Department of Energy
Idaho Operations Office
1955 Fremont Avenue
Idaho Falls, ID 83401

January 31, 2005

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

SUBJECT: License Amendment Request for the Three Mile Island Unit 2 (TMI-2) Independent Spent Fuel Storage Installation (ISFSI) (Docket 72-20) (INTEC-NRC-05-001)

Dear Sir or Madam:

Pursuant to 10 CFR 72.56, DOE-Idaho requests a license amendment to the TMI-2 ISFSI Material License SNM-2508 as described herein, and documented in the enclosed material.

TMI-2 ISFSI Technical Specification (TS) 3.1.1 requires a five-year leak test on each of the dry shielded canisters (DSC). If the leak test fails, the seal must be replaced and/or reseated and then retested. As TS 3.1.1 is currently written, the DSC is to be transported to an appropriate facility for further corrective actions if the test subsequently fails to pass. The requested amendment would allow corrective actions to be taken in-situ without movement of the DSC. In addition to being cost effective, mitigation in place would eliminate unnecessary worker radiation exposure and reduce operational risk, while ensuring the public safety.

In order to ensure the ability to obtain an effective seal, the proposed TS change would also allow for the use of elastomeric seals in place of the metallic seals if replacement were required. This has been proposed due to a concern that a new metallic seal may have difficulty achieving a seal due to slight imperfections in the sealing surface. Properties of the elastomeric seal will meet service conditions while allowing for slight surface imperfections. The use of an elastomeric seal would require replacing the seal every five years.

In addition to the change to TS 3.1.1, DOE-ID also requests NRC approval of changes to TS 4.2.1, Safety Analysis Report Chapters 4, 7 and 8, and TS Bases B 3.1.1 as described in the enclosed material, all which are related to the above change.

Enclosed is a more detailed explanation of the changes, the proposed document revisions, and other supporting documentation.

NMSS01

Though not all the leak tests are due, DOE intends to perform the required leak tests on all canisters this summer. Accordingly, your approval of this license amendment is requested no later than May 2005.

Please contact Jan Hagers (208-526-0758) or Mark Gardner (208-526-5655) of my staff with any questions.

Sincerely,

Elizabeth D. Sellers
Manager

Enclosures

Request for License Amendment
Docket 72-20
TMI-2 ISFSI

Concern

The core debris from the Three Mile Island Unit 2 (TMI-2) reactor is stored in the Department of Energy's Independent Spent Fuel Storage Installation (ISFSI) located at the Idaho National Engineering and Environmental Laboratory. The Dry Shielded Canisters (DSC) are vented through HEPA grade filters to provide a diffusion path for hydrogen from the TMI-2 core debris. The interface between each vent housing and its DSC has dual metallic seals (the vent housing seals) applied between polished surfaces of the DSC and the vent housings.

The vent housing seals are subject to a Limiting Condition for Operation (LCO), which specifies a maximum allowable leak rate (Technical Specification 3.1.1). Verification of the LCO is performed by a surveillance performed on a five-year frequency. Contingency planning to address the possibility of loss of the LCO and entry into the Required Action table has identified concerns with the actions required by TS 3.1.1 and the wording of TS 4.2.1.

Technical Specification 3.1.1 includes the following required actions upon loss of LCO 3.1.1:

> Reseat or replace seals and perform leak check within 7 days.
>
> If seal integrity cannot be restored within 7 days, then the affected DSC must be removed from its HSM to an alternate facility within 30 days.

Procedures and equipment are available to replace a failed seal but it is anticipated that it will be difficult to replace and adequately seat the metallic seals. Therefore, a seal which fails a leak rate surveillance could lead to the requirement to remove the DSC from the TMI-2 ISFSI. Obtaining a transportation cask and trailer and preparing an alternate facility (to position the DSC vertically and provide adequate shielding) are actions likely to require significantly more than 30 days.

The presence of DSC shielding at the TMI-2 ISFSI (provided by the Horizontal Storage Modules) provides an advantage to maintaining the DSC at the TMI-2 ISFSI. A proposed amendment to Technical Specifications 3.1.1 is needed to allow the maintenance of the DSC vent housing seals at the TMI-2 ISFSI beyond the existing 7-day limit.

The use of metallic seals is very sensitive to the presence of minor imperfections on the sealing surfaces of the DSC or the vent housing. Such imperfections can occur from handling or surface oxidation of the carbon steel surface. The amendment to Technical Specification 3.1.1 would alternatively permit the use of elastomeric seals suitable for use in the service conditions expected. The elastomeric seals are less sensitive to surface imperfections but have a lower design life than the metallic seals. Therefore the proposed changes to Technical Specification 3.1.1 include a higher surveillance frequency and a replacement interval for those DSCs with elastomeric seals. Additional changes for the Safety Analysis Report and the Technical Specification Bases describe the radiation protection and engineering bases for the proposed changes and are included in this request package.

Also, Technical Specification 4.2.1.3 and 4.2.1.4 currently require successful tests before commencing TRANSFER OPERATIONS. ("TRANSFER OPERATIONS" is defined in section 1 of the Technical Specifications and includes transfers to, from, and within the TMI-2 ISFSI.) These tests, including non-destructive examination of the seal welds and leak rate tests of the dual metallic seals, were intended to be design verifications before a DSC could be loaded into the TMI-2 ISFSI. Prerequisites for loading into transfer casks or for acceptance into another facility should be removed from the TMI-2 ISFSI design features requirements. A proposed amendment to Technical Specifications 4.2.1.3 and 4.2.1.4 will clarify the intent of the TMI-2 ISFSI design features.

Safety Consequence

The DSC vent housing seals are intended to ensure that air flowing out of the DSC is routed through HEPA grade filters for confinement of radioactive material. It is important to recognize that the DSC is normally vented through the DSC vent filters. In this configuration (vented, without a source of pressure to force material through a restriction), a compressed vent housing seal or any compressed metal-to-metal surface does not represent a viable motive pathway for the uncontrolled release of radioactive materials. This is true even if the seal or compressed metal-to-metal surface fails to meet leak rate specifications. Therefore, the safety consequences of DSC vent housing seals that fail to meet the LCO are not significant when compared to accidents described in the TMI-2 ISFSI Safety Analysis Report (SAR).

A conservative risk assessment was performed using the assumption that the likelihood of vent housing seal leakage exceeding the LCO is possible one or more times in the life of the facility. This event probability results in the classification of the postulated event as an anticipated occurrence. Classifying the event as an anticipated occurrence requires the evaluation of the potential radiological consequences of the event against criteria that are more restrictive than the criteria of design basis accidents. Therefore, the radiological consequences of undetected degraded vent housing seal surfaces have been evaluated against the limits of 10 CFR 72.104, "Criteria for Radioactive Materials in Effluents and Direct Radiation from an ISFSI or MRS".

The radiological consequences of long-term undetected DSC vent housing seal failure have been evaluated and are well within the limits of 10 CFR 72.104. The description of the radiological evaluation is included in proposed changes to SAR Section 7.6.3, "Estimated Dose Equivalents," and SAR Section 8.1.4, "Storage with Leakage of Vent or Purge Port Seals." These proposed changes are included in the license amendment request.

Long-term undetected DSC vent housing seal failure is bounding because the seals are subject to the surveillance requirements of Technical Specification 3.1.1 and the DSC vents are subject to periodic radiation protection surveillance. The proposed license amendment request includes additional Required Actions in Technical Specification 3.1.1 to perform surveys for radiological contamination at any adversely affected DSC vent housing.

The radiological consequences of the existing Technical Specification 3.1.1 required actions and the radiological consequences of the proposed changes are compared below. The engineering evaluation of alternate seal materials (intended to ensure the rapid restoration of the LCO) is also described below.

ALARA Considerations of Seal Replacement

The radiological consequences of the operations required upon failure to replace leaking vent housing seals within 7 days have been evaluated. A required action of Technical Specification 3.1.1 is to move any affected DSC to an alternate facility within 30 days if the leaking vent housing seal cannot be repaired or replaced within 7 days. The radiological consequences of leaving the DSC in its HSM under existing radiation protection program controls, while pursuing additional efforts to reseat or replace the seals, are expected to result in significantly lower occupational radiation exposures. This can be understood by considering that the DSC is stored in a well-shielded system (the reinforced concrete Horizontal Storage Module (HSM). The DSC vent housings are accessible for testing and maintenance through an opening in each HSM. Removal of the DSC to an alternate facility and maintenance of the DSC at an alternate facility would result in increased radiation exposure to workers.

The alternative action of leaving the DSC in its HSM under radiation protection program controls is an essential part of this license amendment request. The proposed change to Technical Specification 3.1.1 is supported by proposed changes to Technical Specification Bases B 3.1.1 and Safety Analysis Report Section 7.4.1, "Operational Dose Assessment."

Alternate Seal Material

An alternate seal material has been identified with an acceptable design life. Using the alternate seal material would provide excellent (very low) leak rates and less sensitivity to installation technique and orientation. The results of the engineering analysis and specification of the alternate seal material are described in Safety Analysis Report Section 4.3.1, "Ventilation and Offgas Requirements," which is included in this license amendment request. To permit the optional use of the alternate seal material, an increased surveillance frequency and a seal replacement interval are requested as additional Technical Specification 3.1.1 changes.

It is expected that the existing DSC sealing surfaces and vent housing seals will remain adequate for the remaining life of the facility. However, if actions are required, then the proposed TS change would also require a 90-day written report to the NRC if any seal leak rate cannot be restored within 7 days or if any metallic seal is replaced with an elastomeric seal. Written reports submitted in response to the TS Required Action table would include actions taken and planned.

The corrective actions described above will ensure an effective, safe, and timely response in the event that adverse trends in vent housing seal performance are observed.

Summary of Approvals Requested

If approved, occupational radiation exposures resulting from a loss of LCO are expected to be reduced and the facility can be safely modified (with the use of alternate seal materials) to restore any loss of LCO more rapidly. The following documents are submitted for approval. These documents are outside of the scope of changes allowed pursuant to 10 CFR 72.48 because they require changes to the Technical Specifications. Each attachment is shown with the current version in markup form and the clean proposed version.

- Attachment 1. Technical Specification 3.1.1, Leak Testing DSC Vent Housing Seals. Changes to the required actions for Condition A, addition of new Condition B, and addition of new Surveillance 3.1.1.2. Editorial change to Technical Specification 3.1.2 are included in this attachment to reflect the page number changes. (Because the change to Technical Specification 3.1.2 is an editorial change, there is no corresponding change to Technical Specification Bases B 3.1.2.)
- Attachment 2, Technical Specification 4.2.1, Dry Shielded Canister (Design Features). The applicability of the two design features specified in 4.2.1.3 and 4.2.1.4 can be interpreted to contradict with the current required action of Technical Specification 3.1.1. The applicability of seal weld non-destructive examinations and the leak rate testing of the vent housing seals is being changed from "prior to commencing TRANSFER OPERATIONS" to "prior to commencing transfers to the TMI-2 ISFSI."
- Attachment 3. Safety Analysis Report Chapter 4, Installation Design. Section 4.3.1, Ventilation and Offgas Requirements. The basis for the optional elastomeric seals to maintain the confinement integrity of the DSC. Also included is the addition to the Chapter 4 references used to support the Section 4.3.1 change.

- Attachment 4. Safety Analysis Report Chapter 7, Radiation Protection. Section 7.4.1, Operational Dose Assessment. Description of the occupational dose assessment of anticipated actions needed to respond to increased surface contamination at the DSC vent housing HEPA filters. Section 7.6.3, Estimated Dose Equivalents. Description of the occupational and public doses as they are affected by bounding surface contamination associated with postulated leaking DSC vent housing seals. Also included is the addition to the Chapter 7 references used to support the Section 7.4.1 and Section 7.6.3 changes.
- Attachment 5. Safety Analysis Report Chapter 8, Analysis of Design Events. Section 8.1.4, Storage with Leakage of Vent or Purge Port Seals. Description of the radiological evaluation of a postulated event for degraded DSC vent housing seals. Also included is the addition to the Chapter 8 references to support the addition of Section 8.1.4.
- Attachment 6. Technical Specification Bases B 3.1.1, Leak Testing DSC Vent Housing Seals. Changes to the bases for the new ACTIONS, SURVEILLANCE REQUIREMENTS, and REFERENCES. These changes conform to the changes to Technical Specification 3.1.1, SAR Section 4.3.1, and SAR Section 8.1.4.

Also attached are two Engineering Design Files that are new references in the Safety Analysis Report. These two files are not part of the license amendment request. They are provided as additional information to facilitate the review of the license amendment.

- Attachment 7. Engineering Design File No. 5003, "TMI-2 ISFSI Alternate DSC Seal Evaluation" Revision 1, 10/18/04
- Attachment 8. Engineering Design File No. 4728, "Radiological Evaluation of TMI-2 ISFSI Technical Specification 3.1.1" Revision 1, 11/10/04

Attachment 1

Technical Specification 3.1.1
Leak Testing DSC Vent Housing Seals

Included in this attachment:

1. The markup of Technical Specification section 3.1, which includes the technical changes to Technical Specification 3.1.1 and the editorial changes to Technical Specification 3.1.2.

2. The proposed clean copy of Technical Specification section 3.1, which incorporates the requested changes.

3.1 DSC INTEGRITY

3.1.1 Leak Testing DSC Vent Housing Seals

LCO 3.1.1 — The leak rate of the vent housing seals shall not exceed 1×10^{-2} standard cc/sec.

APPLICABILITY: During STORAGE OPERATIONS.

ACTION

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. The vent housing seal leak rate is exceeded during STORAGE OPERATIONS	A.1 Reseat or replace seals.	7 Days
	AND	
	A.2 Perform leak check on seal.	7 Days
	OR	
	A.3 Transport the DSC to TAN or other appropriate facility for corrective actions.	30 Days

Replace with Revised Actions

Insert new Condition B and C

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.1.1	Perform leak check of the vent housing double metallic seals on each DSC containing TMI-2 CANISTERs.	Within 7 days after insertion of DSC into HSM. AND Every 5 years during STORAGE OPERATIONS. NOTE: SR 3.0.2 is not applicable.

Insert new SR 3.1.1.2

Amendment No. 4

3.1 DSC INTEGRITY

3.1.1 Leak Testing DSC Vent Housing Seals

LCO 3.1.1 The leak rate of the vent housing seals shall not exceed 1×10^{-2} standard cc/sec.

APPLICABILITY: During STORAGE OPERATIONS.

ACTION

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. The vent housing seal leak rate is exceeded during STORAGE OPERATIONS	A.1 Perform contamination survey at affected DSC-vent housing interfaces.	24 Hours
	AND	
	A.2.1 Reseat or replace seals.	7 Days
	AND	
	A.2.2 Perform leak check on seals.	7 Days
B. The vent housing seal leak rate is not restored within 7 days during STORAGE OPERATIONS	B.1 Perform contamination survey at affected DSC-vent housing interfaces.	Monthly
	AND	
	B.2 Submit report to NRC describing condition, analysis, and actions being taken.	90 Days. Note: LCO 3.0.2 does not apply. This report is required upon entry into Condition B.
C. The vent housing double metallic seals are replaced with double elastomeric seals during STORAGE OPERATIONS	C.1 Submit report to NRC describing condition, analysis, and actions being taken.	90 Days
	AND	
	C.2 Replace the elastomeric seals.	After 5 years in service.

3.1.1 Leak Testing DSC Vent Housing Seals (continued)

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.1.1	Perform leak check of the vent housing double metallic seals on each DSC containing TMI-2 CANISTERs.	7 days after insertion of DSC into HSM. <u>AND</u> Every 5 years during STORAGE OPERATIONS. NOTE: SR 3.0.2 is not applicable.
SR 3.1.1.2	Perform leak check of the vent housing double elastomeric seals on each DSC containing TMI-2 CANISTERs.	Every year during STORAGE OPERATIONS.

3.1 DSC INTEGRITY

3.1.2 DSC Handling and Transport Temperature Limit

LCO 3.1.2 — Handling or transporting a DSC containing TMI-2 CANISTERs shall not be performed when DSC temperature is less than 20 degrees F or when the ambient air temperature is less than 0 degrees F.

APPLICABILITY: During TRANSFER OPERATIONS.

ACTION

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. Temperature limits not met while DSC is being transported	A.1 Place DSC in a safe condition.	Immediately

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
SR 3.1.2.1 Measure the outside air temperature.	Immediately before commencing TRANSFER OPERATIONS. AND During TRANSFER OPERATIONS.
SR 3.1.2.2 Measure the DSC temperature or the cask temperature.	Immediately before commencing TRANSFER OPERATIONS.

Attachment 2

Technical Specification 4.2.1
Dry Shielded Canister

Included in this attachment:

1. The markup of Technical Specification section 4.2.1, which includes the technical changes in the applicability of Technical Specifications 4.2.1.3 and 4.2.1.4.

2. The proposed clean copy of Technical Specification section 4.2.1, which incorporates the requested changes.

4.0 DESIGN FEATURES

4.1 Storage Features

4.1.1 Storage Capacity

The total storage capacity of the TMI-2 ISFSI is limited to 30 HSMs, 29 which will be loaded, and one extra. Each of 29 HSMs holds a NUHOMS®-12T DSC containing up to 12 TMI-2 CANISTERs.

4.2 Codes and Standards

4.2.1 Dry Shielded Canister

4.2.1.1 Design Exceptions to Codes, Standards, and Criteria

Table 4-1 lists approved exceptions for the design and fabrication of the TMI-2 ISFSI Dry Shielded Canister.

4.2.1.2 Construction/Fabrication Exceptions to Codes, Standards, and Criteria

Proposed alternatives to ASME Code, Section III, 1992 Edition with Addenda through 1993, including exceptions allowed by Section 4.3.1, may be used when authorized by the Director of the Office of Nuclear Material Safety and Safeguards or designee. The licensee should demonstrate that:

1. The proposed alternatives would provide an acceptable level of quality and safety, or
2. Compliance with the specified requirements of ASME Code Section III, 1992 Edition with Addenda through 1993, would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Requests for relief in accordance with this section shall be submitted in accordance with 10 CFR 72.4.

4.2.1.3 DSC top shield plug seal weld (inner cover plate) and top cover plate (outer cover plate) seal welds shall meet the applicable requirements of ASME Boiler and Pressure Vessel Code (B&PVC) Section III, NB-5340 for magnetic particle examination (MT) or NB-5350 for liquid penetrant (PT) examination, prior to commencing ~~TRANSFER OPERATIONS~~.

4.2.1.4 Leak rate testing of the vent housing seals shall be conducted in accordance with ANSI N14.5 and shall not exceed 1×10^{-3} standard cc/sec prior to commencing ~~TRANSFER OPERATIONS~~.

(continued)

transfers to the TMI-2 ISFSI.

4.0 DESIGN FEATURES

4.1 Storage Features

4.1.1 Storage Capacity

The total storage capacity of the TMI-2 ISFSI is limited to 30 HSMs, 29 which will be loaded, and one extra. Each of 29 HSMs holds a NUHOMS®-12T DSC containing up to 12 TMI-2 CANISTERs. An extra HSM serves as a backup in case a challenged DSC needs additional confinement. This extra HSM will include a cylindrical overpack so that it can be used to provide an additional barrier for a challenged DSC.

4.2 Codes and Standards

4.2.1 Dry Shielded Canister

4.2.1.1 Design Exceptions to Codes, Standards, and Criteria

Table 4-1 lists approved exceptions for the design and fabrication of the TMI-2 ISFSI Dry Shielded Canister.

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4.2.1.4 The leak rate of the vent housing seals shall be conducted in accordance with ANSI N14.5 and shall not exceed 1×10^{-2} standard cc/sec prior to commencing transfers to the TMI-2 ISFSI.

(continued)

Attachment 3

Safety Analysis Report
Chapter 4, Installation Design

Included in this attachment:

1. The markup of Safety Analysis Report section 4.3.1, which indicates the location of the additional text supporting the Technical Specification changes.

2. The proposed clean copy of the text to be added to section 4.3.1.

3. The markup of Safety Analysis Report section 4.8, References, which includes the location of the additional reference.

4. The proposed clean copy of the text describing reference 4.16, which is to be added to section 4.8.

The HEPA grade filters are sintered stainless steel type used widely within the DOE system for venting various stored wastes, such as transuranic waste, where there is a potential for gas build-up. The filters have an efficiency of greater than 99.97% for particles down to 0.3 microns. These passive filters are designed to be maintenance free. Although the filter housing has a dust cover, each individual filter comes with a dust cover over the filter exit that prevents any direct access to the filter media. The filters could accumulate some dust that may restrict the air flow. The accumulation of dust, although highly unlikely, would occur over a period of time. Periodic sampling of the gas within the DSC is made to assure the hydrogen gas concentration stays below the Technical Specification limit, which includes a limit which will be used as a decision point for purging the system and replacing the filters. Increased levels of hydrogen within the DSC after the hydrogen level has been stable for a period of time (6-12 months) may be caused by clogged filters. If increased hydrogen levels approach the Technical Specification limits, the filters will be replaced.

The filters have been tested in a variety of environments that bound the environment at INEEL. Testing has not shown any significant change of diffusivity or filtration ability. These tests have included artificially forcing dust into the filter. The consequences of all the filters plugging is addressed in Chapter 8 as an abnormal event. The consequences of a complete confinement failure including the filters is considered in the accident scenario release evaluation. The filters are made out of stainless steel that does not readily absorb water. The seals in this passive filter are all static seals. In this application there is no driving pressure or movement that would require the seals to be resilient throughout the design temperature range. The steel housing attaching the vents to the DSC is machined from a piece of plate and sealed using double metallic sealing rings. The filters have a stainless steel housing around the HEPA filter that threads into the carbon steel housing attaching to the DSC. Each of the filters comes with a single neoprene rubber gasket. These filters can easily be threaded in and out through the access door in the HSM rear wall. The access door also provides access for leak testing the housing-to-DSC seals and sampling of the DSC gases for possible build-up of hydrogen. The filters are normally covered with an open dust cover, but can be sealed off to facilitate sampling and purging if necessary. A similar vent is attached to the purge connection on the DSC. The purge sample port can also be used to purge the system. The purge connection is connected to a tube that runs to the far end of the DSC so that, during a purging operation, all areas within the DSC will be purged.

Insert new paragraph attached

The HSM rear wall access hole to the DSC vents is covered with a steel door which is secured to the HSM rear wall to protect the vent system and prevent unauthorized access. The holes in the door allow air circulation to prevent build-up of hydrogen in the HSM, yet prevent natural intrusions. The vents are located approximately three feet back from the outer surface of the HSM. None of the holes are directly over the vent opening. The vent housing dust cover and the individual filter stainless steel dust covers insure that no moisture other than the air humidity can gain access to the filter openings. The vent location and the door are designed to prevent any weather damage.

New fourth paragraph to be inserted into Section 4.3.1.1:

The leak rates of the double metallic seals between the filter/purge housings and the DSC are periodically tested. Failure of this test requires resealing and retesting. The surface of the DSC was polished to a very smooth finish before installation of the metallic seals so a good seal could be established. Replacing the metallic seals and restoring the low leak rate after a leak test failure is expected to be difficult because of the limited workspace provided by the access openings in the HSM and the sensitivity of the metallic seals to minor imperfections on the sealing surface. Elastomeric seals, which are significantly easier to seat and establish a seal, have been specified and tested and shown to be a suitable alternate for the metallic seal [4.16]. The elastomeric seals would require testing and replacement at greater frequencies than the corresponding frequencies for the metallic seals due to a shorter service life for the elastomeric material.

4.12 Safety Analysis Report for the Rancho Seco Independent Spent Fuel Storage Installation, Sacramento Municipal Utility District, USNRC Docket Number 72-11, October 1993.

4.13 "American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More for Nuclear Materials," ANSI N14.6-1993, American National Standards Institute, Inc., New York, New York.

4.14 D.W. Akers, E. L. Tolman, et al., "Three Mile Island Unit 2 Fission Product Inventory Estimates," Nuclear Technology Journal, Volume 87, #1, pp 205-213, August 1988.

4.15 "Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," NUH-003, Revision 4A, VECTRA Technologies, Inc., File No. NUH003.0103, NRC Docket No. 72-1004, June 1999.

Insert new Reference
4.16 - Attached

New reference to be added at the end of Section 4.8:

4.16 Gavalya, R. A. "TMI-2 ISFSI Alternate DSC Seal Evaluation," BBWI, Engineering Design File No. 5003, Revision 1, October 2004.

Attachment 4

Safety Analysis Report
Chapter 7, Radiation Protection

Included in this attachment:

1. The markup of Safety Analysis Report section 7.4.1, Operational Dose Assessment, which indicates the location of the additional text supporting the Technical Specification changes.

2. The proposed clean copy of the text to be added to section 7.4.1.

3. The markup of Safety Analysis Report section 7.6.3, Estimated Dose Equivalents, which indicates the location of the additional text supporting the Technical Specification changes.

4. The proposed clean copy of the text to be added to section 7.6.3.

5. The markup of Safety Analysis Report section 7.7, References, which includes the location of the additional reference.

6. The proposed clean copy of the text describing reference 7.22, which is to be added to section 7.7.

7.4 Estimated On-Site Collective Dose Assessment

7.4.1 Operational Dose Assessment

This SAR section establishes the anticipated cumulative dose exposure to site personnel during the fuel handling and transfer activities associated with utilizing one NUHOMS® HSM for storage of one DSC. Chapter 5 describes in detail the NUHOMS® operational procedures, a number of which involve potential radiation exposure to personnel.

A summary of the operational procedures which result in radiation exposure to personnel is given in Table 7.4-1. The cumulative dose can be calculated by estimating the number of individuals performing each task and the amount of time associated with the operation. The resulting man-hour figures can then be multiplied by appropriate dose rates near the transfer cask surface, the exposed DSC top surface, or the HSM front wall. Dose rates are referenced in Table 7.3-1 for the DSC, cask, and HSM.

Every operational aspect of the NUHOMS® system, from canister loading through, sealing, transport, transfer, and operation is designed to assure that exposure to personnel is ALARA. Dose rates are kept ALARA by the shielded DSC end plugs and shielded cask. The vent and purge ports have been designed with bends and shield plates to minimize streaming during DSC sealing and filter change-outs. Exposures are kept ALARA by performing most operations remotely as follows: (1) The debris canister drying and loading into the DSC are performed remotely in TAN Hot Shop; (2) If it is used, the welding machine is pre-installed on the top shield plug and top cover plates, away from the DSC, and operated remotely; (3) Transfer operations are performed inside the heavily shielded MP187 cask and trailer; and (4) Cask alignment operations are performed using a remote hand-held pendant and the hydraulic ram is operated using a remote power unit. In addition, many engineered design features are incorporated into the NUHOMS® system which minimize occupational exposure to plant personnel during placement of fuel in dry storage as well as off-site dose to the nearest neighbor during storage. The resulting dose at the ISFSI site boundary is well within the limits specified by 10 CFR 72.

Because the predicted dose rates for the NUHOMS®-12T system are well below those predicted for previous NUHOMS® systems, occupational exposures for the TMI-2 ISFSI will be bounded by those observed at other installations. Based on experience from operating NUHOMS® systems at Oconee, Calvert Cliffs, and Davis-Besse, the occupational dose for placing a DSC with TMI-2 core debris into dry storage for the operational steps listed in Table 7.4-1 will be much less than one person-rem. With the use of effective procedures and experienced ISFSI personnel, the total accumulated dose can be reduced below 500 person-mrem per DSC.

Add new paragraph - attached

New fifth paragraph to be inserted at the end of Section 7.4.1:

If a DSC vent housing seal fails a leak rate test, the estimated collective occupational exposure to reseat or replace the seals while the DSC remains in place is 60 person-mrem [7.22]. The estimated collective occupational exposure to transfer a DSC with a failed seal leak rate test to HSM No. 15 and reseat or replace the seals is 80 person-mrem. After discovery of a DSC with a failed leak rate test, any decontamination in a DSC vent housing area will increase the collective occupational exposure at a rate of 5 person-mrem/h.

7.6.3 Estimated Dose Equivalents

Dose equivalents from effluents as a function of distance from the ISFSI have been calculated using the RSAC-5 computer code [7.13]. Meteorological parameters were generated using hourly meteorological data taken over a six-year period. The greatest annual average atmospheric dispersion factor over this period is 4.81×10^{-8} s/m^3, established for Atomic City, 18 km from the INTEC. This corresponds to a 4.45 m/s wind speed with class C stability, which was assumed for the effluent dose calculations. Normal operation nuclide releases from Table 7.2-3 were input to the code for calculations of exposure from inhalation, ingestion, ground surface dose, and immersion.

RSAC-5 calculates inhalation doses using the ICRP 30 [7.16] and DOE [7.17] dose conversion factors. The Committed Dose Equivalent (CDE) for each organ or tissue is multiplied by the appropriate weighting factor and summed to determine the Committed Effective Dose Equivalent (CEDE). Ingestion doses are calculated based on the models and equations of Regulatory Guide 1.109 [7.18]. The dose from radioactivity deposited on the ground surface is calculated using DOE [7.19] dose-rate conversion factors. Immersion doses are calculated using a finite plume model.

Table 7.6-1 provides the thyroid organ dose and the effective dose equivalent (applicable to the whole body) at distances of 100 meters (assumed INTEC boundary), 1000 meters, 13.7 km (INEEL boundary, controlled area boundary, and assumed MEI), and 18 km (Atomic City). Table 7.6-1 also provides the calculated χ/Q for each distance. Doses for the on-site locations are calculated assuming 40 hours per week of occupancy with no contribution from the ingestion pathway. The calculated annual dose at the INTEC boundary is 7 mrem, a small fraction of the 10 CFR Part 20 limits for either occupational exposure or dose to members of the public. The calculated effective dose equivalent at the INEEL boundary is well below the 25 mrem 10 CFR 72.104 limit for the whole body.

7.6.4 Liquid Release

Even though the HSM is provided with a drain to remove any moisture that may get into the HSM, no liquids are expected to be released from the INEEL TMI-2 ISFSI.

Add new paragraph - attached

New fourth paragraph to be inserted at the end of Section 7.6.3:

> The estimated effluent dose equivalent rate for the MEI resulting from an unfiltered bounding DSC vent path is calculated to be 0.17 mrem/y [7.22]. The effective dose equivalent rate for INTEC boundary, calculated based on the ratio of the TEDE values at 100 meters and 13,700 meters documented in Table 7.6-1 and the same assumptions discussed above, is 130 mrem/y.

7.11 "MCNP 4 - Monte-Carlo Neutron and Photon Transport Code System," CCC-200A/B, Oak Ridge National Laboratory, RSIC Computer Code Collection, October 1991.

7.12 Title 40, Code of Federal Regulations, Part 61, "National Emission Standards for Hazardous Air Pollutants."

7.13 Wenzel, D. R., "The Radiological Safety Analysis Computer Program (RSAC-5) User's Manual," WINCO-1123, Revision 1, Idaho National Engineering Laboratory, March 1994.

7.14 American Nuclear Society Standards Committee Working Group ANS-6.4, "American National Standard Guidelines on the Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants," ANSI/ANS-6.4-1977, American Nuclear Society, 1978.

7.15 "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," Sacramento Municipal Utility District, Docket No. 72-11.

7.16 ICRP, "Limits for Intakes of Radionuclides by Workers," Part 1, ICRP Publication 30, Pergamon Press, Oxford, Great Britain, 1979.

7.17 U.S. Department of Energy, "Internal Dose Conversion Factors for Calculation of Dose to the Public," DOE/EH-0071, Washington D.C., 1988.

7.18 U. S. Nuclear Regulatory Commission, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," Regulatory Guide 1.109.

7.19 7.19 U.S. Department of Energy, "External Dose-Rate Conversion Factors for Calculation of Dose to the Public," DOE/EH-0070, Washington D.C., 1988.

7.20 Hall, G. G., "Impact of AmBeCm Sources on the TMI-2 ISFSI Design Basis", Engineering Design File No. 1793, Revision 4, March 15, 2001.

7.21 DOE/ID-12082. Idaho national Engineering and Environmental Laboratory Site Environmental Report, Calendar Year 2001. December 2002.

Add new reference 7.22 - attached

New reference to be added at the end of Section 7.7:

7.22 Hall, G. G., "Radiological Evaluation of TMI-2 ISFSI Technical Specification 3.1.1", Engineering Design File No. 4728, Revision 1, November 2004.

Attachment 5

Safety Analysis Report
Chapter 8, Analysis of Design Events

Included in this attachment:

1. The markup of Safety Analysis Report section 8.1, Normal and Off-Normal Events, which indicates the location of the additional section supporting the Technical Specification changes.

2. The proposed clean copy of the text to be added as new section 8.1.4, Storage with Leakage of Vent or Purge Port Seals.

3. The markup of Safety Analysis Report section 8.5, References, which includes the location of the additional reference.

4. The proposed clean copy of the text describing reference 8.45, which is to be added to section 8.5.

(88°C). This value is well below the short term fuel debris temperature limit of 1058°F (570°C) defined in Section 3.3.7.1.

These temperatures are well within the filter tested temperature range of -194°C to 140° C. The temperatures are also within the operating range for both the metallic seals and the elastomerics used in the filter assembly. The limiting case is the elastomerics used in the filter assembly that has a normal operating range for a static seal between -50°F and 250°F with the capability of going beyond these limits for short periods.

8.1.3.3 Thermal Analysis of the NUHOMS®-12T DSC Inside the MP187 Cask

A. NUHOMS®-12T DSC in Cask During Transfer Operation

The design basis heat load for the MP187 cask for 10 CFR Part 72 conditions is 13.5kW [8.12]. The design basis heat load in the NUHOMS®-12T DSC is 0.86kW. Therefore, the thermal analysis for the NUHOMS®-12T DSC in the MP187 cask is bounded by the results presented in the MP187 10 CFR Part 71 SAR [8.18] and 10 CFR Part 72 SAR [8.12].

Add new Section 8.1.4 - attached

New Section 8.1.4 to be inserted at the end of Section 8.1:

8.1.4 Storage with Leakage of Vent or Purge Port Seals

A Limiting Condition for Operation (LCO) during storage operations at the TMI-2 ISFSI is maintenance of the DSC vent and purge housing seal leak rate below 1E-02 standard cc/s. Compliance with the LCO is demonstrated through periodic performance of a leak check of the vent and purge housing double seals on each DSC containing TMI-2 canisters. If the vent and purge housing seal leak rate is exceeded, then the required action is to reseat or replace the seals, and perform another leak check on the seal within seven days.

The basis for verifying the integrity of the DSC is the need to maintain confinement of the radioactive material stored in each DSC. The vent and purge housing seals make up part of the DSC confinement barrier. Failure of the confinement barrier is considered in the accident analysis discussed in Section 8.2. Verification of the vent and purge housing seal integrity ensures that the HEPA filtered vent system is the only vent path for the DSC. The required action to reseat or replace the vent and purge housing seals within seven days of a failed leak test recognizes the low motive force available to transport radioactive material through the leaking vent and purge seals.

If the seals cannot pass the leak test after being reseated or replaced continued storage with increased radioactive contamination surveys and standard contamination control practices would be implemented.

8.1.4.1 Hydrogen Venting Analysis

Leakage of the vent port seals would not adversely affect the ability of the vent system to allow hydrogen to diffuse through the HEPA filters.

8.1.4.2 Confinement Analysis

Particulate radioactive material release through leaking double seals would be expected to be negligible without a significant motive force. The only motive forces for release through leaking double seals are diffusion, temperature gradients, and atmospheric pressure changes, all of which are quite small. For a release of radioactive material from within a DSC to occur, the radioactive material would have to be so fine that it can pass through a canister seal leak, become airborne and migrate to the DSC seal area, then pass through leaking double seals with a significant motive force to sustain it. Without HEPA filter blockage, most of any motive force would be dissipated through the HEPA filters rather than acting to pass radioactive material through the seals. Even if the double seals were completely missing, the gaps between the vent and purge filter housings and the DSC lid are so small that it would be difficult for particulate radioactive material to pass though without significant motive force. The worst case would be all the particulate radioactive material that could potentially be released from the DSC during normal operation is released unfiltered through the leaking double seals. If such a case is assumed, the release is estimated to be 0.11 Ci/y [8.45].

The worst case release rate from a single DSC due to leaking double seals (0.11 Ci/y of particulate radioactivity) would result in a Total Effective Dose Equivalent (TEDE) rate at the INEEL site boundary of 1.7E-04 rem/y. The TEDE rate at the INTEC fence would be 1.3E-01 rem/y based on the ratio of the Table 7.6-1 TEDE values for 100 and 13,700 meter distances [8.45].

8.1.4.3 Continued Storage Analysis

Neither of the two intended functions, venting and confinement, of the DSC vent system will be compromised with leaking DSC vent or purge housing double seals. Leaking seals will not disrupt the diffusion path for hydrogen. It can be concluded from the calculations that any particulate radioactive material release through leaking double seals would be negligible without a significant motive force. The worst case would be if all the particulate radioactive material that could potentially be released from the DSC during normal operation were released unfiltered through the leaking double seals. Such a release would be estimated to be only 0.11 Ci/y. The resulting dose rate at the INEEL site boundary would be 1.7E-04 rem/y; well below the 100 mrem/y limit in 10 CFR 20.1301. The resulting dose rate at the INTEC fence would be 1.3E-01 rem/y; well below the 500 mrem/y limit in 10 CFR 20.1502.

8.35 "ICPP Interim Storage System (ISS) Lightning Risk Assessment," INEL Engineering Design File 0566 dated Sept. 4, 1996

8.36 "Flammability Characteristics of Combustible Gases and Vapors" Zabetakis, M.J., Bureau of Mines Bulletin 627, United States Department of the Interior, 1965.

8.37 "TMI-2 Canister Stress Analysis," Babcock and Wilcox Company, Document No. 33-1153704

8.38 "ISFSI Fire Exposure Analysis", VECTRA File No. NUH004.0422.

8.39 American Institute of Steel Construction (AISC), Allowable Stress Design, 9th Edition..

8.40 Fisher, R.V., Heiken, G., and Hulen, J.B. (1997) Volcanoes, Crucibles of Change;Princeton University Press, Princeton, N.J., p. 137-146.

8.41 Barberi, F., Carapezza, M.L., Valenza, M., and Villari, L. (1993) The control of lava flow during the 1991-1992 eruption of Mt. Etna; Journal of Volcanology and Geothermal Research, v.56, p.1-34.

8.42 McPhee, J. (1991) The Control of Nature; Noonday Press, New York, chapter 2, Cooling the Lava.

8.43 N.B. Zolders, "Thermal Properties of Concrete Under Sustained elevated Temperatures," ACI Publication, Paper SP25-1, American Concrete Institute, Detroit, MI, 1970.

8.44 ASHRAE Handbook, 1981 Fundamentals, Fourth Printing, American Society of Heating, Refrigerating, and Air-Conditioning Engineering, Inc., 1983.

Add new Reference 8.45 -attached

New reference to be added at the end of Section 8.5:

8.45 Hall, G. G., "Radiological Evaluation of TMI-2 ISFSI Technical Specification 3.1.1", Engineering Design File No. 4728, Revision 1, November 2004.

Attachment 6

Technical Specification Bases B 3.1.1
Leak Testing DSC Vent Housing Seals

Included in this attachment:

1. The markup of Technical Specification Bases B 3.1.1, Leak Testing DSC Vent Housing Seals, which indicates the locations of the modifications supporting the Technical Specification changes.

2. The proposed clean copy of Technical Specification Bases B 3.1.1.

B 3.1.1 Leak Testing DSC Vent Housing Seals (continued)

LCO	Verifying vent housing seal integrity ensures the only vent path for the DSC is through the HEPA filters.
APPLICABILITY	DSC vent housing seal integrity is verified after the DSC is loaded into its HSM and periodically during STORAGE OPERATIONS to confirm that the DSC confinement barrier has not been compromised during shipment to the ISFSI or during the extended storage period.
ACTIONS	Replace with Actions A.1, A.2.1, A.2.2, B.1, B.2, C.1, and C.2 ~~A.1~~ ~~After the DSC has been shipped and loaded into the ISFSI, the seals can be repaired or replaced in the ISFSI. The COMPLETION TIME specified for STORAGE OPERATIONS permits reasonable time to reseat or replace and to recognize the low motive force available to transport radioactive materials through the leaking vent seal.~~ ~~A.2~~ ~~The replaced or reseated seal must be leak checked to meet the LCO for continued STORAGE OPERATIONS.~~ ~~A.3~~ ~~If the replaced or reseated seal cannot meet the LCO, the DSC shall be transported to TAN or other appropriate facility for corrective actions.~~
SURVEILLANCE REQUIREMENTS	SR 3.1.1.1 The method for performing the leak check of the DSC vent housing seals conforms with ANSI N14.5. The leak check for metallic seals is performed after the DSC is loaded into the ISFSI. During prolonged storage at the ISFSI, the leak check for metallic seals is repeated every five years which provides a frequency comparable to similar uses of mechanical sealing systems. Insert new SR 3.1.1.2 for elastomeric seals.
REFERENCES	2. ~~1.~~ SAR Section 8.2.7, DSC Leakage. Insert new References 1 and 3.

Revision No. —
~~3/16/99~~

B 3.1 DSC INTEGRITY

B 3.1.1 Leak Testing DSC Vent Housing Seals

BASES

BACKGROUND

The radioactive material which the TMI-2 ISFSI confines is TMI-2 core debris and the associated contaminated materials. During fuel loading operations, the transportation cask is uprighted, the DSC is installed into the cask, the previously dewatered/dried TMI-2 CANISTERs are placed into the DSC, the DSC top cover plate is installed, the DSC is welded closed, the DSC vent ~~housing is~~ housings are installed, (one at the DSC Purge Port and one at the DSC Vent Port) and the cask lid is bolted.

The DSC has a series of barriers to ensure the confinement of radioactive materials. The DSC is vented to reduce the accumulation of gases generated due to radiolysis. The DSC cavity gases will vent through the HEPA filters into the HSM cavity which in turn is vented through holes provided in the rear access door.

APPLICABLE SAFETY ANALYSIS

The confinement of radioactivity during the storage of spent fuel in a DSC is ensured by the use of multiple confinement barriers. The fuel pellet matrix and fuel cladding were severely damaged during the TMI-2 reactor accident and, therefore, no reliance for confinement of radioactivity is placed on the fuel pellet matrix or the fuel cladding. The TMI-2 CANISTERs provide the first barrier for confinement of radioactive materials. The TMI-2 CANISTERs have two small penetrations which are left open during storage but which do not provide direct paths for fuel debris and do not compromise the canister confinement function. Once inside the sealed DSC, the TMI-2 CANISTERs are confined by the DSC shell and by multiple barriers at the top of the DSC. The DSC confinement boundary includes the DSC shell, the vent system HEPA grade filters, the top shield plug and its weld, the top cover plate and its weld, and the inner bottom cover plate and weld. The failure and degradation of confinement barriers is considered in the ~~accident analysis~~ analyses of accidents and off-normal events.

(continued)

Revision No. ____
~~3/16/99~~

B 3.1 DSC INTEGRITY

B 3.1.1 Leak Testing DSC Vent Housing Seals

BASES

BACKGROUND	The radioactive material which the TMI-2 ISFSI confines is TMI-2 core debris and the associated contaminated materials. During fuel loading operations, the transportation cask is uprighted, the DSC is installed into the cask, the previously dewatered/dried TMI-2 CANISTERs are placed into the DSC, the DSC top cover plate is installed, the DSC is welded closed, the DSC vent housings are installed (one at the DSC Vent Port and one at the DSC Purge Port), and the cask lid is bolted. The DSC has a series of barriers to ensure the confinement of radioactive materials. The DSC is vented to reduce the accumulation of gases generated due to radiolysis. The DSC cavity gases will vent through the HEPA filters into the HSM cavity which in turn is vented through holes provided in the rear access door.
APPLICABLE SAFETY ANALYSIS	The confinement of radioactive material during the storage of spent fuel in a DSC is ensured by the use of multiple confinement barriers. The fuel pellet matrix and fuel cladding were severely damaged during the TMI-2 reactor accident and, therefore, no reliance for confinement of radioactivity is placed on the fuel pellet matrix or the fuel cladding. The TMI-2 CANISTERs provide the first barrier for confinement of radioactive materials. The TMI-2 CANISTERs have two small penetrations which are left open during storage but which do not provide direct paths for fuel debris and do not compromise the canister confinement function. Once inside the sealed DSC, the TMI-2 CANISTERs are confined by the DSC shell and by multiple barriers at the top of the DSC. The DSC confinement boundary includes the DSC shell, the vent system HEPA grade filters, the top shield plug and its weld, the top cover plate and its weld, and the inner bottom cover plate and weld. The failure and degradation of confinement barriers is considered in the analyses of accidents and off-normal events.

(continued)

B 3.1.1 Leak Testing DSC Vent Housing Seals (continued)

LCO	Verifying vent housing seal integrity ensures the only vent path for the DSC is through the HEPA filters.
APPLICABILITY	DSC vent housing seal integrity is verified after the DSC is loaded into its HSM and periodically during STORAGE OPERATIONS to confirm that the DSC confinement barrier has not been compromised during shipment to the ISFSI or during the extended storage period.
ACTIONS	<u>A.1</u> The initial concern upon discovery of degraded seals is the increased potential for radioactive contamination near the DSC vent housing. A survey for radioactive contamination of the accessible areas of the junction at the DSC vent housing and the DSC cover plate addresses the immediate concern. <u>A.2.1</u> After the DSC has been shipped and loaded into the ISFSI, the seals can be repaired or replaced in the ISFSI. The COMPLETION TIME specified for STORAGE OPERATIONS permits reasonable time to reseat or replace the leaking vent seal and recognizes the low motive force available to transport radioactive materials through the leaking vent seal. <u>A.2.2</u> The replaced or reseated seal must be leak checked to meet the LCO for continued STORAGE OPERATIONS. <u>B.1</u> If the seal cannot be repaired or replaced and tested to satisfy the LCO, then the survey for radioactive contamination needs to be repeated during STORAGE OPERATIONS until the LCO is restored. <u>B.2</u> If the seal cannot be repaired or replaced and tested to satisfy the LCO, then concerns related to the adequacy of the seal design and maintenance must be addressed in a written report. This written report is expected to address the characterization and extent of condition, cause or engineering analysis, and corrective actions. The note that LCO 3.0.2 does not apply indicates that, upon entry into Condition B, the report to NRC is required even if the condition is exited before the 90 day completion time of this ACTION.

(continued)

B 3.1.1 Leak Testing DSC Vent Housing Seals (continued)

ACTIONS (continued)	<u>C.1</u> If the metallic seals are replaced with elastomeric seals and the LCO is restored within 7 days, then the reporting requirement of B2 would not be invoked. In this case, action C.1 ensures that NRC is kept informed of the replacement of the original seal design and the commitment of required action C.2 and surveillance SR 3.1.1.2. Condition C can exist even with the LCO met. <u>C.2</u> Elastomeric seals conforming to the design requirements in the SAR may be used in place of the metallic seals. In such a case, the elastomeric seals are not considered to have the same design life as metallic seals. The design life of the elastomeric seals specified for service at the DSC vent housings is expected to exceed 15 years. Therefore, a replacement interval not to exceed 5 years is considered conservative. Condition C can exist even with the LCO met.
SURVEILLANCE REQUIREMENTS	SR 3.1.1.1 The method for performing the leak check of the DSC vent housing seals conforms with ANSI N14.5. The leak check for metallic seals is performed after the DSC is loaded into the ISFSI. During prolonged storage at the ISFSI, the leak check for metallic seals is repeated every five years which provides a frequency comparable to similar uses of similar mechanical sealing systems. SR 3.1.1.2 The method for performing the leak check of the DSC vent housing seals conforms with ANSI N14.5. The leak check for elastomeric seals is performed after any metallic seal is replaced with an elastomeric seal as required by ACTION A.2.2. During prolonged storage at the ISFSI, the leak check for elastomeric seals is repeated every year to reflect the assumed reduced design life of elastomeric seals compared to metallic seals.
REFERENCES	1. SAR Section 8.1.4, Storage with Leakage of Vent or Purge Port Seals. 2. SAR Section 8.2.7, DSC Leakage. 3. SAR Section 4.3.1, Ventilation and Offgas Requirements.

Attachment 7

Engineering Design File 5003
TMI-2 ISFSI Alternate DSC Seal Evaluation

Title: TMI-2 ISFSI Alternate DSC Seal Evaluation **Revision:** 1
Author: Rick A. Gavalya **Date:** 10/14/2004

EDF No.: 5003 EDF Rev. No.: ~~0~~ 1 JLS 10-18-04 Project File No.: NA

1. Title: TMI-2 ISFSI Alternate DSC Seal Evaluation

2. Index Codes: 200
Building/Type CPP-1774 SSC ID DSC-SYS-1774 Site Area INTEC

3. NPH Performance Category: ______ or ☒ N/A

4. EDF Safety Category: ______ or X N/A SCC Safety Category: Safety Class or ☐ N/A

5. Summary:

The Three Mile Island - 2 Dry Shielded Canisters (DSCs) are equipped with a Purge Port Filter Assembly and a Vent Port Filter Assembly. An assembly consists of a carbon steel filter housing with threaded openings to receive purge or vent filters. Two grooves are machined into each filter housing to accept metal "c-seals" fabricated by EG&G Pressure Science. The filter housings bolt to a carbon steel canister with the metal c-seals forming a seal with the corresponding flat surface of the canister. The inner c-seal is the primary containment to prevent radioactive material from escaping the canister. The outer c-seal serves as a backup to the inner seal. The seals are leak tested every five years.

Metal c-seals are very sensitive to minor imperfections that may be on the sealing surfaces of the DSCs or filter housings. Such imperfections can occur from handling operations or surface oxidation of the carbon steel surface. Because of the anticipated difficulty to replace and reseat metal c-seals, a search was conducted to find a replacement seal that is less sensitive to minor sealing surface imperfections.

Elastomeric o-rings made of Ethylene Polymer Diene Monomer (EPDM) were investigated as a replacement for metal c-seals that fail the five-year leak tests. To verify their performance, two different sets of EPDM o-rings were installed and leak tested in the Purge Port filter housing of the overpack for a Dry Shielded Canister located at the Independent Spent Fuel Storage Installation (ISFSI). Both sets of o-rings passed the leak tests with leak rates that were well below the maximum acceptable leak rate of 1×10^{-2} standard cubic centimeters of air/second (std-cc/sec). The first set of o-rings leaked at 3.215×10^{-4} std-cc/sec while the second set leaked at 5.531×10^{-4} std-cc/sec.

It is recommended that EPDM o-rings be used to replace existing metal c-seals that fail to meet the leak test acceptance criteria. As proven during the leak testing, o-rings will form an adequate seal on a surface that has been corroded. Standard EPDM o-rings that fit the Purge Port filter housing are readily available from a large number of suppliers. However, EPDM o-rings for the Vent Port filter housing will have to be custom fabricated. Lead times of four to six weeks for custom o-rings were typically cited by vendors.

6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

	R/A	Typed Name/Organization	Signature	Date
Performer/ Author	N/A	Rick A. Gavalya/4634	Rick A. Gavalya	10.18.04
Technical Checker	R	Jim Deatherage/3A7H	J W Deatherage	10/14/04
Project Engineer	R	David Moser/3A7H	David Moser	10/18/04
Requestor	Ac	Jim Stalnaker/3A7H	[signature]	10/18/04
Approver	A	Stuart Jensen/3A7H	SR Jensen	10/18/04
Doc. Control		R. Aeschbacher/3A7L	Robin Aeschbacher	11/4/04

7. Distribution:
(Name and Mail Stop)

8. Does document contain sensitive unclassified information? ☐ Yes X No
If Yes, what category:

Title: TMI-2 ISFSI Alternate DSC Seal Evaluation
Author: Rick A. Gavalya

Revision: 1
Date: 10/14/2004

EDF No.: 5003 EDF Rev. No.: ~~0~~ 1 SLS 10-18-04 Project File No.: NA

1.	Title: TMI-2 ISFSI Alternate DSC Seal Evaluation
2.	Index Codes: 200 Building/Type CPP-1774 SSC ID DSC-SYS-1774 Site Area INTEC
9.	Can document be externally distributed? ☐ Yes X No
10.	Uniform File Code: 0250 Disposition Authority: ENV1-b-4-a Record Retention Period: Cut off when superceded, obsolete, or cancelled. Destroy 75 years after cutoff.
11.	For QA Records Classification Only: ☐ Lifetime ☐ Nonpermanent X Permanent Item and activity to which the QA Record apply: The QA record applies to the ISFSI while spent nuclear fuel is present.
12.	NRC related? ☒ Yes ☐ No
13.	Registered Professional Engineer's Stamp (if required) NA

Table of Contents

Purpose

The purpose of this EDF is to document the process for recommending an alternative seal to replace any of the Vent Port and/or Purge Port filter housing metal "c-seals" on Three Mile Island – 2 (TMI-2) Dry Shielded Canisters (DSCs) that fail future leak tests. Metal c-seals are very sensitive to minor imperfections that may be on the sealing surfaces of the DSCs or filter housings. Such imperfections can occur from handling operations or surface oxidation of the carbon steel surface. Because of the anticipated difficulty to replace and reseat metal c-seals, a search was conducted to find a replacement seal that is less sensitive to minor sealing surface imperfections. If the seals fail the leak test, the problem must be corrected. There are 29 canisters that have been in storage for three to five years at INTEC. The seals will be tested every five years.

Scope

The work scope includes researching alternative elastomeric materials that could be used for replacement seals and performing a search for readily available "off-the-shelf" seals that will fit in the filter housings; testing the selected alternative seals; providing a brief summary of the test results; and predicting a minimum service life for the alternative seals.

Conclusions

Elastomeric o-rings made of Ethylene Polymer Diene Monomer (EPDM) were selected to replace metal c-seals that fail the five-year leak tests. To verify the selection, two different sets of EPDM o-rings were installed and leak tested in the Purge Port filter housing [ref 1] of the overpack for a DSC located at the Independent Spent Fuel Storage Installation (ISFSI). Both sets of o-rings passed the leak tests with leak rates that were well below the maximum acceptable leak rate of 1×10^{-2} std-cc/sec. The first set of o-rings leaked at 3.215×10^{-4} std-cc/sec while the second set leaked at 5.531×10^{-4} std-cc/sec.

Once installed, the o-rings will remain in a static condition with little exposure to air and radiation, and will not be subjected to sunlight. Because of the low decay heat, temperature effects to the o-rings are not expected to be extreme. These factors will contribute to a long service life of the o-rings. The o-rings are expected to continue providing an effective seal for at least five years. A Parker O-Ring representative stated that there have been instances where o-rings have lasted at least 20 years under static conditions [ref 2]. When informed of the intended o-ring usage, the representative indicated there was a strong possibility the elastomeric o-rings would last for at least 15 – 20 years.

EPDM o-rings will meet all requirements listed in the "Acceptance Criteria" section of this EDF. Leak rate testing demonstrated that the o-rings will form an effective seal with an irregular surface. The temperature range of EPDM o-rings varies from -60° F to +250° F and will easily withstand a pressure differential of 30 psig. The service life of the o-rings is expected to be at least five years.

Recommendations

It is recommended that existing metal c-seals that fail to meet the leak test acceptance criteria be replaced with EPDM o-rings. As demonstrated during the leak testing, o-rings will form an adequate seal on a surface that has been corroded. When installing the o-rings, non-silicone vacuum grease should be used to help retain the o-rings in the grooves. The non-silicone vacuum grease will accommodate hydrogen sampling with an iTX analyzer, which is sensitive to silicone vapors.

Standard EPDM o-rings that fit the Purge Port filter housing are readily available from a large number of suppliers. However, EPDM o-rings for the Vent Port filter housing must be custom ordered. Lead times of four to six weeks for custom o-rings were typically cited by vendors. One supplier quoted a price of approximately $900 for 30 identical o-rings. Most of the cost is due to custom fabricating a mold since the o-rings are non-standard sizes.

If the filter housings are removed to replace the metal c-seals, the DSC sealing surfaces should be cleaned to remove superficial rust and previously applied vacuum grease. After the sealing surfaces have been cleaned, the surfaces should be coated with a material that inhibits future corrosion. Superficial rust and previously applied vacuum grease should also be removed from the filter housings and the surfaces coated to inhibit future corrosion. The EPDM material should be researched to verify that the o-rings will not be chemically affected or harmed by the coating.

The filter housings with metal c-seals have bolts that are torqued to 82 ± 5 ft-lbs when attaching the housing to the canister [ref 1, 3]. The bolts should also be torqued to the same value when o-rings are installed in order to meet seismic and accident requirements.

Structure, System, or Component (SSC) Description

The TMI-2 DSCs are equipped with a Purge Port Filter Assembly and a Vent Port Filter Assembly [ref 1, 3]. An assembly consists of a carbon steel filter housing with threaded openings to accept purge or vent filters. Two grooves have been machined into each filter housing that accept a metal "c-seal" [item 10, refs 1, 3] fabricated by EG&G Pressure Science. The filter housings bolt to a carbon steel canister with the metal c-seals forming a seal with the corresponding flat surface of the canister. The inner c-seal is the primary containment to prevent radioactive material from escaping the canister. The outer c-seal serves as a backup to the inner seal.

The two grooves are interconnected by four channels located 90° apart. The purpose of the connecting channels is to provide an evacuation path so that a uniform vacuum can be applied between the inner and outer seals during leak testing. A hole that is 0.13" in diameter runs between the outside of the flange to one of the connecting grooves. A 1/8" NPT fitting is threaded into the hole on the outside of the flange.

A vacuum line is attached to the 1/8" fitting and the air between the two seals is evacuated. When the proper vacuum between the seals has been achieved, the valve to the vacuum pump is closed off and a pressure gauge monitored to observe the rate at which the vacuum decays. If the leak rate is acceptable, further action is not required. If the leak rate is unacceptable, the leak must be fixed within seven days to comply with Technical Safety Requirement 8.4 (TSR-8.4) [ref 4]. The acceptable leak rate listed in TSR 8.4 is $\leq 1 \times 10^{-2}$ std-cc/sec at approximately one atmosphere differential.

When the filter housings were initially assembled with the metal c-seals, the seals sometimes failed when leak tests were performed. The filter housings had to be removed and vacuum grease applied to the seals in order to pass the leak test. Sealing surfaces were in the best condition during initial installation of the seals. Over time, the sealing surfaces have possibly degraded due to corrosion of the carbon steel. If there is a failure that can be attributed to corrosion, it will be difficult to restore the sealing surfaces to the finish required for a metal seal (32 rms). One solution would be to replace a failed metal seal with an alternative seal that will conform to a more irregular surface than a metal seal.

Below is a 3-D model of the flange of the Purge Port Filter Assembly that shows the sealing grooves, connecting channels, and evacuation path. The 1/8" fitting is not shown in these views.

Title: TMI-2 ISFSI Alternate DSC Seal Evaluation **Revision:** 1
Author: Rick A. Gavalya **Date:** 10/14/2004

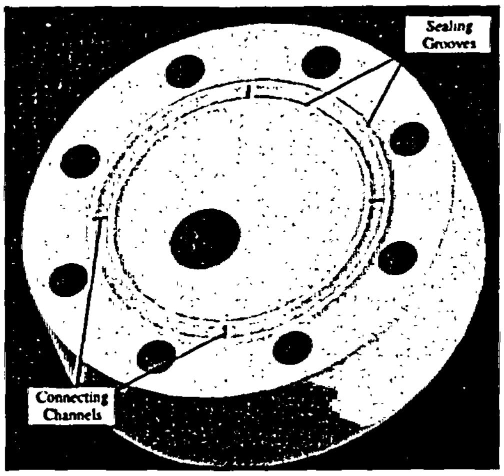

Fig. 1. Purge Port Flange.

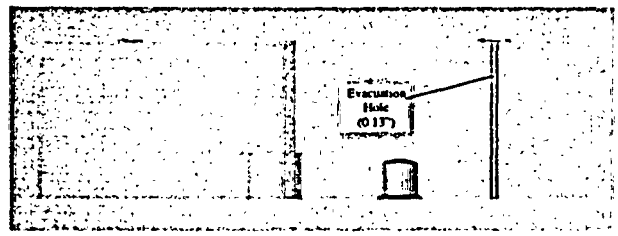

Fig. 2. Purge Port Flange Cross Section.

Safety Category

The TMI-2 Dry Shielded Canister and its components are designated as "Safety Class".

Materials

Since the o-rings will be exposed to low radiation fields (estimated maximum of 100 milliRem/hour based on actual field measurements), it is anticipated that radiation effects will not play a major role in degrading the o-ring material. According to the "Parker O-Ring Handbook" [ref 5], elastomers showed little sign of compression set if the cumulative dose is less than 1×10^6 Rads. Assuming that one Rad is equivalent to one Rem, the estimated daily dose at 100 milliRem/hour will be 2.4 Rad. It would take approximately 1,140 years to acquire a cumulative dose of 1×10^6 Rads. Therefore, selection of material based on radiation resistance is a minor consideration. Other conditions such as temperature fluctuations, exposure to air and light, pressure effects, mechanical usage, and chemical compatibility were also considered when selecting an o-ring material.

Although radiation effects will be negligible, Ethylene Propylene Diene Monomer (EPDM) was chosen as the o-ring material since it is the preferred choice in radiation environments. The working temperature range of EPDM is -60° F to + 250° F. EPDM also features excellent resistance to aging by air, ozone, and sunlight.

<u>Hardness/Durometer</u>

Durometer is a measurement of the hardness of an elastomeric compound. The numerical ratings for hardness range from 40 (softest) to 95 (hardest) with 70 established as the base hardness typically used in industry. When suppliers were contacted to check on availability of o-rings, o-rings with a hardness of 70 were readily available whereas o-rings with a hardness <70 would have to be custom made and take four to six weeks to receive after placing the order. An advantage of using softer o-rings (40 to 50 durometer) is that they would be more likely to conform to irregularities caused by corrosion or mechanical surface damage and form a tighter seal. EPDM o-rings with a hardness of 70 were ordered since they were readily available. If necessary, EPDM o-rings with softer material may be ordered at a future date.

Inputs

The "Seal Design Guide" published by Apple Rubber Products, Inc. [ref 6] and "Parker O-Ring Handbook" [ref 5] published by Parker Hannifin Corporation were used to obtain general information regarding o-ring materials, properties, sizes, and gland designs. More specific information was obtained through telephone conversations and emails.

Acceptance Criteria

As stated in FCF-7371, requirements for an alternative seal are listed below.

1. The alternative seal leak rate shall be less than 1×10^{-2} std cc/sec (of air).
2. The thermal range of operation for the alternative seal shall be -40 to +200° F.
3. The alternative seal shall be able to seal at a pressure differential of 30 psi.
4. The alternative seal shall have a minimum service life of five years.
5. The alternative seal shall be able to withstand a radiation field of 100 millirem/hour (gamma and neutron) during the service life of the seal.
6. The alternative seal shall accommodate the existing configuration assuming the 32 rms finish has undergone oxidation.

Checking Method

This EDF was checked through a detailed document review. The alternative seals were leak tested to verify their performance. Testing details are discussed in the "Analysis" section.

Analysis

Ideally, the replacement seals will be constructed of material that conforms to slight irregularities in surface conditions, will be resistant to radiation effects, and are pre-manufactured in sizes that are commercially available as "off-the-shelf" purchases.

Elastomeric o-rings were selected as the first choice to replace the metal c-seals. Elastomeric o-rings will conform to irregular surfaces more readily than their metal counterparts. Other elastomeric cross-sections such as rectangular, square, or hemispherical are also possible solutions. However, these cross-sections are not available in the necessary sizes and would have to be specially ordered and fabricated whereas o-rings that fit the Purge Port filter housing are standard stocked items.

O-rings have been used extensively in industry for both static and dynamic applications. O-rings are readily available in a variety of materials and sizes from a large number of suppliers. Material properties such as chemical compatibility, radiation resistance, and temperature operating ranges are well known.

<u>Service Life</u>

Application engineers from Apple Rubber Products Inc. and Parker O-Rings were contacted to discuss the expected service life of the o-rings in the proposed application. Neither engineer would provide an estimated service life since many factors influence the aging and degradation process. However, Dan Ewing, another Parker O-Ring representative, said that there have been instances where o-rings have lasted at least 20 years under static conditions. When informed of the intended o-ring usage, Dan said there was a strong possibility the elastomeric o-rings would last for at least 15 to 20 years. Failure will eventually result due to "compression set". Refer to Appendix C for a summary of the telephone conversation.

A performance evaluation of EPDM o-ring seals authored by T. Eric Skidmore of Savannah River Technologies [ref 7] was reviewed to determine if their conclusions and/or seal life predictions would be relevant to our application [Appendix D]. In most instances, further testing of the o-rings under the expected service conditions was suggested to determine the expected seal design life. In one scenario, the seal life was predicted to be two to four years if subjected to a constant temperature of 239° F. High temperatures contribute more to the aging process than cold temperatures since higher temperatures degrade o-ring materials physically and/or chemically. In the DSCs, service temperatures will be much less than the 239° F used to predict the seal life for o-rings used at Savannah River and the o-rings used in the DSCs would be expected to last much longer than two to four years.

Although information is not available regarding o-ring service life, information on the recommended shelf life of EPDM o-rings is readily available. The Parker O-Ring Handbook was initially reviewed to determine the shelf life of o-rings. The handbook refers to ARP 5316 [ref 8], which is the Aerospace Recommended Practice for the shelf life of aerospace elastomeric seals. Although ARP 5316 is not available through the INEEL Technical Library, a search on the web yielded many websites that quoted ARP 5316. The ARP 5316 recommended shelf life for EPDM elastomers is "Unlimited". In contrast, materials such as Nitrile (also know as Buna-N) and Polyacrylate have a recommended shelf life of 15 years. Below is a table showing the ARP 5316 recommended shelf lives of elastomers.

Elastomer Family	ASTM Abbreviation	ARP 5316 Recommended Shelf Life
Aflas®		Unlimited
Butyl Rubber, Isobutylene Isoprene	IIR	Unlimited
Chloroprene (Neoprene®)	CR	15 Years
Epichlorohydrin (Hydrin®)	ECO	NA
Ethylene Acrylic (Vamac®)	AEM	15 Years
Ethylene Propylene, EPDM or EP	EP	Unlimited
Fluorocarbon (Viton®)	FKM	Unlimited
Fluorosilicone	FVMQ	Unlimited
Hydrogenated Nitrile (HNBR or HSN)	HNBR	15 Years
Nitrile (Buna-N or NBR)	NBR	15 Years
Polyacrylate	ACM	15 Years
Polyurethane (Polyester or Polyether)	AU / EU	5 Years
Silicone	VMQ	Unlimited
Styrene Butadiene (Buna-S)	SBR	15 Years

Fig. 3. Recommended Shelf Lives of Elastomers per ARP 5316 [ref 8].

Although the installed o-rings will not be in normal storage conditions (such as a warehouse maintained within a narrow temperature range), there are many factors that will contribute to a long service life of the o-rings that are recommended to replace the existing metal c-seals in the TMI-2 Dry Shielded Canisters. Favorable factors include:

1. Static application – Once in place, the o-rings will not be subjected to dynamic movements that wear and degrade the seal over time.
2. Little exposure to air – The 0.103-inch diameter cross section o-rings will occupy all of the space in the grooves, leaving very little surface area of the seal exposed to air.

3. No exposure to sunlight – Once sealed up, the o-rings will not be subjected to sunlight
4. Low radiation – Deterioration due to radiation should be negligible since the fields are very low (estimated 100 milliRem/hour maximum).
5. No pressure differential – Since the DSC is vented, the pressure will be equal on both sides of the seals and the seal will not be moved inward or outward due to pressure fluctuations. The only time that a pressure differential exists is during leak testing.

In summary, design lives for o-rings are difficult to predict since many factors contribute to the aging and degradation process. However, the case can be argued that once the o-rings are installed, the o-rings will be in a "stored" condition since they will not be subjected to dynamic movements. In addition, the o-rings will experience little or no exposure to air, sunlight, radiation, or pressure differentials. Although their service life may not be "Unlimited", their service life should be at least five years, and could be reasonably expected to last 15 to 20 years or more.

Elastomeric o-rings substituted for metal seals should be leak-tested every five years, along with the remaining metal c-seals, to verify their performance.

Sizing

The groove cross sections in the Vent Port filter housing and the Purge Port filter housing are all identical, 0.074 inch deep by 0.113 inch wide [ref 1, 3]. The inside diameters of the inner and outer grooves in the Purge Port filter housing are 6.760 and 7.800 inches respectively. The inside diameters of the inner and outer grooves in the Vent Port filter housing are 10.850 and 12.450 inches respectively. Therefore, four o-rings with the same cross-section but differing inside diameters will be required.

A "Seal Design Guide" [ref 6] published by Apple Rubber Products Inc., was reviewed to determine if standard o-ring sizes could be used in this application. Also reviewed in this reference were the parameters for designing a groove (or gland) that will accommodate standard o-rings.

Based on this information, the existing 0.074 inch deep groove would require a standard o-ring with a 0.103 inch cross-section diameter. However, the recommended groove width for a 0.103 inch o-ring is 0.146 inch, smaller than the existing groove width of 0.113 inch. The o-ring will fit in the groove but when compressed should almost fill the groove. The cross-sectional area of a 0.103" o-ring is 8.33×10^{-3} in^2 whereas the cross sectional groove area is 8.32×10^{-3} in^2. The difference in cross sectional area is less than 1/10 of 1% and o-ring material compression will compensate for the lesser cross sectional area of the groove.

A representative from Apple Rubber Products was contacted for a recommendation. Romel Ner, an applications engineer, was presented with the above dimensional information and replied via email that the existing groove would require an o-ring that is 0.090 inch in cross-sectional diameter. However, the 0.090 inch o-rings would have to be specifically fabricated since they are not a standard o-ring size.

There are standard 0.103 inch o-rings with inside diameters that will fit inside the two Purge Port grooves. Standard 0.103 inch o-rings are not available for the larger Vent Port grooves. If the standard 0.103 inch o-rings prove to be acceptable for the Purge Port filter housing, a special order will have to be placed to fabricate o-rings for the Vent Port filter housing. Lead times of four to six weeks for custom o-rings were typically cited by vendors. Refer to Appendix B for O-ring quotes.

Mr. Ner recommended that we field test the 0.103 inch o-rings in the Purge Port to determine if this cross-sectional size would be suitable. Samples were sent of 0.103 inch o-rings that had inside diameters of 6.487 inch and 7.487 inch. Although it appears that the inside diameters may be too small, an o-ring stretch of 1 to 5 % is recommended by manufacturers with a 2 % stretch considered ideal. The 6.487 inch and 7.487 inch inside diameter o-rings will stretch approximately 4.2 % when placed inside the grooves, which is within the acceptable stretch range. Refer to Appendix B for emails from Romel Ner, the Apple Rubber Products application engineer.

Below is a table fragment showing standard o-ring dimensions that are close to the groove inside diameters. The AS 568B dash numbers for the two sample o-ring sizes are -165 and -169.

Standard AS 568B Size O-Rings

AS 568B NO.	NOMINAL REFERENCE			ACTUAL DIMENSIONS	
	I.D.	O.D.	Width	I.D. Tol.	W. Tol.
-164	6 1/4	6 7/16	3/32	6.237 ±.040	.103 ±.003
-165	6 1/2	6 11/16	3/32	6.487 ±.040	.103 ±.003
-166	6 3/4	6 15/16	3/32	6.737 ±.040	.103 ±.003
-167	7	7 3/16	3/32	6.987 ±.040	.103 ±.003
-168	7 1/4	7 7/16	3/32	7.237 ±.045	.103 ±.003
-169	7 1/2	7 11/16	3/32	7.487 ±.045	.103 ±.003
-170	7 3/4	7 15/16	3/32	7.737 ±.045	.103 ±.003
-171	8	8 3/16	3/32	7.987 ±.045	.103 ±.003

Fig. 4. Fragment of Standard AS 568B O-Ring Chart. [ref 6]

<u>Test Fitting of O-Rings</u>

Jim Stalnaker, Dave Moser, and Rick Gavalya fitted the two sample 0.103 inch o-rings in a dummy Purge Port filter housing located at the INTEC Warehouse (CPP-1606). It required two people to install the o-rings since the o-rings had a tendency to keep coming out of the grooves. One person had to hold part of the o-ring in the groove while the other person worked the rest of the o-ring into the remaining open groove. The o-ring installation was performed with the filter housing lying horizontal and the grooves in full view. During actual installation of the seals, the filter housing will be in the vertical position with somewhat limited visibility. Since it was difficult to place the o-rings under optimum conditions, it would be much more difficult to place the seals during the actual installation. It was concluded that o-rings with a larger inside diameter would be easier to install.

A picture of the housing with the -165 and -169 o-rings is shown below.

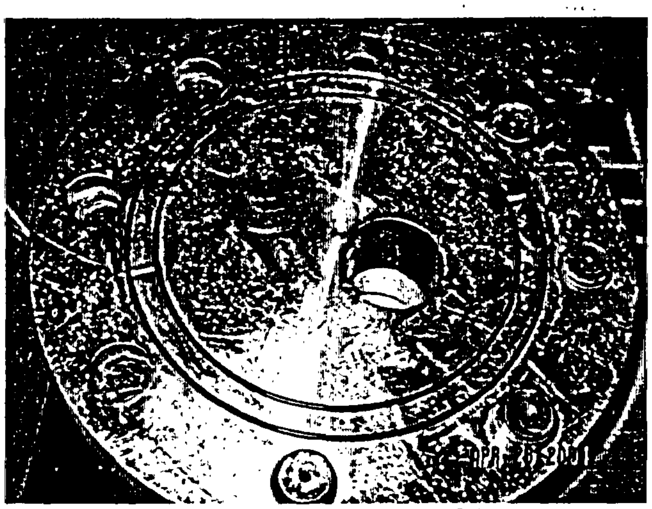

Fig. 5. Purge Port Housing With O-Rings.

The next larger size o-rings were ordered for the inner and outer grooves. The o-ring for the inner groove has an inner diameter of 6.737 inch (-166) while the o-ring for the outer groove has an inner diameter of 7.737 inch (-170). Jim Stalnaker, Rick Gardner, and Rick Gavalya fit these o-rings in the dummy Purge Port filter housing. These o-rings were much easier to install than the previous o-rings although if the o-rings were jarred or bumped, there was a chance that they could come out of the groove(s).

It was suggested that a small amount of non-silicone vacuum grease be applied to the o-rings to help retain the o-rings in the grooves. Non-silicone vacuum grease will accommodate hydrogen sampling with an iTX analyzer, which is sensitive to silicone vapors. The vacuum grease will also help form a better seal if the sealing surfaces are somewhat corroded or irregular.

O-Ring Leak Test

A work request was initiated to install and leak test the –166 and –170 o-rings, along with a set of metric o-rings similar in size to the standard o-rings, in the overpack for a DSC. The surfaces of the DSC were left "as-is" to determine if the o-rings would seal on a surface with some rusting, similar to what may occur on the actual DSCs. If the o-rings leaked at an unacceptable rate, the plans were to clean the surfaces and repeat the leak test. If the o-rings failed again, further evaluation would be required.

The -166 and -170 o-rings were inserted in the grooves of the Purge Port housing. An attempt was made to install the o-rings in the grooves without any vacuum grease but they would not stay in the grooves. When a small amount of vacuum grease was applied to the o-rings, the o-rings remained in the grooves. The housing was then slid into position and bolted to the overpack. The bolts were then torqued to 82 ± 5 ft-lbs.

Before bolting the housing to the overpack, the sealing surface of the overpack was wiped with a cloth to remove any loose debris that remained when the temporary cover was removed. The sealing surface was not scraped or sanded to remove material adhered to the metal.

A picture of the sealing surface is shown below. The grid-like appearance on the upper half was caused by mesh embedded in the fabric of the temporary cover.

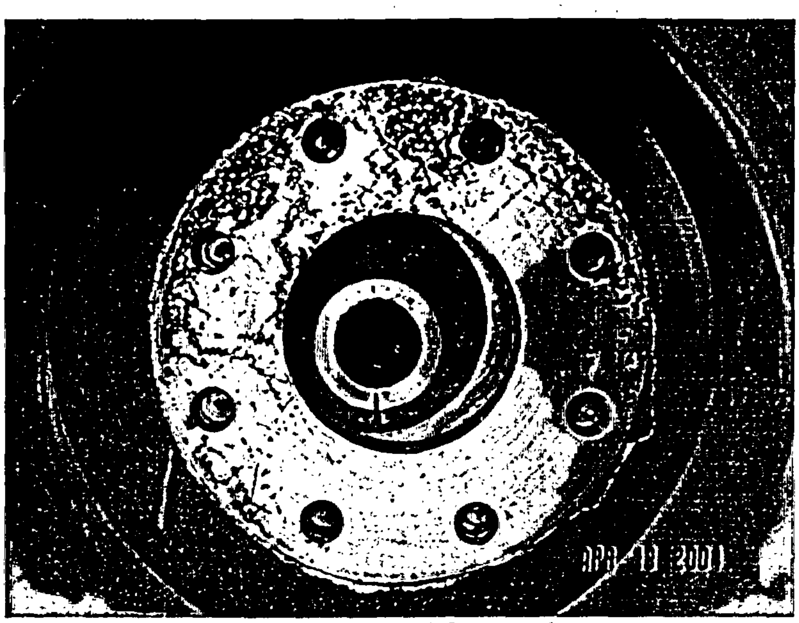

Fig. 6. Rusted Sealing Surface of Overpack.

Leak Test Results

The leak testing apparatus was set up and attached to the filter housing. Lisa Jorgensen and Ridley Justice, Quality Assurance Inspectors, performed the leak testing and setup. The Technical Procedure used for leak testing was TPR-6304, Rev. 2, "Small Volume Pressure Change Leak Test" [ref 9]. Appendix A in TPR-6304 specifically addresses leak testing of the Purge and Vent filter housings. Refer to TPR-6304 for testing details.

The maximum acceptable leakage rate, as specified in the acceptance criteria, was 1×10^{-2} std-cc/sec of air. The first leak test was performed for the –166 and –170 EPDM o-rings that were installed in the filter housing. The calculated leak rate of these o-rings was 3.215×10^{-4} std-cc/sec, well below the acceptable leak rate of 1×10^{-2} std-cc/sec.

The filter housing was unbolted and the –166 and –170 o-rings were removed. Small particles of rust and possibly material from the temporary cover were observed clinging to the o-rings when they were removed from the grooves. It is suspected that when the o-rings were compressed against the sealing surface, material was loosened that subsequently clung to the greased o-rings when the housing was removed.

The overpack sealing surface was wiped with a cloth to remove material loosened by the o-rings. Vacuum grease was applied to the metric o-rings, which were then installed in the housing grooves. The metric o-rings are also made of EPDM with a hardness of 70. The metric o-rings have a cross-section diameter of 2.5 millimeters (0.098 inches) and inside diameters of 170 mm (6.693 inches) and 195 mm (7.677 inches). These o-rings are slightly smaller in cross-section diameter than the o-rings used in the first leak test (0.098 inches vs. 0.103 inches). The inside diameters are also slightly smaller than the o-rings used in the first leak test (6.693 inches vs. 6.737 inches, 7.677 inches vs. 7.737 inches).

The filter housing was loosely bolted to the overpack, followed by tightening of the bolts to 82 ± 5 ft-lbs. The leak test apparatus was reattached to the filter housing and the metric o-rings leak tested. The calculated leak rate of the metric o-rings was 5.531×10^{-4} std-cc/sec, once again well below the acceptable leak rate of 1×10^{-2} std-cc/sec.

Based on the above leak rates, it is recommended that the standard sized o-rings with a 0.103 inch cross section diameter should be used to replace failed metal c-seals since the leak rate of the standard sized o-rings is less than the leak rate of the metric o-rings.

The leak rate documentation for the two sets of o-rings is in Appendix A.

References

1. INEEL Drawing # 513915, Rev 1, "DRY SHIELDED CANISTER PURGE PORT FILTER ASSEMBLY (DSC12T-004 THRU -029)".
2. Telephone Conversation between Rick Gavalya (BBWI) and Dan Ewing (Parker O-Ring Manager), June 15, 2004.
3. INEEL Drawing # 513916, Rev 1, "DRY SHIELDED CANISTER VENT PORT FILTER ASSEMBLY (DSC12T-004 THRU -029)".
4. TSR-8.4, Rev. 3, "Technical Specifications for the INEEL TMI-2 Independent Spent Fuel Storage Installation"
5. "Parker O-Ring Handbook", Parker Hannifin Corporation, 2003.
6. "Seal Design Guide", Apple Rubber Products, Inc., 2000

7. WSRC-TR-2003-00198, Performance Evaluation Of O-Ring Seals In The SAFKEG 3940A Package In KAMS(U), T. Eric Skidmore, May 2003.
8. SAE ARP-5316, Aerospace Recommended Practice: Storage of Aerospace Elastomeric Seals and Seal Assemblies Which Include an Elastomer Element Prior to Hardware Assembly.
9. TPR-6304, Rev. 2, "Small Volume Pressure Change Leak Test".

Appendix A – Test Results

414.A81
09/17/2003
Rev. 00

VACUUM RATE OF RISE LEAK TESTING EXAMINATION REPORT

Page 1 of 4

E-File Name: TMI6-8-04LT-1

Shaded Areas Essential Variable Data

Examination Date: 6-8-04 Project/W.O*: TPR 6304 Report No. *: -1

Inspection Instruction: TPR 6304

System: TMI HSM-15 Component: DSC Drawings*: n/a

Test Method		Test Equipment Gages: (P – Pressure; V – Vacuum; T – Temp)					
Procedure No. / Rev.	TPR-6304 / rev. 2	Type	Description	Range	Units	ID	Calib. Due
Procedure Appendix:	A	V	Readout gauge	1 mTorr	to 1500 Torr	717354	3-8-05
TEST SYSTEM CONTROLS	MANUAL ☒	V	Transducer	1-760	Torr	718259	3-8-05
	AUTO/SOFTWARE ☐	T	Thermometer	-210/1200	C	721720	12-10-04

Test Environmental and System Parameters			
Variable	Description/Data	Variable	Description/Data
Test Gas	AIR	Test Assembly Volume	77.4 cc
Ambient Temp =	30.0 °C	Reference Volume (V_{ref}) =	77.4 CC
Ambient Pressure =	630000.0 mTorr abs	Verify Test Volume (V_T) =	CC Calculated Below:
Test Pressure =	0.0 mTorr abs	cc x [(0.0 - 0.0) ÷ (-)]	
Holding Time =	60 Seconds	V_{ref} x [(P_x - P_{ref})] ÷ [(P_{ref} - P_{system})]	

Acceptance Criteria			
Acceptance Procedure No. / Rev.	Paragraph/Appendix	Maximum Single Leak Rate	Maximum Sum of Leak Rates
TPR-6304 / rev.2	2.15 & app. A	LR ≤ 1.0 X 10^{-2} cc/sec	Σ LR ≤ X 10 cc/sec

Test Results

Note 1: For T_x use Ambient Temperature °K and P_x use Ambient Pressure in milli Torr

√ N/A	Item Name	Origin / Terminus*		Time($I_{s\,\&\,e}$) HH:mm:ss	(S)	Temp. ($T_{1\,\&\,2}$)	Pressure ($P_{1\,\&\,2}$)	Leak Rate Calculation Note¹ $[V_T \cdot T_s/(SP_s)] \cdot [(P_2/T_2 - P_1/T_1)]$	$=L_R$ std-cc/sec
☒	Pretest Assembly Verification VT = Test Assy. Volume	Test Assy. Valve V-1	Start						
			End						
☐	Test of Item	Test Assy. Valve V-1	Start	14:30:00	60	299.00	32	(7.82 x 10-4)(156/301 - 32/299)	3.215 x 10-4
			End	14:31:00		301.00	156		
☒	Re-test of Item	Test Assy. Valve V-1	Start						
			End						

Results, Sketch of Set-up, Amplifying Data:

* See attached "Volume calculations for test apparatus" for Test Assembly Volume.

Cont'd:
Test Equipment - Stop watch 0-99 min. min, secs 715030 11-13-05

This DSC had EPDM 70 N-166 N-170 gaskets installed.

The test is acceptable.

Use additional sheets as needed.

Lisa Jorgensen/Ridley Justice	Lisa Jorgensen / R Justice	6-8-04
Examiner/NDE Title Print/Type	Examiner Signature	Date

*Data not required to be entered.

Title: TMI-2 ISFSI Alternate DSC Seal Evaluation **Revision:** 1
Author: Rick A. Gavalya **Date:** 10/14/2004

414.A81
09/17/2003
Rev. 00

VACUUM RATE OF RISE LEAK TESTING EXAMINATION REPORT

E-File Name: TMI6-8-04LT-2

Shaded Areas Essential Variable Data

Examination Date: 6-8-04 Project/W.O*: TPR 6304 Report No. *: -2

Inspection Instruction: TPR 6304

System: TMI HSM-15 Component: DSC Drawings*: n/a

Test Method		Test Equipment Gages: (P – Pressure; V – Vacuum; T – Temp)					
Procedure No. / Rev.	TPR-6304 / rev. 2	Type	Description	Range	Units	ID	Calib. Due
Procedure Appendix:	A	V	Readout gauge	1 mTorr	to 1500 Torr	717354	3-8-05
TEST SYSTEM CONTROLS	MANUAL ☒	V	Transducer	1-760	Torr	718259	3-8-05
	AUTO/SOFTWARE ☐	T	Thermometer	-210/1200	C	721720	12-10-04

Test Environmental and System Parameters			
Variable	Description/Data	Variable	Description/Data
Test Gas	AIR	Test Assembly Volume	77.4 cc
Ambient Temp =	30.0 °C	Reference Volume (V_{ref}) =	77.4 CC
Ambient Pressure =	630000.0 mTorr abs	Verify Test Volume (V_T) =	CC Calculated below:
Test Pressure =	0.0 mTorr abs	CC X [(-) ÷ (-)]	
Holding Time =	60 Seconds	V_{ref} x [(P_s - P_{ret}) ÷ (P_{ret} - P_{retmax})]	

Acceptance Criteria			
Acceptance Procedure No. / Rev.	Paragraph/Appendix	Maximum Single Leak Rate	Maximum Sum of Leak Rates
TPR-6304 / rev.2	2.15 & app. A	$LR \leq 1.0 \times 10^{-2}$ cc/sec	$\Sigma LR \leq$ X 10 cc/sec

Test Results

Note 1: For T_s use Ambient Temperature °K and P_s use Ambient Pressure in milli Torr

√ N/A	Item Name	Origin / Terminus*		Time($t_{1\&2}$) HH:mm:ss	(S)	Temp. ($T_{1\&2}$)	Pressure ($P_{1\&2}$)	Leak Rate Calculation Note1 $[V_T \cdot T_s/(SP_s)] \cdot [(P_2/T_2 - P_1/T_1)]$	$=L_R$ std-cc/sec
☒	Pretest Assembly Verification VT = Test Assy. Volume	Test Assy. Valve V-1	Start						
			End						
☐	Test of Item	Test Assy. Valve V-1	Start	15:30:00	60	303.00	38	(7.82 x 10-4)(249/299 - 38/303)	5.531 x 10-4
			End	15:31:00		299.00	249		
☒	Re-test of Item	Test Assy. Valve V-1	Start						
			End						

Results, Sketch of Set-up, Amplifying Data:

* See attached "Volume calculations for test apparatus" for Test Assembly Volume.

Cont'd:
Test Equipment - Stop watch 0-99 min. min, secs 715030 11-13-05

This DSC had EPDM 70 N70-M2.5 x 195 and N70-M2.5 x 170 gaskets installed.

The test is acceptable.

Use additional sheets as needed.

Lisa Jorgensen/Ridley Justice — Examiner/NDE Title Print/Type
Lisa Jorgensen / R Justice — Examiner Signature
6-8-04 — Date

*Data not required to be entered.

Title: TMI-2 ISFSI Alternate DSC Seal Evaluation
Author: Rick A. Gavalya

Revision: 1
Date: 10/14/2004

Volume Calculations for Test apparatus

TPR-6304, Appendix A, Fig 1 Item	ITEM	Total Length	Dia.		inch^3	cm^3/cc	Qty in DSC Test and Volume of test		Qty in 200 cc Test & Volume of Test		Qty in 100 cc Test & Volume of Test	
	Long 16x25 Flanged Tube	19.5	0.65		6.47	106.12		0	1	106.1195		0
8	Tee 16x16x16	5.125	0.65		1.70	27.89	1	27.890372	2	55.78074	3	83.67112
6	90 deg. Stop valve 16 Flg.	1.5	0.65		0.50	8.16	1	8.1630358	1	8.163036	2	16.32607
7	16 Flg. 1/8" M Pipe Nipple	1.5	0.19		0.04	0.70	1	0.6974807	1	0.697481		0
	short reducer 16x25	1.125	0.69		0.42	6.90		0		0		0
	Long reducer 16x25 Flanged	1.5	0.69		0.56	9.20		0	1	9.19863		0
-	O-Ring spacer	0.09	0.75		0.04	0.65	3	1.9562305	8	5.216615	7	4.564538
2	Pressure Transducer	2.5	0.19		0.07	1.16	1	1.1624678	1	1.162468	1	1.162468
	25x25 Flg Straight Valve Estimated	2	0.65		0.66	10.88		0	1	10.88405		0
	25x25 Flg Straight Valve Actual	2	1		1.57	25.76		0		0		0
7a	18" extension tube 1/8" Pipe	18	0.26		0.96	15.67	1	15.673029		0		0
N/A	DSC Vent Port Flange inside Groove Volume	34.45385	10.967		0.57	9.41	1	9.4079674		0		0
N/A	DSC Vent Port Flange outside Groove Volume	39.46469	12.562		0.66	10.78	1	10.776227		0		0
N/A	Test port	3.5	0.125		0.04	0.70	1	0.704404		0		0
N/A	Flange Seal	6.4	0.00925		0.06	0.97	1	0.97088		0		0
								77.402095		197.2225		105.7242

Note: This table is used for estimating the volume of the test apparatus used for demonstrations. The test volume used for calculations of leakage rate in the test procedure (110 CC) is more than those listed here, introducing conseratívism into the estimated test leakage rate.

Appendix B – Emails

Title: TMI-2 ISFSI Alternate DSC Seal Evaluation **Revision:** 1
Author: Rick A. Gavalya **Date:** 10/14/2004

[illegible] To: [illegible]
[illegible] cc: [illegible]

Rick
Please modify the below "50 year desgin life" requirement to "minimum 5 year design life"
Thanks
Jim
---- Forwarded by James L Stalnaker/STALJL/CC01/INEEL/US on 06/22/2004 10:47 AM ----

Rick A Gavalya
06/17/2004 07:21 AM

To: James L Stalnaker/STALJL/CC01/INEEL/US@INEL
cc:
Fax to:
Subject: Revised Preliminary TFR for Conceptual Design of "TMI ISFSI Alternate C-seal" Engineering Work Request

---- Forwarded by Rick A Gavalya/RAG/CC01/INEEL/US on 06/17/2004 07:21 AM ----

James L Stalnaker
03/23/2004 02:26 PM

To: Rick A Gavalya/RAG/CC01/INEEL/US@INEL
cc: Stuart R Jensen/SRJ1/CC01/INEEL/US@INEL, David R Moser/MOSEDR/CC01/INEEL/US@INEL
Fax to:
Subject: Revised Preliminary TFR for Conceptual Design of "TMI ISFSI Alternate C-seal" Engineering Work Request

Revised Preliminary TFR for Conceptual Design of "TMI ISFSI Alternate C-seal"

The "Alternate Seal" is intended for use in place of existing EG&G Pressure Science C-Seals
Ideally the Alternate seal could be used in the same configuration as the existing EG&G Seals
See Drawings 513916 sheets 1 thru 3 for detail of flange assembly (item 10 is existing seals)
See drawing 513914 sheet 2 detail 6 for component flange assembly mates with.

Of concern is the 32 rms surface finish of both flange assembly and mating assembly (both of these items are uncoated carbon steel). Oxidation may eventually undermine the ability of the existing seals to function. Restoration of the sealing surfaces to a 32 finish is not desirable.

The "Alternate Seal" shall accomodate the existing configuration assuming the 32 rms finish has undergone oxidation. Testing on existing equipment will be used to confirm.

The testing will entail pulling a vacuum between the seals and establishing a leak rate of less than 1 X 10 (-2) std cc/sec
Thermal range of operation should be approximately -40 to +200 degree F
Design Pressure - 30 PSIA
50 year dsign life

Contact me at 526-3101 for additional information
Jim Stalnaker
TMI & FSV ISFSI System Engineer

James L Stalnaker

James L Stalnaker
02/06/2004 04:30 PM

To: Stuart R Jensen/SRJ1/CC01/INEEL/US
cc: Ronald D Denney/DENNEY/CC01/INEEL/US@INEL
Fax to:
Subject: Preliminary TFR for Conceptual Design of "TMI ISFSI Alternate C-seal" Engineering Work Request

Preliminary TFR for Conceptual Design of "TMI ISFSI Alternate C-seal"

The "Alternate Seal" is intended for use in place of existing EG&G Pressure Science C-Seals
Ideally the Alternate seal could be used in the same configuration as the existing EG&G Seals
See Drawings 513916 sheets 1 thru 3 for detail of flange assembly (item 10 is existing seals)
See drawing 513914 sheet 2 detail 6 for component flange assembly mates with.

Of concern is the 32 rms surface finish of both flange assembly and mating assembly (both of these items are uncoated carbon steel). Oxidation may eventually undermine the ability of the existing seals to function. Restoration of the sealing surfaces to a 32 finish is not desirable.

The "Alternate Seal" shall accomodate the existing configuration assuming the 32 rms finish has undergone oxidation. Testing on existing equipment will be used to confirm.

The testing will entail pulling a vacuum between the seals and establishing a leak rate of less than 1 X 10 (-2) std cc/sec
Thermal range of operation should be approximately -40 to +200 degree F

Contact me at 526-3101 for additional information
Jim Stalnaker
TMI & FSV ISFSI System Engineer

Title: TMI-2 ISFSI Alternate DSC Seal Evaluation **Revision:** 1
Author: Rick A. Gavalya **Date:** 10/14/2004

Hello Rick,

The optimum oring cross section to fit your existing gland set up is .090. However, at the size of ID's that we are working with, it will be rare to find an oring w/ a .090 cross section at such large ID's.

Here are your options:

1) Custom make each size. Your looking at about $1000 non recurring set up charge for each size and about $10.00 each. 6-8 weeks.

2) We can thermal bond .093 cross section cord stock. The problem with thermal bonding is that a seam is present which can be a possible leak path. $20/ea 2 wks

3) The .103 cross section is so close that it is almost worth testing If so, we have two sizes in Buna that will fit the purge port inner seal and purge port outer seal. We have nothing available to fit the vent port outer seal and vent port inner seal.

Let me know how you want to proceed
Romel Ner
Project Engineer
Apple Rubber Products, Inc.
3402 Duchess Lane
Long Beach, CA 90815
ph: 714 225 0575
fx: 562 986 5542
www.applerubber.com

>> Romel,

>> Attached are several documents that will give you some insight into the
>> big picture that I spoke about with you earlier. Basically, I want to
>> find a replacement for existing metal c-seals that are in two different
>> flanges. The Purge Port Flange has two machined grooves that contain two
>> separate c-seals. The Vent Port Flange also has two machined grooves with
>> separate c-seals. If you open up the word document below, you will see
>> 3-D representations of the different flanges along with the proposed
>> o-ring dimensions that I think might work. The proposed o-rings are not
>> standard sized o-rings, they may have to be fabricated. Note that the
>> proposed dimensions are for the inner diameters of the o-rings.

>> (See attached file: 3-D Views, 4-5-04.doc)

>> Dimensions for the existing machined grooves are shown in the next
>> document.

>> (See attached file: Dimensions of Machined Grooves, 4-6-04.doc)

>> After you've had a chance to look at the information, could you please
>> give me a call to let me know if the proposed o-rings would work, what it
>> would take to get them made, etc.? My phone number is 208-526-3764.

>> Thanks for your time and help, I appreciate it.

>> Rick Gavalya
>> Bechtel BWXT Idaho, LLC
>> 208-526-3764

"O-Rings West" <sales@oringswest.com>
06/22/2004 12:04 PM

To: <RAG@inel.gov>
cc:
Fax to:
Subject: RE: Attn: Mike McBrady

Hello:

E70-6103X10787 (10.787" ID x .103" CS EPDM 70 Durometer O-Ring)
30 pieces cost $29.11 each which totals $873.30
50 pieces cost $18.10 each which totals $905.00
100 pieces cost $9.54 each which totals $954.00
250 pieces cost $4.34 each which totals $1,085.00
Delivery: 4-5 weeks.

E70-6103X12387 (12.387" ID x .103" CS EPDM 70 Durometer O-Ring)
30 pieces cost $29.34 each which totals $880.20
50 pieces cost $18.33 each which totals $916.50
100 pieces cost $9.76 each which totals $976.00
250 pieces cost $4.71 each which totals $1,177.50
Delivery: 4-5 weeks.

F.O.B.: Seattle, WA. Terms: 2% 10 Net 30. Quote valid for 60 days.

Please don't hesitate to call if you have any technical, delivery or price questions. Thank you for the opportunity to quote.

Regards,

Robert McBrady
O-Rings West, Inc.
1111 N. 98th St. #3
Seattle, WA 98103 USA
Phone 1-800-722-2602
206-522-2602
Fax 206-522-2621
www.oringswest.com

From: RAG@inel.gov [mailto:RAG@inel.gov]
Sent: Tuesday, June 22, 2004 10:54 AM
To: O-Rings West
Subject: RE: Attn: Mike McBrady

Mike,
I forgot to specify the material as EPDM, 70 durometer. Could you please requote for EPDM?
Thanks... Rick
"O-Rings West" <sales@oringswest.com>

"O-Rings West" <sales@oringswest.com>

06/22/2004 11:35 AM

To <RAG@inel.gov>
cc
Fax to
Subject RE: Attn: Mike McBrady

Hello:

N70-S103X10787 (10.787" ID x .103" CS Nitrile 70 Durometer O-Ring)
30 pieces cost $29.23 each which totals $876.90
50 pieces cost $18.22 each which totals $911.00
100 pieces cost $9.65 each which totals $965.00
250 pieces cost $4.13 each which totals $1,032.50
Delivery: 4-5 weeks.

N70-S103X12387 (12.387" ID x .103" CS Nitrile 70 Durometer O-Ring)
30 pieces cost $29.48 each which totals $884.40
50 pieces cost $18.47 each which totals $923.50
100 pieces cost $9.90 each which totals $990.00
250 pieces cost $4.33 each which totals $1,082.50
Delivery: 4-5 weeks.

F.O.B.: Seattle, WA. Terms: 2% 10 Net 30. Quote valid for 60 days.

Please don't hesitate to call if you have any technical, delivery or price questions. Thank you for the opportunity to quote.

Regards,

Robert McBrady
O-Rings West, Inc.
1111 N. 98th St. #3
Seattle, WA 98103 USA
Phone 1-800-722-2602
206-522-2602
Fax 206-522-2621
www.oringswest.com

From: RAG@inel.gov [mailto:RAG@inel.gov]
Sent: Tuesday, June 22, 2004 9:37 AM
To: sales@oringswest.com
Subject: Attn: Mike McBrady

Mike,
Could you please provide me with a cost estimate for two different sized o-rings?
The first o-ring will have a cross-sectional diameter of 0.103" and have an inside diameter of 10.787".
The second o-ring will have a cross-sectional diameter of 0.103" and have an inside diameter of 12.387".
I realize that these are not standard o-rings and will require a setup charge for each size. We will need 30 o-rings of each size.
If you have any questions, please call me at 208-526-3764
Thanks for your time and help. Also, we used your samples that you sent us of standard-sized o-rings, they worked quite well

Rick Gavalya
Bechtel BWXT Idaho, LLC
--

Appendix C – Telecon

TELEPHONE CONVERSATION

Subject: O-Ring Service Life
Participants: Rick Gavalya, Mechanical Engineer, BBWI, 208-526-3764 (author of this conversation)
Dan Ewing, Manager, Parker O-Rings, 859-268-5013
Date: June 15, 2004

Rick Gavalya called Dan Ewing, a manager at Parker O-Rings, to discuss the expected service life of o-rings that will potentially be used to replace metal c-seals in the TMI-2 Dry Shielded Canisters.

Dan replied that there was no way to accurately predict the service life of o-rings, there are many factors that contribute to o-ring life such as the application (static or dynamic) and environmental conditions (temperature, exposure to air and sunlight). He also stated that if we could come up with a model to predict the service life of o-rings in general, we would be millionaires.

He said that there were many instances where people had brought in o-rings that had been in service for 20+ years. Some of the people were disappointed that some of the o-rings had failed after being in use for that length of time and thought that they should have lasted longer. I asked him if there were hard copy reports of these instances and he said that there weren't, they were just cases that he remembered.

Dan stated that materials have improved and that today's o-rings will probably last longer than yesteryear's o-rings but that we'll have to wait another 20+ years to find out.

Rick explained how the o-rings were going to be used in the Dry Shielded Canisters – static application, little exposure to air, no exposure to sunlight, typically no pressure differential. Dan replied that the o-rings should have a long service life under these conditions, perhaps 15 – 20 years or more.

Rick asked Dan if there was any more information that he could add and he replied that was it. Rick closed the conversation by thanking Dan for his time and help.

Appendix D – Excerpt from SRS Report

WSRC-TR-2003-00198

PERFORMANCE EVALUATION OF O-RING SEALS IN THE SAFKEG 3940A PACKAGE IN KAMS (U)

T. Eric Skidmore

Savannah River Technology Center
Strategic Materials Technology Department
Materials Technology Section

May 2003

Patent Status
This internal management report is being transmitted without DOE patent clearance, and no further dissemination or publication shall be made of the report without prior approval of the DOE-SR patent counsel.

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

This document was prepared in connection with work done under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy

WSRC-TR-2003-00198

1.0 SUMMARY

The purpose of this report is to document the technical basis for acceptance of the EPDM O-ring seals in the SAFKEG 3940A package proposed for storage of Pu-bearing material in the KAMS (K-Area Materials Storage) facility. Based upon limited available aging data, significant loss of compression set and stress-relaxation (90% or more) of the O-ring is possible at the maximum service temperatures of the Inner Containment Vessel (112°C) within 2-4 years, assuming high oxygen availability. The maximum service temperature of the O-ring at the Outer Containment Vessel (93°C) is less than at the ICV, and the O-ring compression set loss may not be as severe even at the high oxygen availability condition. Under limited oxygen and static environmental conditions, the O-ring seals may not exhibit this loss even after longer exposure periods.

limited O_2 ; static environment condition

Baseline characterization of the O-rings in both high and low oxygen concentrations is recommended in order to obtain compound-specific data at the relevant service temperatures. The characterization in combination with a surveillance program will help provide the data needed to assure long-term performance of O-ring seals under actual service conditions for the desired 10+ years.

2.0 BACKGROUND

2.1 SAFKEG 3940A Package Design

Pu-bearing materials (metal, oxides, and impurities) placed in 3013 containers are to be shipped to SRS in Model 9975 packaging assemblies for interim storage at the K-Area Material Storage (KAMS) facility prior to final stabilization. An alternate package (SAFKEG 3940A) made by Croft Associates, Ltd. (est.1980) has been proposed for the same application. The 3940A package is one of a series of SAFKEG packages made by Croft for the packaging and transportation of radioactive materials.

The 3940A SARP (Safety Analysis Report for a Package) is in the process of being approved by the Los Alamos National Laboratory (design authority) [1]. The 3940A package is a general purpose container for the shipment of Type B radioactive material. The 3940A package was designed for a contents heat limit of 40 W, but the SARP is restricted to 20W.

The 3940A package (Figure 1) consists of a double-skin insulated stainless steel keg that is 760 mm (30 in.) long and 425 mm (16.7 in.) diameter [1]. The skin cavity is filled with a proprietary insulating phenolic resin foam (TISAF). Inside the keg is an insulating cork liner, sealed with a proprietary butylated sealant, that varies in thickness from 28 mm (1.1 in.) at the base of the keg to 75 mm (3 in.) at the top.

Inside the cork liner is a double containment configuration of resealable vessels, designs 3941 (outer containment vessel/OCV) and 3942 (inner containment vessel/ICV), Figure 2 [1]. Each vessel is made of stainless steel and sealed with two 3-mm (0.118") thick O-rings of appropriate size. The interspace between them allows for leak testing. The containment boundary for each

3.4. Summary of Literature Review

EPDM elastomers are nominally rated by O-ring manufacturers for service temperatures of –70 to 300°F in air, with higher temperatures possible with compounding and in certain media. In most cases, the high-temperature continuous service ratings are usually generically based on adequate performance for 1000 hours in normal (usually fluid) applications. For most applications, such ratings are sufficient.

Unfortunately, the true service life of an elastomeric O-ring at elevated temperature is dependent upon many variables and can be defined in many ways. Elastomeric seals are known to function even when severely degraded, particularly under static conditions. Of course, the more critical the seal and the more stringent the criteria, the shorter service life becomes.

Based on the limited data reviewed, significant degradation and sealing force decay (compression stress-relaxation) of EPDM elastomers is possible at the maximum inner vessel seal temperature of 112°C (normal service) within 2-3 years, assuming high oxygen availability. The maximum outer vessel seal temperature is 93°C. The time for significant sealing force decay would be expected to be extended beyond 2-3 years; however aging data at these conditions does not exist. There is likely a protective induction time (consumption of antioxidants) of approximately 280 days, beyond which the degradation rate will increase. For one EPDM compound, elongation was essentially zero after approximately 200 days at 125°C and after approximately 1000 days (2.74 years) at 111°C. Other studies indicate that EPDM compounds are highly stable after 2 years at 80°C, but sealing force is essentially lost in the same time period at 125°C.

This behavior is likely heavily influenced by several factors, particularly oxygen availability. As in the 9975 package, the benefit of limited oxygen exposure (lubricated O-ring tightly sealed in a groove within a double containment configuration) is believed to be significant but difficult to quantify. Degradation rates are known to be highly dependent upon oxygen availability, partial pressure, diffusion rates through the material, and the consumption rate. Most if not all of these factors are also dependent upon temperature and specific compounding. Therefore, additional investigation would be required to better evaluate these factors.

Assuming oxygen permeation from only one side of the O-rings and linear behavior between sealing force decay and oxygen diffusion/concentration factors, a service life of 4-6 years is estimated for the SAFKEG EPDM O-rings. Under static conditions, the seals are likely to maintain integrity well beyond this period, but this is unknown. Correlation between sealing force decay, compression stress-relaxation, and leak rate behavior at these temperatures for this or any other EPDM compound is also unknown. Additional testing and surveillance is therefore recommended.

Attachment 8

Engineering Design File 4728, Rev. 1
Radiological Evaluation of TMI-2 ISFSI Technical
Specification 3.1.1

ENGINEERING DESIGN FILE

EDF No.: 4728 EDF Rev. No.: 1 Project File No.: N/A

1. Title: Radiological Evaluation of TMI-2 ISFSI Technical Specification 3.1.1					
2. Index Codes: Building/Type 1774 SSC ID TMI-2 DSC and Canisters Site Area INTEC					
3. NPH Performance Category: ______ or ☒ N/A					
4. EDF Safety Category: SS or ☐ N/A SCC Safety Category: SS or ☐ N/A					

5. Summary:

A Limiting Condition for Operation (LCO) during storage operations at the Three Mile Island, Unit 2 Independent Spent Fuel Storage Installation (TMI-2 ISFSI) is maintenance of the Dry Storage Canister (DSC) vent [and purge] housing seal leak rate below 1E-02 standard cc/s. Compliance with the LCO is demonstrated through periodic performance of a leak check of the vent and purge housing double metallic seals on each DSC containing TMI-2 canisters. If the vent and purge housing seal leak rate is exceeded, then the required action is to either reseat or replace the seals, and perform another leak check on the seal within seven days, otherwise the DSC is to be transported to either Test Area North (TAN) or another appropriate facility for corrective actions within 30 days. Minor imperfections on the unpainted surfaces of the vent and purge housing may make it difficult to either reseat or replace seals after a failed leak check. The availability of an OS-197 or MP-187 transfer cask for lease is limited. There is also an ALARA concern associated with implementing the corrective actions when radiological conditions do not warrant. This EDF documents a review of the TMI-2 ISFSI design basis and an analysis of the radiological consequences of a DSC vent filter housing seal leakage. A proposed Technical Specification change is recommended to allow the licensee to keep a DSC with a failed seal leak check in its current configuration until the seals can be successfully reseated or replaced.

6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

	R/A	Typed Name/Organization	Signature	Date
Performer/ Author	N/A	Gregory G. Hall	G. Hall	11/4/04
Technical Checker	R	Frederick J. Borst	FJ Borst	11/4/04
Technical Checker	R	Allan B. Christensen	Allan B Christensen	11/10/04
Independent Peer Reviewer (if applicable)	R	Kim F. Childs	Kim F. Childs	11/4/04
Approver	A	James E. Kaylor	James E Kaylor	11/4/04
Requestor (if applicable)	Ac	Rick L. Gardner	R Gardner	11/4/04
Doc. Control	N/A	R. Aeschbacher/3A7L	Robin Aeschbacher	11/15/04

7. Distribution: (Name and Mail Stop)	G. G. Hall, MS 3428; F. J. Borst, MS 5104; A. B. Christensen, MS 5106; K. F. Childs, MS 3404; J. E. Kaylor, MS 5104; R. L. Gardner, MS 5104
8. Does document contain sensitive unclassified information? ☐ Yes ☒ No If Yes, what category:	
9. Can document be externally distributed? ☐ Yes ☒ No	
10. Uniform File Code: 0250 Disposition Authority: ENV1-b-4-a Record Retention Period: 75 years after cut off	
11. For QA Records Classification Only: ☒ Lifetime ☐ Nonpermanent ☐ Permanent Item and activity to which the QA Record apply:	
12. NRC related? ☒ Yes ☐ No	

ENGINEERING DESIGN FILE

EDF No.: 4728 EDF Rev. No.: 1 Project File No.: N/A

1.	Title: Radiological Evaluation of TMI-2 ISFSI Technical Specification 3.1.1
2.	Index Codes: Building/Type 1774 SSC ID TMI-2 DSC and Canisters Site Area INTEC
13.	Registered Professional Engineer's Stamp (if required)

Purpose

A Limiting Condition for Operation (LCO) during storage operations at the Three Mile Island, Unit 2 Independent Spent Fuel Storage Installation (TMI-2 ISFSI) is maintenance of the Dry Storage Canister (DSC) vent housing seal leak rate below 1E-02 standard cc/s (TSR-8.4). Compliance with the LCO is demonstrated through periodic performance of a leak check of the vent and purge filter housing double metallic seals on each DSC containing TMI-2 canisters. If the vent or purge filter housing seal leak rate is exceeded, then the required action is to reseat or replace the seals, and perform another leak check on the seal within seven days. Otherwise the DSC is to be transported to Test Area North (TAN) or another appropriate facility for corrective actions within 30 days.

The purpose of this Engineering Design File (EDF) is to analyze the radiological consequences of DSC vent filter housing seal leakage and implementing the required actions associated with loss of the limiting condition. New actions for loss of the limiting condition, as well as an expanded basis for a radiation protection technical specification, are proposed. The driver for performing the radiological evaluation at this time is three-fold. First, minor imperfections on the ASME SA-516, Grade 70 carbon steel sealing surfaces (polished, but not coated with Carbozinc 11) of the DSC vent and purge filter housings attributed to handling or surface oxidation may lead to difficulty in reseating or replacing seals to achieve a leak rate less than the LCO. Second, transporting a DSC to Horizontal Storage Module (HSM) No. 15 or another receiving and repair facility would require more than 30 days due to OS-197 or MP-187 cask availability. Third, and most importantly, there is an As Low As Reasonably Achievable (ALARA) concern with handling a DSC when radiological conditions do not warrant its movement. Movement of a DSC may also facilitate movement of radioactive contamination within a DSC to and possibly through the vent and purge filter housing seal areas.

Twenty-eight of the 29 DSCs in storage at the TMI-2 ISFSI will have the vent and purge filter housing double metallic seals leak checked within the next year. If a failed leak check occurs and DSC transfer is the chosen required action, there is some concern about unnecessary movement of a DSC and the inability to move a DSC within the required completion time. An additional required action allowing continued storage of a DSC after a failed seal leak check in conjunction with additional radiological protection actions will continue to provide for worker and public safety, yet balance the mitigative efforts necessary to maintain projected exposures ALARA.

Scope

The scope of this radiological evaluation is limited to TMI-2 ISFSI Technical Specification 3.1.1, Leak Testing DSC Vent Housing Seals, and the required actions and completion times described in Table 1. A proposed change to the basis for Technical Specification 3.2.2, Vent System HEPA Filters, is included as one of the recommendations. The current Technical Specification 3.2.2 is presented in Table 2 for information.

Table 1. TMI-2 ISFSI Technical Specification 3.1.1 – LCO, Action and Surveillance Requirements.

The leak rate of the vent housing seals shall not exceed 1 x 10^{-2} standard cc/sec.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. The vent housing seal leak rate is exceeded during STORAGE OPERATIONS.	A.1 Reseat or replace seals. AND A.2 Perform leak check on seal. OR A.3 Transfer the DSC to TAN or another appropriate facility for corrective actions.	7 days 7 days 30 days

SURVEILLANCE	FREQUENCY
SR 3.1.1.1 Perform leak check of the vent housing double metallic seals on each DSC containing TMI-2 CANISTERs.	Within 7 days after insertion of DSC into HSM. AND Every 5 years during STORAGE OPERATIONS. NOTE: SR 3.0.2 is not applicable.

Table 2. TMI-2 ISFSI Technical Specification 3.2.2 - LCO, Action and Surveillance Requirements.

The surface dose rate of each HSM rear access door shall not exceed 100 mrem/hour; and the surface dose rate of each HEPA filter housing shall not exceed 1200 mrem/hour.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. If the surface dose rates are exceeded.	A.1 Evaluate the cause of increased dose rates. AND A.2 Take corrective actions to restore dose rates within limits.	7 days 30 days

SURVEILLANCE	FREQUENCY
SR 3.2.2.1 Perform a radiation survey at the vent of each DSC.	Monthly during first year; Quarterly during second through fifth years; Annually thereafter. NOTE: FREQUENCY shall be determined by the number of years after DSC insertion into HSM or the most recent entry into CONDITION A.

Safety Category

The DSC vent seals are classified as Important to Safety because they are part of the radiological confinement barrier and are associated with Technical Specification (LCO 3.1.1). The DSC vent seals are categorized as Safety Class in accordance with MCP-540 based on their potential safety consequence (MCP-540). The calculations in this EDF associated with the DSC vent seals are therefore categorized as Safety Class.

Natural Phenomena Hazards (NPH) Performance Category (PC)

The calculations in this EDF are not associated with any natural phenomena hazard therefore this section is not applicable.

Subject-Specific Data

Design Function

There are three primary design functions described in the TMI-2 ISFSI SAR (SAR-II-8.4) for a DSC stored in the TMI-2 ISFSI. The first is confinement of radioactive TMI-2 fuel debris as provided by the DSC steel shell, the vent system, and the double seal welded inner and outer closures (TMI-2 ISFSI SAR, Section 3.3.7.1.2). The second is maintaining a diffusion path for hydrogen generated by radiolysis as provided by the DSC vent system. The third is structural in that the DSC and its components are to remain intact and provide these design functions under all normal, off-normal, and accident conditions identified in Chapter 8 of the TMI-2 ISFSI SAR (Section 3.4.1). These design functions have been classified as Important to Safety and categorized as Safety Class (TMI-2 ISFSI SAR, Sections 3.3.3.1 and 3.4).

Dose Assessment

A site dose assessment for the ISFSI during normal operations has been performed based on average HSM surface dose rates documented in Section 7.4.2 and Figure 7.3-4 of the TMI-2 ISFSI SAR. Direct and scattered radiation dose rates, as opposed to radiation dose rates due to internal exposure pathways, projected for the INTEC fence (the restricted area boundary) and INEEL site boundary (the controlled area boundary), as documented in Table 7.4-2, are 4.78E-02 mrem/h and 3.68E-06 mrem/h respectively. Annual doses attributed to airborne radioactivity releases during normal operations are 7.26E-03 rem at the INTEC fence and 9.58E-06 rem at the INEEL site boundary (TMI-2 ISFSI SAR, Section 7.6.3 and Table 7.6-1). The Effective Dose Equivalent (EDE) components of the doses attributed to normal operations are summarized in Table 3.

Table 3. EDE Components of Doses Attributed to Normal Operations (rem/y).

Exposure Pathway	INTEC Fence (100 m)	INEEL Site Boundary (13,700 m)
Inhalation (CEDE)	7.21E-03	2.74E-06
Ingestion (CEDE)	0.00E+00	6.51E-06
Ground Surface (EDE)	7.84E-06	2.75E-09
Cloud Gamma (EDE)	4.36E-05	3.24E-07
Total EDE	7.26E-03	9.58E-06

Accident Analysis

HEPA filtered vent and purge ports allow the release of hydrogen gas created by potential radiolysis within the TMI-2 canisters (TMI-2 ISFSI SAR, Section 8.2.7). An accident analysis for a non-mechanistic event causing DSC leakage postulates a direct release to the environment of 40.2 Ci over a one-month period, assuming all twelve TMI-2 canisters in a DSC rupture simultaneously with rupture of the DSC or both HEPA filter trains. Such an undetected and unmitigated accident is estimated to result in 0.28 mrem Total Effective Dose Equivalent (TEDE) and 0.08 mrem organ dose equivalent to the Maximum Exposed Individual (MEI) outside the owner controlled area (INEEL site boundary), and 110 mrem TEDE to a worker spending 40 hours at the INTEC fence.

Installation Design

The DSC ventilation and off gas system is a completely passive design and only takes credit for diffusion for the removal of gases, although some gas flow through the vent system also occurs due to temperature gradients and atmospheric pressure changes (TMI-2 ISFSI SAR, Appendix C). It was conservatively estimated that 12 canisters stored in a DSC could release 84 cc/h of hydrogen. The release is based on a five-inch diameter pipe equivalent filtered opening in the top of the cover plate. Each filter is a HEPA grade sintered stainless steel type for radionuclides, exhibiting a particle removal efficiency of greater than 99.97% for particle sizes down to 0.3 μm (TMI-2 ISFSI SAR, Section 4.3.1).

Technical Specification

The integrity of the vent system seals is verified within seven days after insertion of the DSC into an HSM, and every five years thereafter during storage operations, by leak testing the DSC vent and purge filter housing double metallic seals. A measured leak rate no greater than 1.0E-02 standard cc/s, with the space between the double seals under a pressure of less than 0.1 Torr, is an indication of acceptable DSC integrity. A failed leak test is an indication of failure of either or both double metallic seals. If the above LCO leak rate is exceeded, the vent and purge filter housing seals are required to be reseated or replaced, and leak checked again within seven days of the initial failed leak test. The alternative required action is to transport the DSC to TAN, or another appropriate facility within 30 days, for corrective actions.

Technical Specification Bases

The basis for verifying the integrity of the DSC is the need to maintain confinement of the radioactive material stored in each DSC (TSR-8.4 Bases). The vent and purge filter housing seals make up part of the DSC confinement barrier. Failure of the confinement barrier is considered in the accident analysis previously discussed. Verification of the vent and purge filter housing seal integrity ensures that the HEPA filtered vent system is the only vent path for the DSC. The required action to reseat or replace the vent and purge filter housing seals within seven days of a failed leak test recognizes the low motive force available to transport radioactive material through the leaking vent and purge filter housing seals.

Assumptions

- A failed seal will not decrease hydrogen venting.

- The bounding DSC contains twelve bounding canisters as characterized in the TMI-2 ISFSI SAR, Table 3.1-3.

- The temperature and atmospheric pressure changes produce frequent but small motive forces that can sustain a continuous release from the DSC at a relatively constant rate over the entire year.

- A leaking vent or purge seal in a DSC could go undetected for a period of five years (the maximum time between scheduled surveillances). If such a leak is also characterized by a detectable radioactive material release, then radioactive contamination surveys will also detect a leaking seal.

- Although credit is taken for a 0.0003 filtered release fraction during normal operation, a 0.01 filtered release fraction during an unfiltered leak through a double metallic seal is assumed.

- Although radiation levels at the HSM rear panel doors were projected to average 8 mrem/h with a peak of 105 mrem/h (TMI-2 ISFSI SAR, Figure 7.3-4), actual radiation levels are all less than 0.5 mrem/h. The DSCs therefore contribute equally to the direct and scattered radiation projected at the INTEC fence and INEEL site boundary. Direct and scattered radiation emanating from a DSC will not increase due to a failed seal leak rate test, therefore doses from direct and scattered radiation will be no different from that evaluated in the SAR for normal operations.

- The estimated enveloping time for performing corrective maintenance on a DSC filter housing sealing surface, as documented in Table 7.4-1 of the TMI-2 ISFSI SAR, is independent of the DSC location (stored in an HSM or at another facility).

- Radiological conditions associated with corrective maintenance performed at another facility can be mitigated to less than 10% of unmitigated conditions through ALARA engineering and design.

- Airborne radioactivity and loose surface radioactive contamination are in equilibrium inside the DSC, filter housing seal area, interface between the vent housing assembly and DSC cover plate, and area immediately adjacent to the interface when under secondary containment, the relationship of which can be quantified with a resuspension factor.

Acceptance Criteria

The calculations will show that a DSC with a failed seal leak rate test will continue to satisfy the radiation exposure limits of 10 CFR 72.104 (10 CFR 72). The corrective actions (existing and proposed) performed after a failed seal leak rate test will be evaluated using ALARA principles in accordance with 10 CFR 20.1101(b) (10 CFR 20).

Software

Although software (MCNP, RSAC-5, and CAP-88 computer codes) was used in the original analyses, software was not utilized in this analysis therefore this section is not applicable.

Calculations

<u>Effluent Release</u>

Review of the DSC loading plans filed with the canister storage and transfer records for each of the 29 DSCs transferred to the TMI-2 ISFSI indicates the total fission product activity stored in the facility is 2.025E+06 Ci.[1] Distribution of the radioactivity within the DSCs, as documented in the canister storage and transfer records and summarized in Table 4, is conservatively calculated using the following equation,

$$\Sigma\left(\left(W_{dc} / W_{tdc}\right) \times L_{fc}\right) = L_t$$

where W_{dc} is the weight of the TMI core debris contained in a DSC (lbs), W_{tdc} is the total weight of the TMI core debris (lbs), L_{fc} is the radionuclide-specific full core loading (Ci), and L_t is the sum of the DSC loadings for each radionuclide (Ci). Radioactive source term is decayed to March 1999.

[1] DSC loading plans are filed with the canister storage and transfer records for each of the 29 DSCs (DOE-12T-001 through DOE-12T-029) and are dual-stored as completed Form INTEC-6824X, Canister Storage and Transfer Record [for] INTEC-749, INTEC-603 (IFSF), and INTEC-1774 (TMI-2 ISFSI), Uniform File Code 7652, in the NRC Records Center at INTEC and the Willow Creek Building Document and Records Storage Center.

Table 4. Radioactivity Content of Each HSM/DSC.

HSM No.	DSC No.	Radioactivity (Ci)	HSM No.	DSC No.	Radioactivity (Ci)
1	29	8.354E+04	16	2	8.152E+04
2	28	4.939E+04	17	3	6.332E+04
3	26	4.371E+04	18	20	8.873E+04
4	1	4.367E+04	19	18	7.682E+04
5	24	3.568E+04	20	4	8.010E+04
6	23	7.935E+04	21	9	7.484E+04
7	22	5.289E+04	22	5	7.580E+04
8	21	8.252E+04	23	16	4.692E+04
9	25	8.385E+04	24	11	1.236E+05
10	6	9.719E+04	25	13	8.669E+04
11	12	1.002E+05	26	7	1.006E+05
12	19	1.008E+05	27	8	6.949E+04
13	15	8.573E+04	28	10	2.504E+04
14	17	5.170E+04	29	27	6.328E+04
15	Empty	-	30	14	7.872E+04

A bounding canister is documented as containing 3.17E+04 Ci (TMI-2 ISFSI, SAR, Table 3.1-3). A bounding DSC is assumed to contain twelve bounding canisters; hence 3.8E+05 Ci or, based on the following equation, approximately 19% of the total radioactivity in the TMI-2 core debris.

$$3.8\text{E+05 Ci} / 2.025\text{E+06 Ci} = 0.19$$

The normal radioactive material release from the bounding DSC during a 12-month period through a HEPA filtered vent system is calculated to be 2.6E+03 Ci/y using the following equation,

$$1.4\text{E+04 Ci/y} \times (3.8\text{E+05 Ci} / 2.025\text{E+06 Ci}) = 2.6\text{E+03 Ci/y}$$

where 1.4E+04 Ci/y is the sum of the values in the Normal Operation Release column of TMI-2 ISFSI SAR, Table 7.2-3 and summarized in Table 5.

Table 5. Normal Operation Radioactive Material Release from the ISFSI.

Radionuclide	Normal Operations ISFSI Release (Ci/y)	Radionuclide	Normal Operations ISFSI Release (Ci/y)
Cs-137	1.439E-03	Pu-240	1.178E-05
Ba-137m	1.361E-03	Ni-63	1.093E-05
Y-90	1.151E-03	Eu-154	8.438E-06
Sr-90	1.151E-03	H-3	1.539E+03
Pu-241	8.238E-04	Eu-155	6.081E-06
Kr-85	1.284E+04	Pu-238	5.783E-06
Pm-147	4.954E-05	Sb-125	3.776E-06
Am-241	4.059E-05	Cs-134	1.560E-06
Co-60	2.785E-05	I-129	6.434E-10
Pu-239	2.236E-05	Total	1.438E+04
Sm-151	1.839E-05		

The particulate radioactive material component of the normal release through a HEPA filtered vent system from the bounding DSC is calculated to be 1.1E-03 Ci/y using the following equation,

6.1E-03 Ci/y x (3.8E+05 Ci / 2.025E+06 Ci) = 1.1E-03 Ci/y

where 6.1E-03 Ci/y is the sum of the particulate radionuclide values in the Normal Operation Release column of TMI-2 ISFSI SAR, Table 7.2-3 (excluding H-3, Kr-85, and I-129) also summarized in Table 5. The source term values in TMI-2 ISFSI SAR, Table 7.2-3 are based on the 1984 TMI-2 fuel radionuclide inventory with particulate and solids release fractions based on 40 CFR 61, Appendix D guidance (Staley).

A significant particulate radioactive material release through a failed double metallic seal would not be expected to occur without a significant motive force. The only motive forces for release through a failed double metallic seal are diffusion (for gases only), temperature gradients, and atmospheric pressure changes, all of which are quite small. The passive airflow through DSC vent and purge filter housings is estimated to be 624 cc/h based on a calculated airflow of 52 cc/h per canister documented in EDF-4550 (Murray) and twelve canisters per DSC. For a release of radioactive material from within a DSC to occur, fine radioactive material would have to become airborne, pass through a canister vent, migrate to the DSC filter housing seal area, and then pass through a failed double metallic seal. Without HEPA filter blockage, most of any motive force would be dissipated through the HEPA filters rather than acting to pass radioactive material through the seals. Even if the double metallic seals were completely missing, the gaps between the vent and purge filter housings and the DSC lid are so small that it would be difficult for particulate radioactive material to pass through without significant motive force.

The worst case would be that all the particulate radioactive material that could potentially be released from the bounding DSC during normal operation is released unfiltered through double metallic seals that have failed a leak rate test. In such a case the particulate release is estimated to be 1.1E-01 Ci/y based on the following equation,

1.1E-03 Ci/y x (1.000 / 0.01) = 1.1E-01 Ci/y

where 1.000 / 0.01 is the ratio of the unfiltered release fraction to the filtered release fraction recommended by the Environmental Protection Agency (40 CFR 61). This implicitly assumes the release occurs at a constant rate over the entire year.

Radiation Exposure

Since the direct and scattered radiation dose rates for normal operations projected at the INTEC fence and INEEL site boundary, as documented in Table 7.4-2 of the TMI-2 ISFSI SAR, are 4.78E-02 mrem/h and 3.68E-06 mrem/h respectively, the direct and scattered radiation dose rates at the INTEC fence and INEEL site boundary attributed to the bounding DSC during normal operation are calculated to be 9.0E-03 mrem/h and 6.9E-07 mrem/h by the following equations.

4.78E-02 mrem/h x (3.8E+05 Ci / 2.025E+06 Ci) = 9.0E-03 mrem/h

3.68E-06 mrem/h x (3.8E+05 Ci / 2.025E+06 Ci) = 6.9E-07 mrem/h

The calculated potential total dose equivalent and committed dose equivalents to the MEI outside the INEEL site boundary from filtered and unfiltered particulate releases are summarized in Table 6. The release rate and inhalation, ingestion and total dose equivalents for the normal filtered particulate release from the ISFSI are as documented in Table 7.6-1 of the TMI-2 ISFSI SAR (excluding the contribution from Kr-85, H-3, and I-129). Dose contribution from ground surface contamination is ignored because it is far less limiting, by a factor of about 1,000, relative to that for the inhalation and ingestion exposure pathways. Dose contribution from cloud gamma exposure is ignored because it is primarily attributed to noble gas. The ratio of the particulate release rates for the two scenarios is 1.8E+01 based on the following equation,

1.1E-01 Ci/y / 6.1E-03 Ci/y = 1.8E+01

where 6.1E-03 Ci/y is the sum of the particulate releases during normal operations. The inhalation, ingestion and total dose equivalents for the MEI attributed to an unfiltered particulate release from the bounding DSC are calculated as being a factor of 1.8E+01 higher than that for normal operations.

Table 6. Offsite Dose Attributed to Filtered and Unfiltered Particulate Releases from a DSC.

Scenario	Release Rate (Ci/y)	Maximum Exposed Individual Dose Rate at the INEEL Site Boundary (rem/y)		
		Inhalation CEDE	Ingestion CEDE	Total CEDE
Normal Filtered Particulate Release for the ISFSI	6.1E-03	2.74E-06	6.51E-06	9.25E-06
Unfiltered Particulate Release for the Bounding DSC	1.1E-01	4.9E-05	1.2E-04	1.7E-04

The worst-case release rate from the bounding DSC due to a failed double metallic seal would result in a Total Effective Dose Equivalent (TEDE) rate at the INEEL site boundary of 1.7E-04 rem/y. The projected TEDE rate at the INTEC fence for the worst case release would be 1.3E-01 rem/y based on the ratio of the TMI-2 ISFSI SAR, Table 7.6-1 CEDE values for 100 meters at the INTEC fence (7.21E-03 rem/y) and 13,700 meters at the INEEL boundary (9.25E-06 rem/y).

Non-Mechanistic Event

The non-mechanistic event postulated direct release from a bounding DSC to the environment over a one-month period without HEPA filtration envelopes a postulated non-mechanistic event direct release from a DSC with a failed leak rate test. Table 7 summarizes the release activities by radionuclide (TMI-2 ISFSI SAR, Table 7.2-3).

Table 7. Non-Mechanistic Event Releases from the Bounding DSC.

Radionuclide	Bounding DSC Non-Mechanistic Event Release (Ci/month)	Radionuclide	Bounding DSC Non-Mechanistic Event Release (Ci/month)
Cs-137	7.338E-02	Pu-240	6.009E-04
Ba-137m	6.941E-02	Ni-63	5.572E-04
Y-90	5.871E-02	Eu-154	4.303E-04
Sr-90	5.869E-02	H-3	4.274E+00
Pu-241	4.201E-02	Eu-155	3.101E-04
Kr-85	3.566E+01	Pu-238	2.949E-04
Pm-147	2.526E-03	Sb-125	1.925E-04
Am-241	2.070E-03	Cs-134	7.957E-05
Co-60	1.420E-03	I-129	3.281E-08
Pu-239	1.140E-03	Total	4.025E+01
Sm-151	9.377E-04		

Collective Occupational Radiation Exposure

Since an average of 10 person-mrem has historically been expended for each HSM loading, 20 person-mrem would be projected for a DSC transfer into HSM No. 15, or for transfer to and from some other facility for corrective maintenance. Radiological survey data from several DSCs indicates corrective maintenance on a DSC filter housing sealing surface at another facility would have to be performed in a posted High Radiation Area (equal to or greater than 100 mrem/h), although radiological conditions would be mitigated through ALARA engineering and design. The estimated enveloping time for performing this activity, as documented in Table 7.4-1 of the TMI-2 ISFSI SAR, is 4.0 person-hours for the removal/re-installation of the vent and purge filter housings and transportation covers. If another 8.0 person-hours is estimated for the inspection and reconditioning of the vent and purge filter housing sealing surfaces, and assuming radiological conditions can be mitigated to less than 10% of unmitigated conditions through ALARA engineering and design, then collective exposure of at least 1.4E+02 person-mrem ((4 person-hours + 8 person-hours) x 10 mrem/h + 20 person-mrem) is conservatively projected to complete the existing required corrective action.

Any corrective maintenance on a DSC filter housing sealing surface while the DSC remains in its current storage configuration or following transfer to HSM No. 15 would have to be performed in a posted Radiation Area (equal to or greater than 5 mrem/h). The estimated enveloping time for performing this activity, assuming the same time durations as documented in Table 7.4-1 of the TMI-2 ISFSI SAR, is 4.0 person-hours for the removal/re-installation of the vent and purge filter housings and transportation covers. With another 8.0 person-hours estimated for the inspection and reconditioning of the vent and purge filter housing sealing surfaces, an unmitigated (assuming the limited work space inside the rear panel door would prevent mitigation of radiological conditions) minimum of 6E+01 person-mrem ((4 person-hours + 8 person-hours) x 5 mrem/h) is conservatively projected to complete the existing required corrective action.

Administrative Action Levels

The radioactive particulate airborne activity concentration in the air leaking from an unmitigated vent housing seal leak is calculated to be 2.0E-08 Ci/cc based on the following equations,

1.1E-01 Ci/y / 365 d/y = 3.0E-04 Ci/d

624 cc/h x 24 h/d = 1.5E+04 cc/d

3.0E-04 Ci/d / 1.5E+04 cc/d = 2.0E-08 Ci/cc

where 1.1E-01 Ci/y is the unfiltered particulate release rate for the bounding DSC and 624 cc/h is the estimated passive airflow through DCS vent and purge filter housings.

Cember describes the quantitative relationship between the concentration of loose surface contamination and consequent atmospheric concentration above a contaminated surface due to stirring up the surface as the resuspension factor and is defined in the following equation,

$$f_r = \text{atmospheric concentration } \mu Ci/cm^3 \text{ / surface contamination } \mu Ci/cm^2$$

where f_r is the resuspension factor (Cember). Resuspension factors for loose surface radioactive contamination vary from 1E-04 cm^{-1} to 1E-08 cm^{-1} depending on the physical factors affecting resuspension including type and intensity of disturbance, time since deposition, nature of the surface, particle size distribution, climatic conditions, type of deposition, chemical properties of the contaminant, surface chemistry, and building geometry and physical characteristics. The Nuclear Regulatory Commission recognizes this quantitative relationship and recommends application of the least conservative resuspension factor value of 1E-06 m^{-1} (1E-08 cm^{-1}) in the screening analysis of the inhalation dose calculation for the building occupancy scenario for demonstrating compliance with the license termination rule in 10 CFR 20, Subpart E (NUREG-1720).

Application of this quantitative relationship can be used to estimate the level of loose surface radioactive contamination deposited on a daily basis on the exterior of the vent filter housing adjacent to its interface with the DSC cover plate based on the following equation,

$$(2.0E\text{-}08 \text{ Ci/cc} / 1E\text{-}04 \text{ cm}^{-1}) \times 2.22E\text{+}12 \text{ dpm/Ci} = 4E\text{+}10 \text{ dpm/100 cm}^2$$

where 1E-04 cm^{-1} is the most conservative resuspension factor in this application, 2.22E+12 dpm/Ci is the Curie to disintegration rate conversion factor, and 4E+10 dpm/100 cm^2 is the consequent surface contamination in the immediate vicinity of the double metallic seal, recognizing that the physical factors affecting resuspension increase considerably with distance from the seal area . Application of a secondary containment around the interface between the vent filter housing and DSC cover plate, once radioactive contamination is detected, will ensure the conservatism in the application of the resuspension relationship. Since the annual exposure to the MEI attributed to an unfiltered bounding DSC is 1.7E-01 mrem/y, a conservative dose conversion factor of 2E+11 dpm/100 cm^2/mrem/y is calculated,

$$4E{+}10 \text{ dpm}/100 \text{ cm}^2 / 1.7E{-}01 \text{ mrem/y} = 2E{+}11 \text{ dpm}/100 \text{ cm}^2/\text{mrem/y}.$$

Administrative action levels can be used to trigger mitigative actions. A conservative administrative action level for transfer of a DSC to HSM No. 15 or another facility could be established at 7E+10 dpm/100 cm^2/DSC based on the following equation,

$$(10 \text{ mrem/y} / 29 \text{ DSCs}) \times 2E{+}11 \text{ dpm}/100 \text{ cm}^2/\text{mrem/y} = 7E{+}10 \text{ dpm}/100 \text{ cm}^2/\text{DSC}$$

where 10 mrem/y is the more restrictive 10 CFR 20 exposure limit for the MEI attributed to airborne emissions, and all 29 DSCs have failed a seal leak test.

Loose surface radioactive contamination, as well as radioactive contamination buildup within HEPA filters, will contribute to the radiation level detected at the filter housing surface. Since the LCO 3.3.2 limit for the HEPA filter housing surface dose rate is 1,200 mrem/h, a more appropriate administrative action level for transfer of a DSC can be correlated to the LCO 3.3.2 based on the survey method employed.

Using the rule of thumb for beta particles that says the surface dose rate through 7 mg/cm^2 from a uniform thin deposition of 1 μCi/cm^2 is about 9 rads/h for energies above 0.6 MeV (Voss), 7E+10 dpm/100 cm^2 on a DSC surface equates to about 3E+03 rad/h based on the following equation,

$$7E{+}10 \text{ dpm}/100 \text{ cm}^2 / (1 \ \mu\text{Ci/cm}^2 \times 2.22E{+}06 \text{ dpm}/\mu\text{Ci}) / 9 \text{ rads/h} = 3E{+}03 \text{ rad/h}.$$

Since LCO 3.3.2 limits the surface dose rate to 1.2 rem/h, an administrative action level of 7E+10 dpm/100 cm^2/DSC would be reduced to 3E+07 dpm/100 cm^2 based on the following equation,

$$(1.2 \text{ rem/h} / 3E{+}03 \text{ rad/h} \times 1 \text{ rem/rad}) \times 7E{+}10 \text{ dpm}/100 \text{ cm}^2 = 3E{+}07 \text{ dpm}/100 \text{ cm}^2$$

where 1 is the quality factor (rad to rem conversion) for gamma radiation and beta radiation greater than 0.03 MeV.

A more conservative administrative action level can be derived based on the fact that ionization chambers and GM counters are both routinely used for radiation surveying at the TMI-2 ISFSI, and both have a moderate efficiency for detecting beta radiation (Shleien). GM counter sensitivity to beta/gamma radiation from Cs-137 is typically on the order of 1E+03 to 4E+03 cpm/mR/h. (Ludlum, Thermo Electron). A DSC surface deposition of 7E+10 dpm/100 cm^2 would therefore equate to about 7E+03 R/h based on the following equation,

$$7E{+}10 \text{ dpm}/100 \text{ cm}^2 / (1E{+}03 \text{ cpm/mR/h} / 0.1 \text{ cpm/dpm}) = 7E{+}06 \text{ mR/h}$$

where 0.1 is the conservatively assumed detection efficiency used in field measurements, and the detector probe area is 100 cm^2. Since LCO 3.3.2 limits the surface dose rate to 1.2 rem/h, an administrative action level of 7E+10 dpm/100 cm^2/DSC would be reduced to 1E+07 dpm/100 cm^2 based on the following equation,

$$(1.2 \text{ rem/h} / 7E{+}03 \text{ R/h} \times 0.87 \text{ rad/R} \times 1 \text{ rem/rad}) \times 7E{+}10 \text{ dpm/100 cm}^2 = 1E{+}07 \text{ dpm/100 cm}^2$$

where 0.87 is the Roentgen to rad conversion factor based on energy deposition per gram in air.

Since the RO-20 portable air ionization chamber is the instrument most often used for beta/gamma radiation surveying at the TMI-2 ISFSI, and the beta response of the RO-20 is reported to be 30% of true beta radiation fields (RO-20), another possible administrative action level is calculated based on the following equation,

$$(1{,}200 \text{ mrem/h} / 1 \text{ mrem/mrad}) \times 0.3 = 4E{+}02 \text{ mrad/h}.$$

Upper Bound of Acceptable Vent Housing Seal Leak Rate

Although LCO 3.1.1 limits the DSC vent housing seal leak rate below 1E-02 standard cc/s, the following calculation shows that the seal leak rate could be as high as 7E-02 standard cc/s before challenging the exposure limit of 10 mrem/y to the MEI.

$$(7E{+}10 \text{ dpm/100 cm}^2\text{/DSC})(1E{-}04 \text{ cm}^{-1}) / (2.22E{+}12 \text{ dpm/Ci}) = 3E{-}06 \text{ Ci/cc/DSC}$$

$$(10 \text{ mrem/y} / 1.7E{-}01 \text{ mrem/y})(1.1E{-}01 \text{ Ci/y}) / (3E{-}06 \text{ Ci/cc/DSC}) / (3E{+}07 \text{ s/y}) = 7E{-}02 \text{ cc/s}$$

Conclusions

The intended functions of the DSC vent system will not be compromised with a failed leak rate test. A failed leak rate test will not disrupt the diffusion path for hydrogen. Any particulate radioactive material release associated with a failed leak rate test will be negligible without a significant motive force. The worst-case release would be if all the particulate radioactive material that could potentially be released from the bounding DSC during normal operation was released unfiltered through the leaking double metallic seals. The estimated release would be 1.1E-01 Ci/y. The resulting exposures to the worker and general public, as summarized in Table 8 along with corresponding exposures realized during normal ISFSI operations, indicate a DSC with a failed seal leak rate test will continue to satisfy the radiation exposure limits of 10 CFR 72.104 (0.025 rem/y whole body to the MEI due to radioactive material in effluents and direct radiation) and 10 CFR 20.1101(d) (0.01 rem/y to the MEI due to airborne emissions).

Table 8. Calculated Radiation Exposure Summary.

Exposure Pathway	Exposed Worker at the INTEC Fence (rem/y)[2]	MEI at the INEEL Boundary (rem/y)
Airborne Radioactivity from Normal ISFSI Operations	7.26E-03	9.58E-06
Direct and Scattered Radiation from Normal ISFSI Operations	9.6E-02	3.2E-05
Total Exposure from Normal ISFSI Operations	1.0E-01	4.2E-05
Unfiltered Particulate Airborne Radioactivity from Bounding DSC	1.3E-01	1.7E-04
Direct and Scattered Radiation from Unfiltered Bounding DSC	1.8E-02	6.0E-06
Total Exposure from Unfiltered Bounding DSC	1.5E-01	1.8E-04

The projected exposure of 1.5E-01 rem/y to the worker at the INTEC fence from an unfiltered bounding DSC is 50% higher than that projected for normal operations (a difference of 50 mrem/y). Corrective action exposures are summarized in Table 9. Evaluation of the estimated exposures, using ALARA principles in accordance with 10 CFR 20.1101(b) (10 CFR 20) and Regulatory Guide 8.10 (USNRC), indicates implementation of the existing required action option to transfer the DSC to TAN or another facility will result in a collective occupational exposure that is more than twice that projected for performing corrective maintenance on the DSC in its current configuration. Transfer of the DSC to HSM No. 15 with no corrective maintenance would result in the lowest exposure expenditure, but does not fix the problem, and eliminates this required action option for any subsequent failed seal leak rate tests on other DSCs. Performing corrective maintenance on a DSC while it remains in its current storage configuration will result in a relatively low exposure expenditure, and will reserve HSM No. 15 for future use. The ALARA guidance in 10 CFR 20 and Regulatory Guide 8.10 would suggest that performing corrective maintenance on a DSC while it remains in its current storage configuration is the preferred option. Although there is also little motive force to cause migration of contamination from within a DSC when it is stored in a HSM, any movement (transfer and/or cask uprighting) of a DSC could cause migration of contamination to the vent and purge filter housings, hence creating a greater radiological risk to personnel. It is therefore safer not to move the DSC unless warranted by ALARA considerations.

Table 9. Collective Occupational Exposure Summary.

Required Action Option	Estimated Collective Exposure (person-rem)
DSC Transfer to HSM No. 15 with No Corrective Maintenance	2E-02
DSC Transfer to HSM No. 15 with Corrective Maintenance	8E-02
DSC Transfer and Corrective Maintenance at TAN or Another Facility	1.4E-01
Corrective Maintenance of the DSC while Stored in Current Configuration	6E-02

[2] Direct and scattered radiation exposures are calculated based on a 40-hour workweek, 50 weeks per year.

Recommendations

The preceding discussion concludes that a failed leak rate test associated with a worst case DSC would neither provide a significant hindrance to a diffusion path for hydrogen such that the LCO for hydrogen concentration would be exceeded, nor a lack of radioactive material confinement resulting in significant on-site or off-site dose under either normal operations or accident conditions. It is therefore recommended that the required actions for LCO 3.1.1 be revised such that the licensee will be allowed to keep a DSC with a failed leak rate test in its current configuration until the seals can be successfully reseated or replaced.

Changes to the LCO 3.1.1 Action are proposed. A new proposed required action is to characterize the radiological contamination condition around the vent housing within 24 hours, the results of which will trigger radiation protection and contamination control actions in accordance with the Radiation Protection Program (PRD-317). The required action to reseat or replace the seals and perform a leak check on the seal within 7 days should be retained. If the vent housing seal leak rate LCO cannot be restored within 7 days, then two additional required actions are proposed. Radioactive contamination surveys of the interface between the vent system filter housing and the DSC cover plate should be performed on a monthly frequency. A report should also be submitted to the NRC within 90 days describing the condition, results of engineering evaluations, and actions being taken. The described actions being taken should include survey methods for loose surface radioactive contamination described in the Radiological Environmental Monitoring Program (MCP-2955). Any detectable fission or activation product contamination found by such surveys should be considered indication of a radioactive release.

Although not within the original scope of this EDF, a proposed change to the allowed vent housing seal leak rate may also provide some increased margin to operate within if the seals become difficult to reseat or seal. The calculations present the upper bound of the vent housing seal leak rate (7E-02 cc/s) necessary to demonstrate compliance with 10 CFR 20.1101.

LCO 3.2.2 is more limiting than the MEI exposure limits of 10 CFR 72.104 and 10 CFR 20.1101 in terms of acceptable levels of loose surface radioactive contamination that might contribute to the radiation level measured at the vent housing. The basis for Technical Specification 3.2.2 will need to recognize this contribution to the vent housing radiation level, and allow for decontamination, shielding, and/or containment to be employed to maintain radioactive contamination and beta radiation levels below 1E+07 dpm/100 cm^2 and 4E+02 mrad/h, respectively.

If it is decided to request a license amendment, two sections of the TMI-2 ISFSI SAR will need to be revised to reflect the proposed facility change. Sections 7.4 and 7.6 should be updated to reflect doses attributed to a leaking vent system seal. Section 8.1 should be revised to include a subsection on off-normal operation with a leaking vent system seal.

References

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- TSR-8.4, TMI-2 ISFSI Technical Specifications, 3.2 Radiation Protection, 3.2.3 DSC Hydrogen Concentration
- TSR-8.4 Bases, Technical Specifications Bases for the INEEL TMI-2 Independent Spent Fuel Storage Installation
- USNRC Regulatory Guide 8.10, Operating Philosophy for Maintaining Occupation Radiation Exposure As Low As Reasonably Achievable (ALARA)
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