroit, MI, 1995

5. R. E. Einziger, M. A. McKinnon, A. J. Machiels, *Extending Dry Storage Of Spent LWR Fuel For Up to 100 Years*, International Symposium on Storage of Spent Fuel from Power Reactors, November 1998

6. Letter GGH-01-09, dated April 20, 2009 from G. G. Hall to M. D. Wilberg, *Shielding Analysis to Support Three Mile Island Unit 2 Independent Spent Fuel Storage Installation Horizontal Storage Module Concrete Assessment*

Appendix A - Definitions

ACI 349R-36, RC.7, Impactive Effects Definitions:

- Penetration – Displacement of a missile into an impacted structural element. It is a measure of the depth of the crater formed at the zone of impact.
- Perforation – the passing of a missile completely through the impacted structural element with or without exit velocity (that is, "full penetration").
- Scabbing – Ejection of material from the back face of the impacted structural element opposite to the face of impact.
- Spalling – Ejection of material form the front face of the impacted structural element (that is, the face on which the missile impacts).

Normal and Off-Normal Operations – normal operating design conditions consist of a set of events that occur regularly, or frequently, in the course of normal operation of the NUHOMS®-12T system. These normal operating loading conditions for the HSM addressed in SAR Table 8.1-1 are; dead weight, normal thermal, normal handling and live loads. Off-normal operating design conditions are events that could occur with moderate frequency, possibly once during any calendar year of operation. These off-normal operation loading conditions addressed in SAR Table 8.1-2 are dead weight, off-normal thermal, and off-normal handling.

Accidents Postulated – The design basis accident events specified by ANSI/ANS 57.9-1984 and other credible and noncredible accidents postulated to affect the normal safe operation of the TMI-2 ISFSI are addressed in Chapter 8 of the SAR. In accordance with 10 CFR Part 72, analyses are provided for a range of hypothetical accidents, including those with the potential to result in an annual dose greater than 25 mrem outside the owner-controlled area. The postulated accidents considered in the analyses and the associated NUHOMS®-12T components affected by each accident condition for the HSM shown in SAR Table 8.2-1 are tornado wind, tornado missiles, earthquake, lightning, fire and explosion, and load combinations. Based on a review of the Safety Analysis Reports of other facility activities within the INTEC site, it has been determined that no credible explosion or fire associated with a co-located INTEC facility could occur that would pose a threat to the ISFSI which either exceeds a vehicular fire related to an ISFSI service vehicle (SAR Section 8.2.9), or exceed the potential impacts of either the wind loading, or airborne missile impact of a tornado scenario (SAR Section 8.2.2). Thus, the impacts of any credible accidents involving fire or explosion at co-located INTEC facilities are bounded by the analysis of the design basis tornado and the combustion of fuel from an ISFSI service vehicle.

HSM Missile Impact – The side walls and roof slab of the reinforced concrete HSM are 24 and 30 inches thick, respectively. The walls and roof are designed to provide adequate biological shielding and easily meet the minimum acceptable barrier thickness requirements for local damage against tornado generated missiles, as specified for Region III in NUREG-0800, Section 3.5.3, Table 2. To demonstrate the adequacy of the HSM design for tornado missiles, a bounding analysis of the end module in an array was performed. The items evaluated include the resistance to penetration, spalling, scabbing, and perforation for a postulated missile impact. In addition, the tornado missile loads are individually applied to the roof and walls of the HSM analytical model shown in SAR Figure 8.1-13. The resultant tornado missile forces and moments are combined with other loads as required by SAR Table 3.2-4 and the results are reported in Table 3. For these analyses, a rigid, penetration-resistant missile consisting of a 125 Kg (276 lb), 8-inch diameter blunt nosed hardened steel object traveling at 35% of the maximum wind speed (103 fps) is conservatively postulated. The method of analysis is based on the modified National Defense Research Committee (NDRC) formula as recommended in Section 3.5.3 of NUREG-0800.

Load Combination – The load categories associated with normal operating conditions, off-normal conditions, and postulated accident conditions are described and analyzed in various SAR sections. The ultimate strength method of analysis is utilized with the appropriate strength reduction factors as described in SAR Chapter 3 Table 3.2-2. The load combinations specified in Section 6.17.3.1 of ANSI 57.9-1984 are used for combining normal operating, off-normal, and accident loads for the HSM. All seven load combinations specified are considered and the governing combinations are selected for detailed design and analysis. The HSM design load combinations and the appropriate load factors are presented in SAR Chapter 3 Table 3.2-3. The HSM governing load combination results are presented in Table 3

Appendix B - Concrete Core Drilling Process

It is planned to retrieve twelve core samples 4 inches in diameter and between 12 inches to 20 inches in length plus or minus 2 inches. Core samples may be taken perpendicular to the roof top and face, and front and back walls (side walls are inaccessible). The roof, front and back wall concrete thicknesses are 30 inch, 30 inch, and 36 inches respectively. The core is limited to 20 inches plus or minus 2 inches to ensure the roof bottom reinforcement is not interrupted or the inside space of the HSM is not open exposing the DSC to the outside environment. The roof bottom reinforcement top of steel is located 23 inches from roof top surface (30 inches roof slab thickness minus 4 inches concrete seal minus 11/2 inches reinforcement cover minus 1 inch for #8 reinforcement minus 1/2 inch error factor equals 23 inches (30 – 4 – 1 1/2 – 1 – 1/2 = 23). See Figure 1.

The process for obtaining the core samples, hereafter called core drilling process or drilling process, is as follows. A covermeter (reinforcement) survey will be performed to identify location of reinforcement so the core sample can be taken without interrupting reinforcement. One or two holes 5/8 inch diameter by approximately 3 inches deep holes will be drilled. A drop anchor will be inserted into the holes and all thread bolts will be used to secure and maintain the core drilling machine in place while the core is being drilled. When the core drilling machine (with water supply) has been anchored in place, drilling will commence. A small stream of water will be used to aid the drill bit during the drilling process. When drilling on the roof horizontal surface a wet vacuum will be used to collect the slurry during the drilling process to eliminate ponding or streams of slurry running over the roof. Drilling these holes requires a small amount of water during the drilling process. When drilling holes in the walls (front, back, or roof face) a piece of plastic will be taped to the surface to collect the water and slurry and direct it into a barrel located on the scaffolding or the ground. The amount of water used will depend on the time it takes to drill a hole. Nearly all the water and slurry produced during the drilling process will be collected and removed.

The drilling will proceed until one core ranging in length from 12 to 20 inches plus or minus 2 inches core section is removed.. When the core is removed the core drilling machine and water supply will be unbolted and moved away from the coring area. Any remaining water and slurry will be cleaned up. The core hole and core will be inspected. The core hole will be cleaned and prepared to be grouted with a prepared Sika dry pack grout mix. The dry pack grout mix will be rodded and/or hammered into the core hole in a series of lifts until the hole is filled. The hole will only exist as long as it takes to remove the core; remove the drill; clean the water and slurry; inspect the core and core hole, clean, prepare, and fill the hole with the grout mix. The grout mix will be smoothed to match the existing surface level. A curing medium will be applied to the grout mix surface. The anchor bolt holes will then be cleaned (drop anchor may remain in place), prepared, and filled with grout mix and finished in the manner the core hole grout mix is finished.

A radiation survey will be performed to verify contact radiation levels are less than those assumed and documented in the SAR.

Once the core drilling process starts it will continue without stopping until the anchor bolt hole(s) is filled and curing material applied. This process will limit the time that there is a hole in the HSM concrete to the time it takes to remove the core drilling machine, clean, prepare, inspect core and core hole, and fill the core and bolt hole.

During the grouting process the work will be observed by a Quality Assurance Inspector and inspection reports will be kept to document accomplishment of Quality Level 1 work per an approved inspection plan.

A wind restriction is in place when using mechanical lifts or working at heights at the HSMs. When the wind speed approaches 25 miles per hour work continuance will be evaluated. Wind conditions will be checked in the morning before work begins and periodically during the work day. If it appears that a core drilling process cannot be completed because of impending wind conditions, work will stop before the drilling process begins. This process will ensure no hole will be made in an HSM and left open during wind conditions that could develop into tornado winds.

If drilling has commenced and the wind speed exceeds 25 mph, the drill and core will be left in place until they can be removed. If the core has been removed and is not filled with grout and work is stopped, a core or a prepoured plug will be inserted into and left in the hole until the grouting can continue. In the unlikely event that the removal of the core leaves a hole open to the inside of the HSM, a prepoured plug or the core will be inserted in the hole and held from above and additional shielding will be provided as necessary. A Radiation Control Technician (RCT) will be present to monitor radiation change when the core is removed.

Appendix C - Testing of Grout

The grout to be used to pack the core holes has been tested to verify compressive strength and density. The test results are attached. The test results show that the 7-day compressive strength (7,600 psi) exceeds the HSM compressive strength (5,000 psi). The grout density is 149 pcf which exceeds the HSM density of 140 pcf.

MATERIALS TESTING & INSPECTION

~~COMPRESSIVE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS (ASTM C39)~~ TP
High Strength Grout w/ 3/8" pea gravel

☐ Environmental Services ☐ Geotechnical Engineering ☐ Construction Materials Testing ☑ Special Inspections

Date: 4-20-09 MTI File #: E9006O Project Name: TMI 2 HSM Grout Testing
Contractor Name: CWI Permit #: NA
Inspector Name: ~~Sika~~ TAP Troy A. Pasta Weather: Clear
Supplier: Sika Grout Truck #: N/A Ticket #: N/A
Mix ID#: Sika Grout 212 Total # of Yards Placed: N/A 2 #50 bag mix
Location: Trial batch mock up in Bldg 1653

☑ ~~Concrete~~ Cylinders (High strength Grout) ☐ Concrete Cores

MIX PROPORTIONS PROVIDED BY SUPPLIER:		TEST PROPERTIES & CONDITIONS	
Batch Size (cy):	—	Ambient Temperature:	62
Cement (lbs):	2 #50 bags	Concrete Temp (ASTM C 1064):	NA
Fly Ash (lbs):	—	Time Batched:	1045
Water (gals):	13 pints	Time Cast:	1100
Coarse Agg. #1 (lbs):	#50 of 3/8"	% Air Content (ASTM C 231 or C 173):	N/A
Coarse Agg. #2 (lbs):	—	Slump (inches) (ASTM C 143):	N/A
Fine Agg. #1 (lbs):	—	Unit Weight (pcf) (ASTM C 138):	Perform on each cyl.
Fine Agg. #2 (lbs):	—	Yield (cy) (ASTM C 138):	—
Admix #1 (oz):	—	Water Added (gals):	—
Admix #2 (oz):	—	H/L Initial Curing Temp:	—
Admix #3 (oz):	—		
Water/Cement Ratio:	—	Notes:	FC Set 2

# of Cylinders: 4 Nominal Size: 6X12 Specified f'c (psi): 5000

ID	Cyl Dia	Ht	Corr Fctr	Cyl Area	Test Age	Test Date	Failure Load	Compress. Strength	Weight (~~C-617 Cap~~)	Fracture Type	Break Time
91031	5.97	11.05		27.98	3 FC	4-23	137365	4910	27.02	4	3 pm
91032	6.00	10.80	28.26	~~28.25~~	5 FC	4-25	175080	6200	26.25	5	2:16 pm
91033	6.01	10.9		28.35	7 FC	4-27	215560	7600	26.67	5	12 20
91034					28 FC	5-18					

NOTES: ASTM is a sulfer cap; neoprene pads are utilized unless otherwise noted

Remarks: Measure & weigh each one for unit wt (similar to IWTU)

Initial Curing < or = 48 hrs Yes______ No X Why? Field cure

Cylinders placed in curing facility within 30 minutes of stripping mold?