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72-1007

HOLTEC INTERNATIONAL

Holtec Center, 555 Lincoln Drive West, Marlton, NJ 08053
Telephone (856) 797-0900
Fax (856) 797-0909

72-1008

November 24, 1999

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Subject: NRC 10 CFR 72 Certificate of Compliance No. 1008, TAC L22019
License Amendment Request 1008-1

References:
1. Holtec Project No. 5014
2. Holtec Topical Safety Analysis Report No. HI-941184, Revision 10.

Dear Sir:

Holtec International hereby submits License Amendment Request (LAR) 1008-1, Revision 0, proposing certain amendments to 10 CFR 72 Certificate of Compliance (CoC) No. 1008 and its supporting Topical Safety Analysis Report for the HI-STAR 100 System. Information describing and justifying the changes requested by this LAR is contained in the attachments listed below. In preparing this amendment request package, we have intentionally included non-mandatory material, such as marked-up and final versions of the CoC, and proposed Topical Safety Analysis Report (TSAR) changes. This non-mandatory information adds to the overall bulk of the submittal, but should greatly facilitate the NRC staff's review effort. A final Revision 11 of the HI-STAR 100 TSAR will be submitted within 90 days of the date of publication of the final rulemaking that issues the CoC amendment.

Attachment 1: Summary of Proposed Changes, including the descriptions, reasons, and justifications for the proposed changes.

Attachment 2: Mark-ups of Proposed Changes to CoC Appendices A and B (strikeout/italic format).

Attachment 3: Proposed Revised CoC Appendices A and B (final form).

Attachment 4: Drawing Revision Summary, Revised Holtec Design Drawings, and New Dresden Unit 1 Damaged Fuel Canister and Thoria Rod Canister Drawings.

Attachment 5: Proposed Revision 11 Changes to the HI-STAR Topical Safety Analysis Report.

This LAR proposes changes to the Appendices to the CoC, the design drawings, and the TSAR which include 1) editorial corrections and clarifications, 2) revisions to limits for existing fuel

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array/classes 3) two new fuel array/classes, 4) two new fuel canisters, 5) two types of non-fuel PWR hardware, and 6) antimony-beryllium neutron sources. The new fuel canisters added are those in which Dresden Unit 1 fuel assemblies previously stored at West Valley are now stored in Dresden Units 2 and 3 spent fuel pools.

The drawing changes (indicated by "Rev triangles" in the body of the design drawings and Bills-of-Material) are entirely due to the minor errors, internal consistencies, and ambiguities in the previous revisions which have been detected during the manufacturing process of the prototype and the first production unit (Serial No. 001) for Plant Hatch. The changes to the drawings accordingly seek to clarify inspection criteria, remove ambiguity in verbiage, provide explicit design direction to the manufacturer, eliminate internal inconsistencies, and replace unfabricable details with those that can be fabricated with reduced welding-induced distortion. In some cases, where experience has shown that a higher quality level can be achieved through well-calibrated fixturing, the recourse to inherently inferior palliatives (such as shims) has been removed to assure improved hardware quality. In all cases, the safety margins reported in the TSAR and in the NRC's Safety Evaluation Report continue to remain robust.

All changes in the drawings and TSAR text material have been subjected to our rigorous multi-disciplinary engineering change acceptance review process and appropriately documented in our quality files.

In order to be able to implement these enhancements into the ongoing fabrication of the HI-STAR 100 Systems for Southern Company's Plant Hatch and Commonwealth Edison's Dresden Unit 1, and to support defueling of the D-1 pool in ca. 2000, it is essential that we receive NRC's approval of this amendment by February 28, 2000. We believe that the scope of this amendment request, as it relates to the underlying design analyses, is minor enough that direct-to-final rulemaking would be the appropriate process for approval.

This submittal also contains information in the form of a Holtec Standard Procedure (HSP-107) which is commercially sensitive to Holtec International and is treated by us with strict confidentiality. This information is of the type described in 10CFR2.790(b)(4). The entirety of this procedure is considered proprietary to Holtec. The attached affidavit sets forth the bases for which the information is required to be withheld by the NRC from further disclosure, consistent with these considerations and pursuant to the provisions of 10CFR2.790(b)(1). It is therefore requested that the proprietary information enclosed be withheld from public disclosure in accordance with applicable NRC regulations.

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We appreciate the SFPO's consideration of our request for an expedited review and approval of this amendment application.

Sincerely,

Brian Gutherman, P.E.
Licensing Manager

Approved:

K. P. Singh, Ph.D., P.E.
President and CEO

Document I.D.: 5014354

Attachments: 1 – 5: As Stated Above
6. Affidavit Pursuant to 10 CFR 2.790

Enclosure: Holtec Standard Procedure HSP-107

Cc: Ms. Virginia Tharpe, USNRC, (10 hard copies, w/attach and encl.; one HI-STAR TSAR, Revision 10 on CD-ROM; and floppy disk of cover letter and Attachments 1 through 3)

Dr. Stan Turner Florida Operations Center (cover letter only)
Mr. E. W. Brach (cover letter only)
Ms. S. Frant-Shankman (cover letter only)
Mr. Ross Chappell (cover letter only)

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INTERNATIONAL

Holtec Center, 555 Lincoln Drive West, Marlton, NJ 08053
Telephone (856) 797-0900
Fax (856) 797-0909

Technical Concurrence:

Mr. Bernard Gilligan (Configuration Control)	[signature]
Dr. Alan Soler (Structural Evaluation)	Alan Soler
Dr. Indresh Rampall (Thermal/Accident Evaluations)	Indresh Rampall
Dr. Everett Redmond II (Shielding Evaluation)	[signature]
Dr. Stefan Anton (Criticality Evaluation)	Stefan Anton
Mr. Kris Cummings (Confinement Evaluation)	[signature]
Mr. Steve Agace (Operations)	[signature]
Mr. Mark Soler (Quality Assurance)	[signature]

Client Distribution (w/ attach. 1, w/o encl.) :

Recipient	Utility
Mr. David Bland	Southern Nuclear Operating Company
Mr. Ken Phy	New York Power Authority
Mr. J. Nathan Leech	Commonwealth Edison
Dr. Max DeLong	Private Fuel Storage
Mr. Stan Miller	Vermont Yankee Nuclear Power Corporation
Mr. Bruce Patton	Pacific Gas & Electric – Diablo Canyon
Mr. Mark Smith	Pacific Gas & Electric – Humboldt Bay
Mr. Rodney Pickard	American Electric Power
Mr. David Larkin	Energy Northwest
Mr. Eric Meils	Wisconsin Electric Power Company
Mr. Paul Plante	Maine Yankee Atomic Power Company
Mr. Jeff Ellis	Southern California Edison
Mr. Darrell Williams	Entergy Operations – Arkansas Nuclear One
Mr. Joe Andrescavage	GPUN – Oyster Creek Nuclear Power Station
Mr. Ron Bowker	IES Utilities

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Holtec Center, 555 Lincoln Drive West, Marlton, NJ 08053

Telephone (856) 797-0900
Fax (856) 797-0909

Client Distribution (w/ attach. 1, w/o encl.) (cont'd):

Mr. William Swantz	Nebraska Public Power District
Mr. Chris Kudla	Entergy Operations – Millstone Unit 1 Decommissioning
Mr. Keith Waldrop	Duke Power
Mr. Matt Eyre	PECO Energy
Mr. Al Gould	Florida Power & Light
Dr. Seymour Raffety	Dairyland Power
Mr. John Sanchez	Consolidated Edison
Ms. Kathy Picciott	Niagara Mohawk

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HI-STAR 100 CERTIFICATE OF COMPLIANCE 72-1008

CERTIFICATE AMENDMENT REQUEST 1008-1

993470002

U.S. Nuclear Regulatory Commission
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Document ID 5014354
Attachment 6

AFFIDAVIT PURSUANT TO 10CFR2.790

I, Alan I. Soler, being duly sworn, depose and state as follows:

(1) I am Executive Vice President of Holtec International and have reviewed the information described in paragraph (2) which is sought to be withheld, and am authorized to apply for its withholding.

(2) The information sought to be withheld are is Holtec International Document ID No. HSP-107, *Manufacturing and Testing Procedure for Holtite Neutron Shielding Material*, Revision 3. This document is considered proprietary to Holtec International.

(3) In making this application for withholding of proprietary information of which it is the owner, Holtec International relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4) and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10CFR Part 9.17(a)(4), 2.790(a)(4), and 2.790(b)(1) for "trade secrets and commercial or financial information obtained from a person and privileged or confidential" (Exemption 4). The material for which exemption from disclosure is here sought is all "confidential commercial information", and some portions also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by Holtec's competitors without license from Holtec International constitutes a competitive economic advantage over other companies;

AFFIDAVIT PURSUANT TO 10CFR2.790

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b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.

c. Information which reveals cost or price information, production, capacities, budget levels, or commercial strategies of Holtec International, its customers, or its suppliers;

d. Information which reveals aspects of past, present, or future Holtec International customer-funded development plans and programs of potential commercial value to Holtec International;

e. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs 4.a, 4.b, 4.d, and 4.e, above.

(5) The information sought to be withheld is being submitted to the NRC in confidence. The information (including that compiled from many sources) is of a sort customarily held in confidence by Holtec International, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by Holtec International. No public disclosure has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to the NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

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(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access to such documents within Holtec International is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his designee), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside Holtec International are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information classified as proprietary was developed and compiled by Holtec International at a significant cost to Holtec International. This information is classified as proprietary because it contains detailed descriptions of analytical approaches and methodologies not available elsewhere. This information would provide other parties, including competitors, with information from Holtec International's technical database and the results of evaluations performed by Holtec International. Release of this information would improve a competitor's position without the competitor having to expend similar resources for the development of the database. A substantial effort has been expended by Holtec International to develop this information.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to Holtec International's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of Holtec International's comprehensive spent fuel storage technology base, and its commercial value extends beyond the original development cost. The

value of the technology base goes beyond the extensive physical database and analytical methodology, and includes development of the expertise to determine and apply the appropriate evaluation process.

The research, development, engineering, and analytical costs comprise a substantial investment of time and money by Holtec International.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

Holtec International's competitive advantage will be lost if its competitors are able to use the results of the Holtec International experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to Holtec International would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive Holtec International of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

U.S. Nuclear Regulatory Commission
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Attachment 6

AFFIDAVIT PURSUANT TO 10CFR2.790

STATE OF NEW JERSEY)
) ss:
COUNTY OF BURLINGTON)

Dr. Alan I. Soler, being duly sworn, deposes and says:

That he has read the foregoing affidavit and the matters stated therein are true and correct to the best of his knowledge, information, and belief.

Executed at Marlton, New Jersey, this 22nd day of November, 1999.

Alan Soler

Dr. Alan I. Soler
Holtec International

Subscribed and sworn before me this 22nd day of November, 1999.

Maria C. Pepe

MARIA C. PEPE
NOTARY PUBLIC OF NEW JERSEY
My Commission Expires April 25, 2000

ATTACHMENT 1

SUMMARY OF PROPOSED CHANGES

SUMMARY OF PROPOSED CHANGES

SECTION I – PROPOSED CHANGES TO CERTIFICATE OF COMPLIANCE 1008

Proposed Change No. 1

Certificate of Compliance, Appendices A and B, Definitions:

a. The definition of DAMAGED FUEL ASSEMBLY is revised as shown in the attached marked-up pages of Appendices A and B to add the words "as determined by a review of records." The definition in Appendix B is also revised to make it consistent with Appendix A.

b. The definition of DAMAGED FUEL CONTAINER (DFC) in Appendices A and B is revised to include both the Holtec-designed DFC and a Transnuclear (TN) DFC[1] currently containing Dresden Unit 1 (D-1) fuel. Drawings of the TN DFC are contained in Attachment 4 and will be added to TSAR Section 1.5 (see Section II of this attachment for the list of drawings).

c. The definition of PLANAR-AVERAGE INITIAL ENRICHMENT is revised as shown in the attached marked-up pages of Appendix B to delete the word "simple" and add the word "initial."

Reason for Proposed Changes

a and c. The current definitions of these terms are inconsistent between these two appendices and between the storage and transportation certificates of compliance.

b. There are a significant number of Dresden Unit 1 fuel assemblies meeting the HI-STAR fuel specifications which are currently stored in TN DFCs. Authorizing this fuel for storage in the HI-STAR 100 system without having to remove it from the TN/D-1 DFCs and load it into the Holtec DFCs will avoid imposing undue burden on the general licensee with no additional safety benefit. Implementation of this change will allow Dresden Unit 1 to complete decommissioning of the plant in a timely manner. Further, the fuel in the TN/D-1 DFCs is currently located in the Dresden Unit 2/3 spent fuel pool. Removal of this fuel is necessary to maintain full core offload capability and allow D-2/3 to continue operation.

[1] The terms Damaged Fuel Container and Damaged Fuel Canister are used interchangeably throughout this document and "DFC" is applicable to both.

Justification for Proposed Changes

a and c. Required for editorial consistency within, and between the HI-STAR CoCs.

b. The justification for this proposed change is provided below, arranged by technical discipline, as applicable. Conforming changes to the TSAR are summarized in Section II of this attachment and included in Attachment 5.

Structural Evaluation

The TN/D-1 DFC was previously approved for use in the TN-9 transportation package. In addition, the TN/D-1 DFC has been structurally evaluated by Holtec International and found to meet all design requirements for storage in the HI-STAR 100 system. The details of this evaluation are contained in proposed new TSAR Appendix 3.AI, included in Attachment 5 to this letter. All required safety margins are greater than zero or, in other words, the factors of safety are greater than 1.0.

The TSAR Chapter 3 NUREG-1536 compliance matrix has been revised to address the new DFCs and the supporting appendix. Since all required text changes are confined to the new appendix, no new chapter text is required.

Thermal Evaluation

Storage of damaged fuel and fuel debris meeting the specifications of the CoC is permitted in the HI-STAR MPC-68 and –68F when encased in a DFC. The thermal characteristics of the TN/D-1 DFC and the Holtec DFC shown on their respective design drawings (Attachment 4) were compared in support of this amendment request. The TN/D-1 DFC is a square shaped canister box fabricated from 12 gage stainless steel plates. A bounding thermal calculation has been prepared in support of this amendment to determine the most heat resistive fuel from the Low Heat Emitting (LHE) group of assemblies encased in a DFC. It is noted that in this configuration, interruption of radiation heat exchange between the fuel assembly and the fuel basket by the DFC boundary renders the DFC configuration as the bounding case when compared with the absence of a DFC. Both canister designs were evaluated and the one exhibiting lower heat dissipation characteristics was adopted for analysis.

For the LHE group of assemblies, the low decay heat load of D-1 fuel (approximately 8 kW) guarantees large thermal margins to permit safe storage of D-1 fuel in the TN/D-1 DFC. The HI-STAR temperature field for this case was calculated and is reported in proposed revisions to HI-STAR TSAR Chapter 4 at Subsection 4.4.1.1.16 (see Attachment 5). Substantial cladding thermal margins (approximately 50°F) are demonstrated by the analysis.

Shielding Evaluation

Storage of damaged fuel and fuel debris meeting the specifications of the CoC is permitted in the HI-STAR MPC-68 and MPC-68F when encased in a DFC. Sections 5.4.2 and 5.4.4 of the HI-STAR TSAR, Revision 10 discuss the post-accident shielding evaluation for the damaged fuel. These sections assume that the damaged fuel assemblies and fuel debris collapse to a height of 80 inches. This dimension was calculated based on the inside dimension of the DFC and the dimensions of the fuel assemblies. Since the TN/D-1 DFC has a smaller inside dimension than the Holtec DFC, the analysis in Sections 5.4.2 and 5.4.4 of the HI-STAR TSAR is applicable and conservative. In addition, the shielding analysis does not take credit for the DFC container in determining the acceptability of storing the approved damaged fuel and fuel debris. Therefore, the use of the TN/D-1 DFC does not affect the shielding analysis and no changes to the Chapter 5 of the TSAR are necessary as a result of this proposed change.

Criticality Evaluation

The TN/D-1 DFC was analyzed with the same set of contents used for the analysis of the Holtec DFC documented in Rev. 10 of the HI-STAR 100 TSAR. This set includes 6x6 and 7x7 fuel assemblies with various numbers of rods missing, a collapsed assembly and dispersed fuel powder. The maximum k_{eff} values for both DFCs are listed in proposed Revision 11 TSAR Table 6.4.5 (Attachment 5). There is no significant difference in reactivity between the two DFCs. For only one case (collapsed assembly), the reactivity for the TN/D-1 DFC is increased marginally ($\Delta k = 0.0012$) compared to the Holtec DFC. In all other cases, the reactivity for the TN/D-1 DFC is below the reactivity of the Holtec DFC with the same contents. Therefore, with the TN/D-1 DFC used instead of the Holtec DFC, the cask system is still in compliance with the regulatory requirement of $k_{eff} < 0.95$ for all authorized contents.

Proposed Change No. 2

Certificate of Compliance, Appendix A, LCO 2.1.1 and Table 2-1:

The MPC helium backfill *density* limit is revised to be a maximum helium backfill *pressure* with acceptance criteria as shown in the attached marked-up LCO and table.

Reason for Proposed Change

Technical Specification (TS) density limits for helium backfill of the MPC are necessary when basket internal convection heat transfer is relied upon for safe storage of the spent nuclear fuel. The HI-STAR licensing basis completely neglects this mode of heat transfer. The existing TS limits on helium backfill density are, therefore, overly restrictive and a change in favor of a simpler requirement is warranted. The change is designed to relieve the users of an unnecessary burden of confirming helium backfill within in a very narrow range of acceptance.

Justification for Proposed Change

The proposed change to the MPC helium backfill TS requires the users to backfill the MPC up to a maximum helium pressure. This ensures the presence of helium in the MPC free space. Any positive helium pressure in the MPC (i.e., > 1 atm) is consistent with the governing thermal analyses. The positive helium pressure in the MPC along with the helium pressure of between 10 and 14 psig in the HI-STAR overpack annulus (also required by the TS) provide reasonable assurance of no air inleakage into the MPC cavity during storage operations. The upper pressure limit protects the MPC from potential overpressure during the hypothetical accident scenario where 100% of the fuel rods are assumed to rupture.

Proposed Change No. 3

Certificate of Compliance, Appendix B, Subsection 1.1.1:

a. The wording of Item 1.1.1.a is revised to add the words "and certain non-fuel hardware" and to revise the cross reference from "Table 1.1-5" to "Table 1.1-6."

b. The existing subsection numbering includes two "Item c's." Correct the second Item "c" to be Item "d."

Reason for Proposed Changes

a. This is a conforming change to support the addition of Burnable Poison Rod Assemblies (BPRAs) and Thimble Plug Devices (TPDs)[2] to the CoC for storage in HI-STAR 100.

b. Editorial correction.

Justification for Proposed Changes

a. Clarification to recognize that BPRAs and TPDs are authorized for loading.

b. Editorial correction.

Proposed Change No. 4

Certificate of Compliance, Appendix B, Section 1.4, Subsection 6.d:

The underlining of the words between "...USCS)..." and "...Standard Test Method..." is removed.

Reason and Justification for Proposed Change

Editorial Correction.

Proposed Change No. 5

Certificate of Compliance, Appendix B, Section 1.5, Subsection 1.5.2.1:

The term "painted surface of" is replaced with "paint used on."

Reason for Proposed Change

To clarify the intent of the TS requirement to mean that the paint used on the overpack must have an emissivity of no less than 0.85.

Justification for Proposed Change

This clarification allows qualification of a paint and a process rather than requiring an emissivity test on the surface of every painted overpack. The change

[2] In this text and in the proposed CoC and TSAR changes, the terms BPRA and TPD are used as generic terms for all similarly designed devices with different names, including Wet Annular Burnable Absorbers (WABAs) and orifice rod assemblies. Appropriate clarifying text has been added to TSAR Chapter 5.

still ensures the underlying technical requirement that the overpack surface have an emissivity no less than 0.85.

Proposed Change No. 6

Certificate of Compliance, Appendix B, Table 1.1-1:

The following editorial corrections in Table 1.1-1 are made:

a. Item II.B for the MPC-68 is revised to make "up to a total of" lower case.

b. The word "specified" is added after the word "criteria" in Item III.A.1 for the MPC-68F.

Reason and Justification for Proposed Changes

Editorial corrections.

Proposed Change No. 7

Certificate of Compliance, Appendix B, Table 1.1-1:

MPC-24, Items I.A and C, and Tables 1.1-4 and 1.1-5 are revised; and new Table 1.1-6 is added as shown in the attached marked-up CoC pages to allow storage of Burnable Poison Rod Assemblies and Thimble Plug Devices.

Reason for Proposed Change

Non-fuel hardware, included in the original HI-STAR TSAR for initial licensing, was voluntarily removed during the review process in 1998 to help expedite the issuance of a CoC for the HI-STAR 100 System. A large number of PWR plant fuel assemblies are currently stored in spent fuel pools with either BPRAs or TPDs (including similarly design devices with different names) as integral hardware to the assembly. This irradiated hardware must be authorized for dry storage with the assemblies to accommodate user needs and is therefore proposed to be added to the authorized contents.

Justification for Proposed Change

Structural Evaluation

There is no effect on the structural evaluation because these changes do not change the fuel assembly length, width, or weight used in the structural analyses.

The limits on these parameters as stated elsewhere in the CoC fuel tables remain the same and fuel assemblies containing these components must meet these limits.

Thermal Evaluation

The non-fuel bearing hardware (i.e. BPRAs and TPDs), as a result of in-core irradiation becomes activated. In the dry cask storage scenario, this hardware represents a Low Heat Emitting (LHE) source distributed over the length of the fuel assembly. The non-fuel hardware contribution to the total decay heat load burden of a cask is quite small (~0.3 kW).

The BPRAs, when inserted in the fuel assemblies, displace the gas in the guide tubes and replace them with solid materials (neutron absorbers & metals) which conduct heat much more readily. As a result, dissipation of heat by the fuel assemblies is enhanced by the presence of these components. In the thermal evaluation supporting this amendment request, no credit was taken for this enhanced decay heat dissipation. Thus, the design basis heat load (Q_d) of the HI-STAR cask is conservatively unaltered by this proposed change. The total design basis decay heat load on the HI-STAR cask is the sum of the decay heat from fuel assemblies (Q_f) and from the non-fuel hardware (Q_h). The maximum decay heat contribution by non-fuel hardware is determined by source term calculations documented in Chapter 5. To determine permissible burnup and cooling time limits for storage in the HI-STAR cask, Q_f is computed by the difference between Q_d and Q_h. This adjusted total fuel assembly heat load (after accounting for non-fuel hardware contribution) was then used to propose the burnup and cooling time limits for storage of those assemblies containing BPRAs or TPDs (see proposed revised CoC Tables 1.1-4 and 1.1-5 and new Table 1.1-6).

The addition of this non-fuel hardware has two effects on the MPC cavity pressures. As discussed in the last paragraph, non-fuel hardware enhances heat dissipation, thus lowering fuel and MPC cavity fill gas temperatures. The gas volume displaced by the mass of the non-fuel hardware lowers the cavity free volume. These two effects, namely, temperature lowering and free volume reduction have opposing influence on the MPC cavity pressure. The first effect lowers the gas pressure while the second effect raises it. In the HI-STAR thermal analysis, the computed temperature field (with non-fuel hardware *excluded*) provides a conservatively bounding thermal response of the HI-STAR cask. The MPC cavity free space was computed based on displacement by the heaviest fuel (bounding weight) with non-fuel hardware *included*. Thus, the previously computed MPC cavity pressure results remain conservative with respect to gas temperature and free space as affected by the changes proposed in this amendment.

BPRAs containing helium gas have been evaluated under the hypothetical accident condition where 100% of the BPRAs rupture, releasing all of the contained helium into the MPC-24 cavity. The maximum helium backfill pressure TS limit for the MPC-24 is adjusted appropriately lower (than that for the MPC-68 and –68F) so that the resultant post-accident MPC cavity pressure, including BPRAs gas release, is limited to an acceptable value, within the design pressure of the MPC. Appropriate discussion has been added to proposed Revision 11 TSAR Chapters 4 and 11 (see Attachment 5).

Shielding Evaluation

Burnable Poison Rod Assemblies (including Wet Annular Burnable Absorbers and other similarly designed devices with different names) and Thimble Plug Devices (including orifice rod assemblies, guide tube plugs, and other similarly designed devices with similar names) are an integral, yet removable, part of a large portion of PWR fuel. The TPDs are not used in all assemblies in a reactor core, but are re-used from cycle to cycle. Therefore, these devices can achieve very high burnups. In contrast, BPRAs are burned with a fuel assembly in core and are not reused. In fact, many BPRAs are removed after one or two cycles before the fuel assembly is discharged. Therefore, the achieved burnup for BPRAs is not significantly different than fuel assemblies.

TPDs are made of stainless steel and contain a small amount of Inconel. These devices extend down into the plenum region of the fuel assembly but do not extend into the active fuel region with the exception of the Westinghouse 14x14 water displacement guide tube plugs. Since these devices are made of stainless steel, there is a significant amount of Co-60 produced during irradiation. This is the only significant radiation source from the activation of steel and Inconel.

BPRAs are made of stainless steel in the region above the active fuel zone and may contain a small amount of Inconel in this region. Within the active fuel zone the BPRAs may contain 2-24 rodlets which are burnable absorbers clad in either zircaloy or stainless steel. The stainless steel clad BPRAs create a significant radiation source (Co-60) while the zircaloy clad BPRAs create a negligible radiation source. Therefore the stainless steel clad BPRAs are bounding.

SAS2H and ORIGEN-S were used to calculate a radiation source term and decay heat level for the TPDs and BPRAs. These calculations were performed by irradiating the appropriate mass of steel and Inconel using the flux calculated for the design basis B&W 15x15 fuel assembly. The mass of material in the regions above the active fuel zone was scaled by the appropriate scaling factors listed in Table 5.2.10 of the HI-STAR TSAR, Rev. 10 in order to account for the reduced flux levels above the fuel assembly. The total curies of cobalt and the decay heat load were calculated for the TPDs and BPRAs as a function of burnup and cooling time. For burnups beyond 45,000 MWD/MTU, it was assumed, for the purpose of the calculation, that the burned fuel assembly was replaced with a fresh fuel assembly every 45,000 MWD/MTU. This was achieved in ORIGEN-S by resetting the flux levels and cross sections to the 0 MWD/MTU condition after every 45,000 MWD/MTU.

Since the HI-STAR 100 cask system is designed to store many varieties of PWR fuel, a bounding TPD and BPRA had to be determined for the purposes of the analysis. This was accomplished by analyzing all of the fuel containing BPRAs and TPDs (Westinghouse and B&W 14x14 through 17x17) found in references [5.2.5] and [5.2.7] listed in Section 5.6 of the TSAR to determine the TPD and BPRA which produced the highest Co-60 source term and decay heat for a specific burnup and cooling time. The bounding TPD was determined to be the Westinghouse 17x17 guide tube plug and the bounding BPRA was actually determined by combining the higher masses of the Westinghouse 17x17 and 15x15 BPRAs into a single hypothetical BPRA. The masses of this TPD and BPRA are listed in Table 5.2.29 of the proposed Revision 11 of the HI-STAR TSAR (see Attachment 5). As mentioned above, reference [5.2.5] describes the Westinghouse 14x14 water displacement guide tube plug as having a steel portion which extends into the active fuel zone. This particular water displacement guide tube plug was analyzed and determined to be bounded by the design basis TPD and BPRA.

Once the bounding BPRA and TPD were determined, the allowable decay heat load and Co-60 source from the BPRA and TPD were specified: 0.77 Watts and 50 Curies for each TPD, and 13.0 watts and 831 Curies for each BPRA. Table 5.2.30 of the proposed Revision 11 of the HI-STAR TSAR shows the Curies of Co-60 that were calculated for BPRAs and TPDs in each region of the fuel assembly (e.g., incore, plenum, top). The allowable decay heat load for the TPDs and BPRAs was subtracted from the allowable decay heat load per assembly to determine the allowable PWR fuel assembly burnup and cooling times listed in Appendix B, Table 1.1-5 of the proposed changes to the Certificate of Compliance. Since the decay heat load of the TPDs is negligible, the same burnup and cooling time is used for assemblies with or without TPDs. However, a different burnup and cooling time is used for assemblies that contain BPRAs to account for the allowable BPRA decay heat load of 13.0 watts. A separate allowable burnup and cooling time is used for the BPRAs and TPDs themselves. These burnup and cooling times assure that the decay heat load and Co-60 activity remain below the allowable levels specified above. It should be noted that at very high burnups (greater than 200,000 MWD/MTU) the TPD decay heat load for a given cooling time actually decreases as the burnup continues to increase. This is due to a decrease in the Co-60 production rate as the initial Co-59 impurity is depleted. Conservatively, a constant cooling time has been specified for burnups from 180,000 to 630,000 MWD/MTU for the TPDs.

In order to verify that the BPRAs and TPDs do not affect the shielding analysis in Revision 10 of the HI-STAR TSAR, total dose rates were calculated for the HI-STAR 100 assuming all fuel assemblies in the MPC contained either BPRAs or TPDs. For this calculation, burnups slightly higher than the allowable burnups listed in the proposed revised Certificate of Compliance were used for a chosen cooling time. The dose rates were shown to be bounded by the current dose rates listed in Revision 10 of the HI-STAR TSAR for a burnup of 40,000 MWD/MTU and 5 year cooling for PWR fuel assemblies. Therefore, the addition of BPRAs and TPDs to the MPC-24 is bounded by the shielding analysis in Revision 10 of the HI-STAR TSAR. Section 5.4.6 of the proposed Revision 11 of the HI-STAR 100 TSAR gives a detailed comparison of the dose rates for fuel assemblies with BPRAs and TPDs to the dose rate from the design basis fuel assemblies (see Attachment 5).

Criticality Evaluation

Inserts into PWR fuel assemblies such as TPDs and BPRAs, have no effect on the criticality analyses. The reactivity of any PWR assembly with inserts is bounded by (i.e. lower than) the reactivity of the same assembly without the insert. This is due to the fact that the insert reduces the amount of moderator in the assembly, while the amount of fissile material remains unchanged. Therefore, from a criticality safety perspective, inserts into PWR assemblies are acceptable for all allowable PWR types, and increase the safety margin.

Proposed Change No. 8

Certificate of Compliance, Appendix B, Table 1.1-1:

New Items II.A.5 and III.A.7 are added to Table 1.1-1 for MPC-68 and MPC–68F as shown in the attached marked-up pages of the CoC table to allow storage of one Dresden Unit 1 (D-1) Thoria Rod Canister in these MPC models. Drawings of the D-1 Thoria Rod Canister are provided in Attachment 4 and will be added to Section 1.5 of the TSAR (see Section II of this attachment). Conforming revisions are also made to Appendix B, Items II.B and III.B.

Reason and for Proposed Change

Dresden Unit 1 needs to place one Thoria Rod Canister into dry storage to support plant decommissioning.

Justification for Proposed Change

Structural Evaluation

The Dresden Unit 1 Thoria Rod Canister has been structurally evaluated by Holtec International and found to meet all required design requirements for storage in the HI-STAR 100 system. The details of this evaluation are contained in proposed Revision 11 TSAR Appendix 3.AI, included in Attachment 5 to this letter. All required safety margins are greater than zero or, in other words, the factors of safety are greater than 1.0.

Thermal Evaluation

The Thoria Rod Canister is designed to hold a maximum of 20 fuel rods arrayed in a 5x4 configuration. Eighteen rods are actually in the canister. The fuel rods contain a mixture of enriched UO_2 and thorium oxide in the fuel pellets. The fuel rods were originally constituted as part of an 8x8 fuel assembly and used in the second and third cycle of Dresden-1 operation. The maximum fuel burnup of these rods is quite low (< 16,000 MWD/MTIHM). The Thoria Rod Canister internal design is a honeycomb structure formed from 12 gage stainless steel plates. The rods are loaded in individual square cells and thus are isolated from each other by the cell walls. The few number of rods (18 per assembly) and very low burnup of fuel stored in these Dresden-1 canisters render them as miniscule sources of decay heat. The canister all-metal internal honeycomb construction serves as an additional means of heat dissipation in the fuel cell space. In accordance with preferential fuel loading requirements imposed in the Technical Specifications, low burnup fuel is required to be loaded toward the basket periphery (i.e., away from the hot central core of the fuel basket). All these considerations provide ample assurance that these fuel rods will be stored in a benign thermal environment and therefore remain protected during long term storage.

Shielding Evaluation

The Dresden Unit 1 Thoria Rod Canister contains 18 thoria rods which have obtained a relatively low burnup, 16,000 MWD/MTIHM. These rods were removed from two 8x8 fuel assemblies which contained 9 rods each. The irradiation of thorium produces an isotope which is not commonly found in depleted uranium fuel. Th-232, when irradiated, produces U-233. The U-233 can undergo an (n,2n) reaction which produces U-232. The U-232 decays to produce Tl-208 which produces a 2.6 MeV gamma during beta decay. This results in a significant source in the 2.5-3.0 MeV range which is not commonly present in depleted uranium fuel. Therefore, this single DFC container was analyzed to determine if it was bounded by the current shielding analysis.

A radiation source term was calculated for the 18 thoria rods using SAS2H and ORIGEN-S for a burnup of 16,000 MWD/MTIHM and a cooling time of 18 years. Table 5.2.31 of proposed Revision 11 of the HI-STAR TSAR (Attachment 5) describes the 8x8 fuel assembly that contains the thoria rods. Table 5.2.32 and 5.2.33 of proposed Revision 11 of the HI-STAR TSAR shows the gamma and neutron source terms, respectively, that were calculated for the 18 thoria rods in the Thoria Rod Canister. Comparing these source terms to the design basis 6x6 source terms for Dresden Unit 1 fuel in TSAR Tables 5.2.6 and 5.2.14 clearly indicates that the design basis source terms bound the thoria rod source terms in all neutron groups and in all gamma groups except the 2.5-3.0 MeV group. As mentioned above, the thoria rods have a significant source in this energy range due to the decay of Tl-208.

It is obvious that the neutron spectra from the 6x6 fuel assembly bounds the thoria rod neutron spectra with a significant margin. In order to demonstrate that the gamma spectrum from the single Thoria Rod Canister is bounded by the gamma spectrum from the design basis 6x6 fuel assembly, the gamma dose rate on the outer radial surface of the overpack was estimated conservatively assuming an MPC-68 filled with Thoria Rod Canisters. This gamma dose rate was compared to an estimate of the dose rate from an MPC full of design basis 6x6 fuel assemblies. The gamma dose rate from the 6x6 fuel was higher than the dose rate from an MPC full of Thoria Rod Canisters. This, in conjunction with the significant margin in neutron spectrum and the fact that only one thoria rod canister is proposed to be authorized for storage in the HI-STAR 100 System clearly demonstrates that the Thoria Rod Canister is acceptable for storage in the MPC-68 or the MPC-68F.

Criticality Evaluation

The Thoria Rod Canister is similar to a DFC with an internal separator assembly containing 18 fuel rods. The configuration is illustrated in proposed Revision 11 TSAR Figure 6.4.10 (Attachment 5). The k_{eff} value for an MPC-68F filled with Thoria Rod Canisters is calculated to be 0.18. This low reactivity is attributed to the relatively low content in ^{235}U (equivalent to UO_2 fuel with an enrichment of approximately 1.7 wt% ^{235}U), the large spacing between the rods (the pitch is approximately 1", the cladding outside diameter is 0.412") and the absorption in the separator assembly. Together with the maximum k_{eff} values listed in TSAR Tables 6.1.2 and 6.1.3 this result demonstrates that the k_{eff} for a Thoria Rod Canister loaded into the MPC68 or the MPC68F together with other approved fuel assemblies or DFCs will remain well below the regulatory requirement of $k_{eff} < 0.95$.

Confinement Evaluation

The HI-STAR confinement analyses have been revised to account for several new isotopes associated with the Thoria Rod Canister. These isotopes (Bi-212, Pb-212, Po-216, Ra-224, Rn-220, Th-228 and U-232) had a negligible effect on the resulting doses because only one Thoria Rod Canister is authorized for loading in an MPC-68 or –68F with 67 other design basis BWR assemblies. Therefore, the Thoria Rod isotopes are not included in the presentation of the confinement analysis inputs or results in the TSAR.

Proposed Change No. 9

Certificate of Compliance, Appendix B, Table 1.1-1

New Items II.D and III.D are added as shown in the attached marked-up CoC pages to authorize Dresden Unit 1 fuel assemblies containing up to one antimony-beryllium neutron source in the assembly lattice for storage.

Reason for Proposed Change

Dresden Unit 1 needs to place fuel assemblies containing antimony-beryllium neutron sources into dry storage to support plant decommissioning.

Justification for Proposed Change

Structural Evaluation

The structural evaluation is not affected because the fuel assembly parameters used in the design basis structural evaluations are not affected by this change. The neutron sources have no impact on component temperatures or fuel assembly size and weight.

Thermal Evaluation

The substitution of antimony-beryllium sources in a fuel assembly in lieu of heat emitting fuel rods is bounded by the existing thermal analyses, which assume decay heat production from the replaced fuel rods.

Shielding Evaluation

Dresden Unit 1 has antimony-beryllium neutron sources which are placed in the water rod location of their fuel assemblies. These sources are steel rods which contain a cylindrical antimony-beryllium source which is 77.25 inches in length. The steel rod is approximately 95 inches in length. Information obtained from Dresden Unit 1 characterizes these sources in the following manner: "About one-quarter pound of beryllium will be employed as a special neutron source material. The beryllium produces neutrons upon gamma irradiation. The gamma rays for the source at initial start-up will be provided by neutron-activated antimony (about 865 curies). The source strength is approximately 1E+8 neutrons/second."

As stated above, beryllium produces neutrons through gamma irradiation and, in this particular case, antimony is used as the gamma source. The threshold gamma energy for producing neutrons from beryllium is 1.666 MeV. The outgoing neutron energy increases as the incident gamma energy increases. Sb-124, which decays by beta decay with a half life of 60.2 days, produces a gamma of energy 1.69 MeV which is just energetic enough to produce a neutron from beryllium. Approximately 54% of the beta decays for Sb-124 produce gammas with energies greater than or equal to 1.69 MeV. Therefore, the neutron production rate in the neutron source can be specified as 5.8E-6 neutrons per gamma (1E+8/865/3.7e+10/0.54) with energy greater than 1.666 MeV or 1.16E+5 neutrons/curie (1E+8/865) of Sb-124.

With the short half life of 60.2 days, all of the initial Sb-124 is decayed and any Sb-124 that was produced while the neutron source was in the reactor is also decayed since these neutron sources are required to have the same minimum cooling time as the Dresden 1 fuel assemblies (array classes 6x6A, 6x6B, 6x6C, and 8x8A) of 18 years. Therefore, there are only two possible gamma sources which can produce neutrons from this antimony-beryllium source. The first is the gammas from the decay of fission products in the fuel assemblies in the MPC. The second gamma source is from Sb-124 which is produced in the MPC from neutron activation by neutrons from the decay of fission products.

MCNP calculations were performed to determine the gamma source as a result of decay gammas from fuel assemblies and Sb-124 activation. The calculations explicitly modeled the 6x6 fuel assembly described in Table 5.2.2 of Revision 10 of the HI-STAR TSAR. A single fuel rod was removed and replaced by a guide tube. In order to determine the amount of Sb-124 that is activated from neutrons in the MPC it was necessary to estimate the amount of antimony in the neutron source. The O.D. of the source was assumed to be the I.D. of the steel rod encasing the source (0.345 in.). The length of the source is 77.25 inches. The beryllium is assumed to be annular in shape encompassing the antimony. Using the assumed O.D. of the beryllium and the mass and length, the I.D. of the beryllium was calculated to be 0.24 inches. The antimony is assumed to be a solid cylinder with an O.D. equal to the I.D. of the beryllium. These assumptions are conservative since the antimony and beryllium are likely encased in another material which would reduce the mass of antimony. A larger mass of antimony is conservative since the calculated activity of Sb-124 is directly proportional to the initial mass of antimony.

The number of gammas from fuel assemblies with energies greater than 1.666 MeV entering the 77.25 inch long neutron source was calculated to be 1.04E+8 gammas/sec which would produce a neutron source of 603.2 neutrons/sec (1.04E+8 * 5.8E-6). The steady state amount of Sb-124 activated in the antimony was calculated to be 39.9 curies. This activity level would produce a neutron source of 4.63E+6 neutrons/sec (39.9 * 1.16E+5) or 6.0E+4 neutrons/sec/inch (4.63E+6/77.25). These calculations conservatively neglect the reduction in antimony and beryllium which would have occurred while the neutron sources were in the core and being irradiated at full reactor power.

Since this is a localized source (77.25 inches in length) it is appropriate to compare the neutron source per inch from the design basis Dresden Unit 1 fuel assembly, 6x6, containing an Sb-Be neutron source to the design basis fuel neutron source per inch. This comparison, presented in Table 9.1 below, demonstrates that a Dresden Unit 1 fuel assembly containing an Sb-Be neutron source is bounded by the design basis fuel.

As stated above, the Sb-Be source is encased in a steel rod. Therefore, the gamma source from the activation of the steel was considered assuming a burnup of 120,000 MWD/MTU which is the minimum burnup assuming the Sb-Be source was in the reactor for the entire 18-year life of Dresden Unit 1. The cooling time was assumed to be 18 years which is the minimum cooling time for Dresden Unit 1 fuel. The source from the steel was bounded by the design basis fuel assembly. In conclusion, storage of a Dresden Unit 1 Sb-Be neutron source in a Dresden Unit 1 fuel assembly is acceptable and bounded by the current analysis.

Table 9.1
Comparison of Neutron Source per Inch per Second for Design Basis 7x7 Fuel and Design Basis Dresden Unit 1 Fuel

Assembly	Active fuel length (inches)	Neutrons per sec per inch	Neutrons per sec per inch with Sb-Be source	Reference for neutrons per sec per inch
7x7 design basis	144	5.60E+5	N/A	Table 5.2.13 Rev. 10 HI-STAR TSAR 35 GWD/MTU and 5 year cooling
6x6 design basis	110	2.0E+5	2.6E+5	Table 5.2.14 Rev. 10 HI-STAR TSAR
6x6 design basis MOX	110	3.06E+5	3.66E+5	Table 5.2.17 Rev. 10 HI-STAR TSAR

Criticality Evaluation

The reactivity of a fuel assembly is not affected by the presence of a neutron source (other than by the presence of the material of the source, which is discussed later). This true because in a system with a k_{eff} less than 1.0, any given neutron population at any time, regardless of its origin or size, will decrease over time. Therefore, a neutron source of any strength will not increase reactivity, but only the neutron flux in a system, and no additional criticality analyses are required. Sources are inserted as rods into fuel assemblies, i.e., they replace either a fuel rod or water rod (moderator). Therefore, the insertion of the material of the source into a fuel assembly will also not lead to an increase of reactivity.

Proposed Change No. 10

Certificate of Compliance, Appendix B, Tables 1.1-2 and 1.1-3

Notes at the end of Tables 1.1-2 and 1.1-3 are revised/added as shown in the attached marked-up pages of the CoC. Pointers to these notes in the tables are also revised accordingly.

a. Note 1 in both tables is revised to reduce the scope of the note to apply to dimensional limits only.

b. Note 3 in both tables is revised address only the uranium weight data previously included in Note 1. The note has also been revised to clarify the intent. Previous Note 3 in Table 1.1-2 is now Note 4. Previous Notes 3 through 9 in Table 1.1-3 are now Notes 4 through 10.

c. Re-numbered Note 4 in Table 1.1-3 is revised to increase the allowable weight percent of U-235 in the MOX rods of fuel assembly array/class 6x6B from 0.612 to 0.635. This note is also clarified to state that the weight percentages are to be calculated based on the total fuel weight (i.e., uranium oxide plus plutonium oxide).

d. New Note 11 is added to Table 1.1-3.

e. New Note 12 is added to Table 1.1-3.

f. New Note 13 is added to Table 1.1-3.

Reason for Proposed Changes

a. The current Note 1 addresses both dimensional limits and uranium weight limits. This was inappropriate since the note conveys different information for these different data types. Splitting the notes removes a potential source of confusion for the user and makes HI-STAR consistent with HI-STORM (Docket 72-1014).

b. As currently worded, it is unclear whether implementation of the tolerance offered by Note 3 allows adjusting the value of the as-delivered uranium mass for a fuel assembly, or adjusting the uranium mass limit specified in the table for comparison against users' fuel records. The intent is to adjust the uranium mass limit up (within the prescribed tolerance), as necessary, for comparison against users fuel records. This eliminates a potential poor practice of users adjusting uranium mass values found on fuel records.

c. User feedback indicates that there are fuel assemblies with MOX rods containing less than 1.578 weight percent fissile plutonium in natural uranium. To bound this situation, the uranium content in the MOX rods is increased slightly. The second change to Note 4 is proposed to improve clarity regarding the intent of the note.

d. New Note 11 is proposed in response to user feedback that some assemblies may include non-fuel rods which are filled with non-fissile material in lieu of water.

e. New Note 12 is proposed to be added for information on this new array/class.

f. New Note 13 is proposed to address a situation for the 9x9E fuel assembly array/class where one assembly type in the class (SPC 9x9-5) contains rods of different dimensions within the array.

Justification for Proposed Changes

a. Enhances user implementation.

b. None. The tolerance in the mass limit allowed by this note is in the current, approved CoC.

c. All criticality calculations for the 6x6B fuel assembly array/class were re-performed (see proposed revised TSAR Table 6.2.38 in Attachment 5). The change in reactivity for this change is small (less than 2σ). This demonstrates that the maximum k_{eff} remains below 0.95 with the increased uranium concentration. The second change is proposed for clarity.

d. Replacing water with a non-fissile material will reduce the amount of moderator without increasing the amount of fissile material. This results in a decreased reactivity. This situation is comparable to the overall reduction of water density analyzed in Section 6.4.2.1 of the TSAR, which shows a decrease of reactivity with decreasing water density (i.e. decreasing the amount of water in the cask). The existing calculations assuming water in the water rods are therefore bounding for rods with non-fissile material in lieu of water.

e. New fuel assembly array/class 8x8F represents a unique fuel assembly type known as the QUAD+. New Note 12 is proposed to describe the unique water rod features of this assembly.

f. The SPC 9x9-5 fuel type is configured with two types of fuel rods having differing dimensions. Accordingly, the criticality analyses have been performed considering the varying fuel rod dimensions in the SPC 9x9-5 fuel type. Bounding all fuel rods in the assembly with one set of rod dimensions is not feasible because of excessive dimensional overlap. The SPC 9x9-5 fuel type is configured with two types of fuel rods having differing dimensions. Accordingly, the criticality analyses have been performed considering the varying fuel rod dimensions in the SPC 9x9-5 fuel type. Bounding all fuel rods in the assembly with one set of rod dimensions is not feasible because of excessive dimensional overlap.

Proposed Change No. 11

Certificate of Compliance, Appendix B, Tables 1.1-2 and 1.1-3 :

The maximum allowed design initial uranium masses for selected fuel assemblies are increased as shown in the marked-up CoC tables. This affects PWR fuel assembly array/classes 14x14A, 14x14B, 14x14C, 15x15A, 16x16A, 17x17A, 17x17B, and 17x17C in Table 1.1-2 and BWR fuel assembly array/classes 6x6A, 6x6B, 6x6C, 8x8E, 9x9A, 9x9B, 9x9C, 9x9D, 9x9E, 9x9F, 10x10A, 10x10B, and 10x10C in Table 1.1-3.

Reason for Proposed Changes

To respond to user feedback describing certain fuel assemblies which have uranium masses slightly above the specified limit (including the tolerance allowed by Note 3) for the applicable fuel assembly array/class. These changes are required to ensure users can load all of the fuel they plan to place into dry storage.

Justification for Proposed Changes

Structural Evaluation

There is no effect on the existing structural evaluation. The increased uranium masses do not cause an increase in the overall assembly weight limits in the CoC. These weights (or greater) were used in the structural evaluation. Since the allowed assembly weights are not being changed, the structural evaluation is unaffected.

Thermal Evaluation

There is no effect on the existing thermal evaluation. This is because the allowed heat load for the cask is computed based on the heat transfer characteristics of the cask system and peak cladding temperature limitations. The increase in uranium weight does not impact any assumption made in determining the heat transfer characteristics of the cask system.

Shielding Evaluation

The uranium mass limit is a value that is determined from the shielding analysis. An increase in the mass of uranium will result in an increase in the neutron and gamma source term and decay heat load for a specified burnup and cooling time. The current CoC developed from the analyses in Revision 10 of the HI-STAR TSAR provides some margin between the analyzed mass of uranium and the approved mass of uranium as listed in the CoC. The allowable burnup and cooling times in the CoC were developed by comparing the calculated decay heat for the design basis assemblies to the allowable decay heat load as determined in the thermal analysis. The decay heat values that are compared against the limits were calculated using the mass of uranium listed in Chapter 5 of the HI-STAR TSAR for the design basis fuel assemblies. Since a lower mass of uranium will result in a lower decay heat, it is conservative, and provides margin, to specify the allowable mass of uranium in the current CoC for the design basis fuel assemblies (B&W 15x15 and 7x7) lower than the values analyzed in TSAR Chapter 5.

As discussed in Section 5.2.5 of the HI-STAR TSAR Revision 10, the design basis assembly was chosen by comparing the source terms for many different types of assemblies. All of the assemblies were shown to have a lower source term than the design basis fuel assemblies. For additional conservatism, the mass of uranium specified in the current CoC for these non-design basis fuel assemblies is also specified lower than the mass used in the comparison in Chapter 5 of TSAR Revision 10. This level of conservatism is unnecessary since the decay heat load used to determine the allowable burnup and cooling times for all assemblies was the decay heat load from the design basis fuel assemblies. Therefore, there was already a significant amount of conservatism for the non-design basis fuel assemblies included by using the design basis decay heat to determine the allowable burnup and cooling times. Section 5.2.5.3 of Revision 10 of the HI-STAR TSAR provides an indication of the level of conservatism associated with using the design basis decay heat for the non-design basis fuel assemblies.

The proposed change in the CoC is to increase the mass of uranium for the non-design basis fuel assemblies up to the value that was used in the analysis in Chapter 5 of the HI-STAR TSAR to determine the design basis fuel assembly. As mentioned above, this change eliminates unnecessary over-conservatism while still maintaining a significant degree of conservatism and margin for the non-design basis fuel assemblies. The allowable mass loading for the design basis fuel assemblies remains unchanged. Therefore, the proposed change does not affect the shielding analysis presented in Revision 10 of the HI-STAR TSAR. Additional clarification has been added to the proposed Revision 11 of the HI-STAR TSAR to discuss this issue (see Attachment 5).

Criticality Evaluation

The criticality analyses are not affected by these changes. Criticality analyses for the bounding assembly in each array/class are performed with a fuel (uranium) mass exceeding the mass limit in the CoC for that array/class. This is due to the assumed fuel density of 96.0% of the theoretical fuel density of 10.96 g/cm^3 for all criticality calculations.

Confinement Evaluation

As described in the shielding evaluation, the values of uranium mass used in the shielding analyses have not changed. These proposed changes simply increase the allowed uranium masses for non-design basis fuel assemblies to those used in the analysis for the design basis fuel assembly. The source terms used in the confinement analyses were taken from the design basis source terms used in the shielding analyses. Therefore, the existing confinement evaluation is still bounding for the proposed new uranium mass limits.

Proposed Change No. 12

Certificate of Compliance, Appendix B, Tables 1.1-2 and 1.1-3 :

Certain fuel assembly parameter limits are revised as shown in the attached marked-up CoC tables. This affects PWR fuel assembly array/class 14x14C in Table 1.1-2 and BWR fuel assembly array/classes 6x6A, 6x6B, 7x7A, 7x7B, 8x8A, 8x8B, 8x8D, 9x9B, 9x9D, 9x9E, 9x9F, and 10x10C in Table 1.1-3.

Reason for Proposed Changes

To respond to user feedback describing certain fuel assemblies which have parameters outside of the limits in the existing CoC Tables. These changes are required to ensure users can load all of the fuel they plan to place into dry storage.

Justification for Proposed Changes

Structural Evaluation

The proposed changes to fuel parameter limits for some of the existing fuel assembly array/classes have no impact on the structural evaluation because the design basis weights used in the analyses (and provided as limits elsewhere in the CoC) are not changed, the design basis temperatures are not changed, and the lengths and widths of the fuel assemblies (also limited by the CoC) are not changed.

Thermal Evaluation

The active fuel length for array/classes 6x6A and 6x6B is proposed to be increased to 120 inches to bound an earlier variant of Dresden-1 fuel. Among the fuel assemblies included in the 6x6A array/class, one particular fuel type was determined to be fabricated with a thinner cladding (0.026 in.) relative to other fuel in this class (minimum 0.030 in. cladding). In the 7x7A array/class of fuel assemblies, minor adjustments to the fuel parameters[3] was necessary to bound Humboldt Bay fuel. Changes to the 7x7B and 8x8B array/classes were necessary to bound the fuel types at Oyster Creek plant. Accordingly, the thermal analyses for these fuel types were evaluated in support of this amendment and additional analyses performed, as required.

A review of the Oyster Creek fuel parameters against the fuel parameters of other fuel types in the same array/classes has revealed no significant differences. The Oyster Creek 7x7 fuel rod mechanical parameters are identical to an existing member of the 7x7B class. The relatively larger pellet diameter (from 0.491 vs. 0.488 in) necessitates an adjustment to the uranium weight limit for this array/class. The Oyster Creek 8x8 fuel rod diameter is slightly larger than other members in the 8x8B class and has a thicker cladding.

An 8x8 fuel assembly used at Browns Ferry and a 9x9 fuel assembly from Grand Gulf, have been evaluated in support of this amendment request to modify the BWR fuel parameters. Likewise, a Millstone Unit 2 14x14 fuel assembly has been evaluated to support modification of the PWR fuel tables. As explained below, these PWR and other BWR fuel have been evaluated in accordance with the NRC approved HI-STAR thermal analysis methodologies to confirm that the HI-STAR 100 temperature field is bounded by the design basis analyses.

The overall HI-STAR thermal analysis methodology is partitioned into two evaluations. The first evaluation pertains to determining the appropriate peak cladding temperature limits for long term dry storage for each proposed fuel type. In the second evaluation, the temperature field in the HI-STAR 100 cask is computed and the resulting cladding temperatures demonstrated to be below the respective temperature limits. The analytical evaluations are further sub-divided in two groups of fuel assemblies classified as Low Heat Emitting (LHE) fuel assemblies and Design Basis (DB) fuel assemblies. The LHE fuel assemblies are characterized by low burnup, long cooling time and short active fuel lengths.

[3] Cladding thickness change from 0.033 inch to 0.0328 inch and active fuel length from 79 in to 80 in.

Consequently, their heat loads are dwarfed by the full active length DB fuel assemblies. The additional Dresden-1 and Humboldt Bay fuel assemblies in the 6x6A and 7x7A array/classes belong to the LHE group of fuel, while the additional Oyster Creek, Browns Ferry, and Grand Gulf fuel assemblies are included in the DB group.

In accordance with the PNL-6189 methodology, peak fuel cladding temperature limits are specified as a function of cladding stress and age of fuel. The cladding stress calculations for the additional fuel are documented in proposed revised TSAR Tables 4.3.5 and 4.3.6 in Attachment 5 to this letter. The cladding stress in the additional DB fuel types is bounded by the limiting cladding stress computed previously. An adjustment to the 10x10 SVEA-96 fuel parameters (an O.D. change by 0.001 inch) is insignificant for the cladding stress evaluation as it is bounded by the design basis cladding stress. Consequently, the age-dependent peak fuel cladding temperature limits do not require changes to accommodate the additional fuel. For the LHE fuel group, the thin-clad Dresden-1 fuel type is determined to be the limiting fuel resulting in a downward shift in the applicable fuel cladding temperature limit. The revised temperature limits for LHE and DB fuel are summarized in proposed revised TSAR Table 4.3.7.

The second evaluation pertaining to computation of the HI-STAR 100 cask temperature field is functionally dependent upon the effective conductivity of fuel assemblies loaded in the MPC-68 fuel cells. The LHE fuel assemblies are further analyzed under the assumption that they are loaded while encased in stainless steel DFCs. Due to interruption of radiation heat exchange between the fuel assembly and the fuel basket by the DFC boundary, this configuration is bounding for the thermal evaluation. Two DFC designs are evaluated - a previously approved Holtec design (Holtec Drawing No. 1783) and an existing TN/D-1 DFC in which some of the Dresden-1 fuel is currently stored (see Proposed Change Number 1.b) . The most resistive fuel assembly determined by analytical evaluation is considered for the HI-STAR 100 cask thermal evaluation. The results of the evaluation of additional fuel types performed in support of this amendment request are summarized in proposed revised Table 4.4.6 for LHE and DB fuel (see Attachment 5).

In both groups investigated, the thermal conductivity of the additional fuels are bounded by the limiting fuel types in each group. For the DB group of fuel assemblies, it is shown that the peak cladding temperature limits for the limiting fuel type adequately cover the additional fuel. The most resistive fuel characteristics also bound the additional fuel in the list of DB fuel types authorized for storage in the HI-STAR 100 System. Thus, the design basis thermal analysis results envelope the HI-STAR 100 System thermal response when loaded with the additional BWR and PWR fuel. No additional analysis is required. For the LHE group of assemblies, the low decay heat load burden on the HI-STAR 100 cask (~ 8kW) guarantees large thermal margins to permit safe storage of Dresden-1 and Humboldt Bay fuel. Nevertheless, a conservative analysis was performed and is described in the proposed Revision 11 TSAR and the temperature field determined and reported Subsection 4.4.1.1.16 (see Attachment 5).

Shielding Evaluation

The accuracy of the shielding analysis is dependent upon the calculation of the radiation source term. The source term is dependent on the mass of uranium in the fuel assembly. For a specified burnup and cooling time, the radiation source term will increase as the mass of uranium increases (this is addressed in Proposed Change Number 11). The minor changes proposed for the dimensions of the fuel assembly array/classes will have a negligible impact on the radiation source term. Since the allowable uranium mass loadings are not being changed as a result of these changes in dimensions, it is concluded that these changes will have a negligible effect of the shielding analysis and therefore are not explicitly considered in Revision 11 of Chapter 5 of the HI-STAR TSAR.

Criticality Evaluation

For the criticality evaluation, the fuel assemblies are grouped into assembly array/classes. The proposed CoC modifications to fuel assemblies already included are reflected in proposed revised TSAR Table 6.2.1 (see Attachment 5). For each assembly array/class, a theoretical bounding assembly is defined. The characteristics of the bounding assembly for each affected array/class was amended to reflect the additional fuel types within an array/class.

Criticality calculations were performed for the changed fuel types and the bounding assembly in each array/class to account for the modified dimensions. Table 12.1 below shows the comparison between the maximum k_{eff} for each of the affected array/classes and the corresponding current values (i.e. TSAR Rev. 10). The TSAR table number containing the detailed results is also listed. The comparison demonstrates that the maximum k_{eff} of each affected class only changes slightly as a result of the changes in fuel assembly characteristics. Furthermore, the highest reactivity calculated for any BWR or PWR class (0.9457 for the bounding assembly in the BWR 10x10A class and 0.9478 for PWR assembly class 15x15F remains unaltered (see proposed revised TSAR Tables 6.2.30 and 6.2.13, respectively). Therefore, with the proposed changes, the cask system is still in compliance with the regulatory requirement of $k_{eff} < 0.95$ for all authorized fuel assembly array/classes.

Table 12.1
Comparison of Maximum k_{eff} for TSAR Rev. 10 and Proposed Rev. 11

Assembly Array/Class	Maximum k_{eff} TSAR Rev. 10	Table Number in TSAR Rev. 10	Maximum k_{eff} TSAR Proposed Rev. 11	Table Number in Proposed Rev. 11 of the TSAR
6x6A	0.7602	6.2.35	0.7888	6.2.37
6x6B	0.7611	6.2.36	0.7824	6.2.38
7x7A	0.7973	6.2.38	0.7974	6.2.40
7x7B	0.9375	6.2.19	0.9386	6.2.20
8x8A	0.7685	6.2.39	0.7697	6.2.41
8x8B	0.9368	6.2.20	0.9416	6.2.21
8x8D	0.9366	6.2.22	0.9403	6.2.23
9x9B	0.9388	6.2.25	0.9422	6.2.27
9x9D	0.9392	6.2.27	0.9394	6.2.29
9x9E	0.9406	6.2.28	0.9424	6.2.30
9x9F	0.9377	6.2.29	0.9424	6.2.31
10x10C	0.8990	6.2.32	0.9021	6.2.34
14x14C	0.9361	6.2.6	0.9400	6.2.6

Confinement Evaluation

There is no effect of these proposed changes on the confinement evaluation because the source terms used in the confinement analysis are not changed.

Proposed Change No. 13

Two new fuel assembly array/classes 15x15H (PWR) and 8x8F (BWR) are added to Appendix B, Tables 1.1-2 and 1.1-3, respectively, as shown in Tables 13.1 and 13.2 below and in the attached marked-up CoC tables. Items II.A.1.d and e in Table 1.1-1 are also revised to add decay heat, cooling time, and burnup limits for the 8x8F array/class.

Table 13.1
New Fuel Assembly Array/Class 15x15H

Fuel Assembly Array/Class	**15x15H**
Clad Material	Zr
Design Initial U (kg/assy.)	≤ 475
Initial Enrichment (wt % ^{235}U)	≤ 3.8
No, of Fuel Rods	208
Clad O.D. (in.)	≥ 0.414
Clad I.D. (in.)	≤ 0.3700
Pellet Dia. (in.)	≤ 0.3622
Fuel Rod Pitch (in.)	≤ 0.568
Active Fuel Length (in.)	≤ 150
No. of Guide Tubes	17
Guide Tube Thickness (in.)	≥ 0.0140

Table 13.2
New Fuel Assembly Array/Class 8x8F

Fuel Assembly Array/Class	**8x8F**
Clad Material	Zr
Design Initial U (kg/assy.)	≤ 185
Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% ^{235}U)	≤ 4.2
Initial Maximum Rod Enrichment(wt.% ^{235}U)	≤ 5.0
No. of Fuel Rods	64
Clad O.D. (in.)	≥ 0.4576
Clad I.D. (in.)	≤ 0.3996
Pellet Dia. (in.)	≤ 0.3913
Fuel Rod Pitch (in.)	≤ 0.609
Design Active Fuel Length (in.)	≤ 150
No. of Water Rods	N/A
Water Rod Thickness (in.)	≥ 0.0315
Channel Thickness (in.)	≤ 0.055

Reason for Proposed Changes

Based on user feedback, additional fuel assemblies were identified which did not fit into any of the existing fuel assembly array/classes. Two new assembly array/classes are required to assure all user fuel types can be loaded. The 15x15H includes the B&W Mark B11 fuel design. The 8x8F represents the unique "QUAD+" assembly.

Justification for Proposed Changes

Structural Evaluation

The addition of new fuel types permitted to be stored in the HI-STAR 100 System can have an effect on the structural analyses performed in Chapter 3 if, and only if, one or more of the following occurs because of the new fuel types:

1. The design basis weights of 700 lbs (BWR) or 1680 lbs. (PWR) are exceeded.

2. The design basis temperatures are exceeded because of the presence of the new fuel types.

3. The lengths of the new fuel assemblies cause an increase in the length of the Holtec fuel spacers.

Section 3.0 of the HI-STAR TSAR contains a compliance matrix showing how the structural review requirements of NUREG 1536 have been satisfied by the totality of analyses currently reviewed and reported in Chapter 3. To ascertain whether any of the proposed amendment items require a re-visiting of any or all of the currently approved analyses reported in Chapter 3, the Compliance Matrix was reviewed and the following conclusions reached.

1. The weights of the proposed new fuel types do not exceed the limiting (i.e., design basis) fuel weights specified in Table 1.1-1 of Appendix B to the CoC. Therefore, no structural analysis currently approved needs to be re-visited.

2. The design basis temperatures of all components have not exceeded the values currently licensed. Therefore, no structural analyses or free thermal expansion analyses currently approved needs to be revisited.

3. The lengths of the proposed new fuel types are longer than the minimum length of the fuel assemblies currently approved for the HI-STAR 100. Therefore, the fuel spacer stability analysis in the TSAR remains bounding.

The lengths of the proposed new fuel types are also less than the maximum lengths specified in Table 1.1-1 of Appendix B to the CoC.

Thermal Evaluation

The B&W Mark B11 and the QUAD+ fuel types have been evaluated along with the changes to the existing 8x8 and 15x15 fuel assembly array/classes as described in Proposed Change No. 12 above. The PWR fuel assembly is bounded by the existing design basis thermal analyses. The QUAD+ is included in the LHE group of fuel assemblies has been found acceptable for safe storage in proposed Revision 11 TSAR Subsection 4.4.1.1.16.

Shielding Evaluation

The accuracy of the shielding analysis is dependent upon the calculation of the radiation source term. The source term is dependent on the mass of uranium in the fuel assembly. For a specified burnup and cooling time, the radiation source term will increase as the mass of uranium increases. Minor variations in the dimensions of a fuel assembly will have a negligible impact on the radiation source term if the mass or uranium remains constant. The additional fuel assemblies proposed for the CoC are not significantly different than the currently licensed fuel assemblies to require an assembly-specific source term calculation. These new fuel assemblies are bounded by the current design basis fuel assemblies. In addition, the allowable uranium mass loadings for these new fuel assemblies is specified consistent with similar fuel assemblies in the CoC thereby assuring that these assemblies are bounded by the current design basis fuel assemblies. Therefore, these additions will have a negligible effect of the shielding analysis and therefore are not explicitly considered in proposed Revision 11 of Chapter 5 of the HI-STAR TSAR.

Criticality Evaluation

Criticality calculations were performed for both new fuel array/classes. The maximum k_{eff} for the 15x15H array/class was computed to be 0.9411 as shown in proposed revised TSAR Table 6.2.15. The maximum k_{eff} for the 8x8F array/class was computed to be 0.9140 as shown in proposed revised TSAR Table 6.2.25. Furthermore, the highest reactivity calculated for any BWR or PWR class (0.9457 for the bounding assembly in the BWR 10x10A class and 0.9478 for PWR assembly class 15x15F remains unaltered (see proposed revised TSAR Tables 6.2.30 and 6.2.13, respectively). Therefore, with the proposed changes, the cask system is still in compliance with the regulatory requirement of $k_{eff} < 0.95$ for all authorized fuel assembly array/classes.

Confinement Evaluation

The source terms used for the existing confinement analysis bound those of the new fuel assembly array/classes. Therefore, there in no impact on confinement.

Proposed Change No. 14

Certificate of Compliance, Appendix B, Tables 1.1-4 and 1.1-5:

a. In Table 1.1-4, the "≤" signs in the cooling time column are changed to "≥" signs, a "≥" sign is added to the 5-year cooling time, and the last year in the column is changed from 14 to 15 in Table 1.1-4.

b. In Tables 1.1-4 and 1.1-5, "Note 1" is added to the table title and the following new Note 1 is added at the bottom of the table:

Note 1: Linear interpolation between points is permitted.

Reason for Proposed Changes

To improve implementation of the table and to be consistent with HI-STORM (Docket 72-1014).

Justification for Proposed Changes

The current sign convention made the first set of decay heat limits unusable because fuel cooled less than five years is not authorized for storage. Fuel cooled between five and six years would have been governed by the decay heat limits for the "≤ 6 years" value. The new sign convention allows the decay heat limits for "≥ 5 years" to be used for fuel cooled between five and six years. Allowing interpolation provides flexibility for users to calculate appropriate decay heat and burnup limits, if necessary, for actual fuel cooling times.

Proposed Change No. 15

Certificate of Compliance, Appendix B, Table 1.3-1:

a. A new Code exception is added to Table 1.3-1 for the MPC lid-to-shell weld as shown in the attached marked-up CoC table. The affected Code section is NB-5230, which requires radiography (RT) or ultrasonic (UT) examination of all pressure boundary welds. A UT or multi-layer PT examination has been previously approved for this weld.

b. The entry in the "Exception, Justification & Compensatory Measures" column for the exception to Code Section NB-5230 for the closure ring, vent, and drain cover plate welds is clarified as shown in the attached marked-up CoC table to recognize welds which may be single pass welds.

c. The entry in the "Exception, Justification & Compensatory Measures" column for the exception to Code Section NB-6111 is re-worded as shown in the attached marked-up CoC table to clarify this exception and make it consistent with HI-STORM (Docket 72-1014).

Reason for Proposed Change

a. To add a Code section (NB-5230) affected by this previously approved exception to NB-6111.

b. To provide clarification and as a conforming change to a proposed drawings change (see Attachment 4).

c. To clarify the justification and compensatory measures for this Code exception to be consistent with ISG-4, Revision 1 and the HI-STORM CoC (Docket 72-1014).

Justification for Proposed Change

a. The existing CoC table includes this exception to NDE requirements for NB welds under Code Section NB-6111 for pressure testing. Code Section NB-5230 is the primary section from which the exception is needed. This proposed change makes HI-STAR consistent with HI-STORM (Docket 72-1014). This is an editorial change. There is no change to the alternate inspection requirements in the CoC under this exception.

b. Small welds, such as 1/8 inch will likely be completed in one pass, with no root.

c. This is an editorial change. The revised wording reflects the evolution of this issue and consistent with ISG-4, Revision 1 and the same exception in the HI-STORM CoC (Docket 72-1014).

SECTION II – PROPOSED CHANGES TO THE TSAR

Proposed Change No. 16

TSAR Chapter 1

a. The last paragraph of Section 1.0 is revised to annotate that this is Revision 11 and it has been made on a page basis.

b. The definitions of Damaged Fuel Assembly, Fuel Debris, and Intact Fuel Assembly in Table 1.0.1 are revised to match the revisions proposed for the CoC.

c. The definition of Damaged Fuel Container in Table 1.0.1 is revised to include the Transnuclear Dresden Unit 1 design.

d. The definition of Holtite-A in Table 1.0.1 is revised to specify the B_4C loading as nominal in lieu of minimum.

e. Table entries 6.6 and 7.2.1 in Table 1.0.2 are revised in column "Applicable 10CFR72 or 10CFR20 Requirement" to add "–" and change a one to the letter "l", respectively.

f. Subsection 1.2.1 is revised to clarify that the cited dimensions in the text are nominal and approximate. The actual dimensional requirements are provided in the Design Drawings provided in Section 1.5.

g. The text of Subsection 1.2.1.1 is revised to clarify the description of the heat conduction elements and to refer to the fuel spacer lengths in Tables 2.1.9 and 2.1.10 as suggested values.

h. Subsection 1.2.1.3.2 is revised to specify the 1% boron carbide as a nominal value rather than a minimum value.

i. Subsections 1.2.2.1 and 1.2.2.2 and Table 1.2.2 are revised to specify that the MPC is backfilled with a helium pressure in lieu of a helium mass and to delete the free volume measurement.

j. Subsection 1.2.2.2 is revised to note that this section provides a summary of the "general actions needed for loading" to ensure that it is understood that these operations are described generically.

k. Subsection 1.2.3 is revised to reflect the changes in authorized contents as described in the proposed CoC amendments in Section I of this attachment.

l. The Holtec Design Drawings in Section 1.5 affected by the drawing revisions proposed in Attachment 4 are replaced with the later revisions. In addition, the following drawings for the TN/D-1 Damaged Fuel Canister and Thoria Rod Canister are added to Section 1.5:

Drawing No.	Rev.	Title
9317.1-120-2	0	D-1 Canister Assembly
9317.1-120-3	1	D-1 Canister Lid Assembly
9317.1-120-4	0	D-1 Canister Body
9317.1-120-5	1	D-1 Canister Bottom Assembly
9317.1-120-6	1	D-1 Canister Lower Lid Box Assy
9317.1-120-7	0	D-1 Canister Bumper Plate
9317.1-120-8	0	D-1 Canister Bale
9317.1-120-9	1	D-1 Canister Hanger
9317.1-120-10	1	D-1 Canister Lid Box
9317.1-120-11	1	D-1 Canister Lid Frame
9317.1-120-13	0	D-1 Canister Guide Bar
9317.1-120-14	0	D-1 Canister Fuel Support Plate
9317.1-120-15	0	D-1 Canister Screen Support Plate
9317.1-120-17	0	D-1 Canister Strut
9317.1-120-18	1	D-1 Canister Screen
9317.1-120-19	2	D-1 Canister Thin (Inner) Wiper
9317.1-120-20	0	D-1 Canister Spacer
9317.1-120-21	0	D-2/3 Fuel Spacer for TN-9 Cask
9317.1-120-22	0	D-1 Canister Thick Wiper
9317.1-120-23	0	D-1 Canister Lid Assembly For Failed Fuel
9317.1-182-1	1	Thoria Rod Canister Assembly
9317.1-182-2	1	Thoria Rod Canister Spacer
9317.1-182-3	1	Thoria Rod Canister Separator Plate Assembly
9317.1-182-4	1	Thoria Rod Canister Retaining Plate Assembly
9317.1-182-5	1	Thoria Rod Canister Retaining Plate Details
9317.1-182-6	2	Thoria Rod Canister Parts List

m. Appendix 1.B is revised to change the Holtite-A density value from a maximum value to a nominal value.

n. Appendix 1.C is revised to add NEVER-SEEZ NGBT to FEL-PRO N-5000 as an acceptable lubricant.

Reason for Proposed Changes

a. This change is required to maintain consistency and specify that this revision is made on a page by page basis.

b. This is a conforming change to match the revised definitions for these terms in the CoC.

c. This change to the definition is made to reflect the proposed changes in authorized contents requested in Section I of this attachment.

d. The weight percent boron carbide used in the procedure for mixing each batch of Holtite-A remains greater than 1%. However, the as-mixed boron carbide weight percent can vary from slightly above to slightly below the 1% value. This change provides necessary flexibility for field mixing of the Holtite-A.

e. This change is made to correct editorial errors.

f. This change is made to clarify that the cited dimensions are approximate. The dimensional requirements are specified in the design drawings in Section 1.5.

g. The text describing the heat conduction elements is clarified to note that the design ensures a snug fit in the periphery of the basket in lieu of just the shape. The text regarding fuel spacers is clarified as a conforming change to match proposed change 16.k below.

h. Changing the boron carbide to a nominal value allows for minor variations which may occur during fabrication.

i. Conforming change. See Proposed Change Number 2.

j. The loading operations described in TSAR Subsection 1.2.2.2 do not include a statement allowing users to depart from the specific wording in this TSAR section provided the intent of the TSAR is met. This flexibility is already included in TSAR Section 8.0, making this a conforming change to match a previously approved provision in another TSAR section.

k. This is a conforming change to reflect the proposed changes in authorized contents requested in Section I of this attachment.

l. The Holtec HI-STAR 100 design drawings are contained in Section 1.5 and require replacement to reflect the revisions described in Attachment 4. The TN/D-1 DFC and Thoria Rod Canister drawings were used to qualify those canister designs for storage in the HI-STAR 100 System.

m. The as-poured Holtite-A density can vary slightly above or below the nominal value of 1.68 g/cc.

n. This lubricant is commonly used at nuclear power plants and is an acceptable alternative to that currently specified in Appendix 1.C.

Justification for Proposed Changes

a. This is a conforming change to make Revision 11 consistent.

b. This is a conforming change to make the definitions consistent with the CoC.

c. This is a conforming change. The justifications for these changes are described in Section I of this attachment.

d. Sensitivity analyses have been performed by reducing the boron carbide concentration from 1% to 0.5% and 0.75%. The sensitivity analyses demonstrate that at a boron carbide loading of 0.75% (a 25% reduction) the total dose rate (gamma and neutron) increases by only 3%. It should be noted that this increase is not much greater than the accuracy of the calculation and occurs at the higher burnups. The effect is lessened as the burnup decreases. Therefore, if a value can vary by as much as 25% without significantly effecting the dose rates, it is clearly a nominal value.

e. This is an editorial correction.

f. The intent of the dimensions presented is to provide the reader with a general idea of the size of the MPC and overpack. They were not intended to be design dimensions. By adding "approximate" and "nominal", it is clarified that these are not design requirements as the design dimensions are specified in the Design Drawings in Section 1.5.

g. The minor revision to the heat conduction element description is editorial. The change to the spacer lengths in Tables 2.1.9 and 2.1.10 being suggested values is a conforming change. See Proposed Change Number 17.b.

h. This is a conforming change. See Proposed Change Number 16.d.

i. This is a conforming change. See Proposed Change Number 2.

j. The intent of the operating procedures in Chapter 8 and the short description of loading operations in Chapter 1 is to describe the general sequence of operations and desired objective of the steps. The TSAR information is not detailed enough to use for implementation at a user's site, nor should it be, for a generically certified cask system. Chapter 8 at Section 8.0 currently allows users to perform steps in different sequence than shown, to delete or add steps as necessary, and to use different equipment than specified provided the intent of the steps is met. These changes to Chapter 1 are being made to be consistent with Chapter 8.

k. This is a conforming change. The justifications for these changes are described in Section I of this attachment.

l. The justification for the drawing revisions is provided in Attachment 4.

m. The current version of the TSAR specifies the Holtite density as 1.68 g/cc maximum. The shielding analysis conservatively assumes a Holtite density of 1.61 g/cc. This density accounts for any potential weight loss or inability to reach the required density. Increasing the Holtite density only acts to increase the effectiveness of the shielding. By deleting the maximum, the density is allowed to be increased. The small variations in Holtite density will have a negligible effect on the total weight of the cask. The total weight of the Holtite in the overpack is less than 13,000 lbs. An increase in the Holtite density from 1.68 g/cc to 1.70 g/cc equates to only a 150 pound increase.

n. The additional alternative lubricant provides the same function as that currently specified and is equally competent in performing its design function.

<u>Proposed Change No. 17</u>

<u>TSAR Chapter 2</u>

a. Section 2.0 is revised to change helium "mass" to "pressure" in the discussion of MPC backfill.

b. Table 2.0.1 is revised to 1) remove the term "& Fabrication" under the listing of Structural design codes, 2) replace "mass" with "pressure" under "Canister Backfill", 3) remove the note prohibiting storage of control components under "Spent Fuel Specification", and 4) remove a duplicated page of the table.

c. Table 2.0.2 is revised to remove the term "& Fabrication" under the listing of Structural design codes.

d. Section 2.1 is revised to reflect the CoC changes and additions to the fuel array/classes authorized for loading in the HI-STAR 100 System.

e. Subsection 2.1.4 and Tables 2.1.9 and 2.1.10 are revised to clarify the intent of the lengths provided for the fuel spacers.

f. Subsection 2.1.6 is revised to add discussion of the Thoria Rod Canister, the antimony-beryllium neutron sources, and non-fuel hardware being added to the CoC for storage.

g. Subsection 2.1.7 is revised to provide missing text which discusses the ^{10}B density in Boral.

h. Subsection 2.1.8 is revised to add discussion of BPRAs and TPDs, the Thoria Rod Canister, and the antimony-beryllium neutron sources.

i. Table 2.1.2 is revised to delete the exception for 8x8 WE QUAD+ assemblies.

j. Tables 2.1.3 and 2.1.4 are revised to modify the fuel parameters as proposed in the CoC changes in Section I of this attachment.

k. Table 2.1.6 is revised to reflect the addition of fuel assembly array/class 8x8F.

l. New Table 2.1.12 is added for the Thoria Rod Canister.

m. Figure 2.1.6 is revised to add a curve for PWR fuel containing BPRAs.

n. Subsection 2.2.3.1 is revised to add clarification that handling requirements apply to loaded overpacks.

o. Table 2.2.3 is revised to add temperature data for the neutron shield enclosure.

p. Table 2.2.6 is revised to 1) replace the term "helium retention" with "confinement" in the MPC section, 2) replace the term "confinement" with "helium retention" in the overpack section, 3) delete the line items for the backing strip, rupture disk coupling, rupture disk pipe, and alignment pin, 4) change the material designation for the rupture disk from "brass" to "commercial" and 5) change the safety class for the closure bolt washer from "C" to "NITS."

q. Table 2.2.15 is revised to reflect the CoC changes/additions to the authorized exceptions to the ASME Code. See Proposed Change Number 15.

r. Table 2.2.17 is revised to add a note specifying how to measure the cask carry height.

s. Table 2.3.1 is revised to reflect the new dose limit criteria specified in the regulations.

Reason for Proposed Changes

a. This is a conforming change in support of the change from MPC helium backfill density (mass) to pressure in the CoC (see Proposed Change Number 2).

b. 1) Clarification. 2) Conforming change. 3) Conforming change. 4) Editorial.

c. Clarification.

d. This is a conforming change in support of the revised and new fuel assembly array/classes. See Section I of this attachment.

e. The lengths of fuel spacers provided for the various fuel types in TSAR Tables 2.1.9 and 2.1.10 do not account for the assemblies having BPRAs or TPDs installed. Authorization for loading these types of non-fuel hardware is being proposed in this amendment request. Therefore, the presentation of fuel spacer lengths in these tables needs to be qualified to provide the necessary flexibility for users to size the spacers for their specific fuel storage needs.

f. This is a conforming change in support of the addition of the Thoria Rod Canister, Sb-Be neutrons sources, and BPRAs/TPDs being added to the CoC for storage in HI-STAR 100.

g. To correct an editorial error in the previous TSAR revision.

h. This is a conforming change in support of the addition of the Thoria Rod Canister, Sb-Be neutrons sources, and BPRAs/TPDs being added to the CoC for storage in HI-STAR 100.

i. This is a conforming change in support of adding the QUAD+ assembly to the CoC for storage in HI-STAR 100.

j. This is a conforming change in support of revising the fuel parameters in the CoC.

k. This is a conforming change in support of adding the QUAD+ assembly to the CoC for storage in HI-STAR 100. This is a conforming change in support of adding the QUAD+ assembly to the CoC for storage in HI-STAR 100.

l. This is a conforming change in support of adding the D-1 Thoria Rod Canister to the CoC for HI-STAR storage.

m. This is a conforming change in support of adding BPRAs to the CoC for storage with PWR fuel in HI-STAR 100.

n. Clarification.

o. This is a clarification to specify design temperatures for the neutron shield enclosure which were inadvertently omitted from the previous TSAR revision.

p. 1) Editorial. 2) Editorial. 3) Backing strips and alignment pins were previously deleted from the design drawing and inadvertently not deleted from this table. The rupture disk coupling and pipe have been integrated into the rupture disk design. 4) This is a conforming change to match the same change on the Bill-of-Materials. The commercially purchased rupture disk is not required to be brass. 5) Correction.

q. This is a conforming change in support of changes to the Code exception table in the CoC (see Proposed Change Number 15).

r. Clarification.

s. This is conforming change to reflect 1998 rule changes to 10 CFR 72.104 and 72.106.

Justification for Proposed Changes

a. This is a conforming change. See Section I of this attachment.

b. 1) This is a clarification. The applicable Code requirements for fabrication are specified in Table 2.2.7. 2) This is a conforming change in support of changing the MPC helium backfill acceptance criterion from density (mass) to pressure (see Proposed Change Number 2). 3) This is a conforming change in support of the proposed change to the CoC to allow the storage of BPRAs and TPDs (see Proposed Change Number 7). 4) Editorial. The information on pages 2.0-15 and 2.0-16 in the current TSAR is identical.

c. This is a clarification. The applicable Code requirements for fabrication are specified in Table 2.2.7.

d. This is a conforming change. See Section I of this attachment.

e. The purpose of the fuel spacers is to ensure the active fuel region remains adjacent to the Boral neutron absorber affixed to fuel cell walls. Allowing fuel assemblies to be stored with their integral BPRAs and TPDs may alter the overall height of the assembly. It is not possible to predict, under a general certification, the exact length of fuel spacers each user will need. The specific length of a given fuel spacer is to be determined by the user. The user is obligated under 10 CFR 72.212 to ensure that the active fuel region of all assemblies is located correctly with regard to the Boral neutron absorber in accordance with the TSAR.

f. This is a conforming change. See Section I of this attachment.

g. Editorial.

h. This is a conforming change. See Section I of this attachment.

i. This is a conforming change. See Section I of this attachment.

j. This is a conforming change. See Section I of this attachment.

k. This is a conforming change. See Section I of this attachment.

l. This is a conforming change. See Section I of this attachment.

m. This is a conforming change. See Section I of this attachment.

n. This is a clarification made based on user feedback regarding the applicability of cask handling requirements.

o. Editorial for clarification.

p. 1) Editorial. 2) Editorial. 3) and 4) These are conforming changes to support changes to the drawings (see Attachment 4) 5) The closure bolt washer is not required for safe operation of the cask system. Based on a review in accordance with Holtec's safety classification procedure, which incorporates the guidance contained in NUREG-6407, the washers are not important to safety.

q. This is a conforming change. See Section I of this attachment.

r. This is a clarification to ensure users have the correct information in determining compliance with the carry (lift) height limits. The new note is consistent with the assumptions in the structural analyses for drops.

s. This is a conforming change to match 1998 rule changes to 10 CFR 72.104 and 106.

Proposed Change No. 18

TSAR Chapter 3

a. Table 3.0.1, under "Specific Analyses" is revised to refer to Appendices 3.B and 3.AI.

b. Table 3.2.3 is revised to correct the weight for the lift yoke to be 3,600 lb.

c. Table 3.2.4 is revised to add a listing of the nominal dimensions used in the structural analyses.

d. Subsection 3.6.3 is revised to add Appendix 3.AI to the list of Appendices.

e. Appendix 3.E is revised to reflect the reduction in closure ring weld size to 1/8 inch.

f. Appendix 3.J is revised to analyze the modifications to the upper fuel spacers for the MPC-24 (Design Drawing 1396, Sheet 6).

g. Appendix 3.AG has been revised to reflect the new, optional weld detail proposed for the overpack neutron shield enclosure panel to radial channel weld. The optional detail reduces the weld size from 7/16 inch to 3/16 inch.

h. New Appendix 3.AI has been added to address the TN/D-1 Damaged Fuel Canister and Thoria Rod Canister.

Reason for Proposed Changes

a. Editorial to correct an oversight and to add reference to a new appendix.

b. Editorial to correct the value based on actual lift yoke design. The lift yoke weight is provided for information to the users to determine total load on the plant crane hook.

c. To provide clarifying information regarding the dimensions used in the structural analyses.

d. Editorial to add new Appendix 3.AI to the list of appendices.

e. Field experience with the closure ring has necessitated reducing the closure ring weld size to ensure proper fit-up and a good quality weld.

f. An alternate design for these fuel spacers has been developed and is included as an option, as necessary, for certain PWR fuel types.

g. The optional weld details allows users to reduce the amount of weld material and accept a surface which is irregular, rather than smooth.

h. This new appendix supports the request to include the TN/D-1 Damaged Fuel Canister and the Thoria Rod Canister for storage of fuel in the HI-STAR 100 System.

Justification for Proposed Changes

a. Editorial

b. Editorial. The weight of the lift yoke is not used in any cask structural analysis.

c. This is a clarifying change to supplement the weight data in the same table. The nominal dimensions used in the structural analyses are consistent with the dimensions and tolerances on the design drawings.

d. Editorial.

e. The smaller weld sizes provide adequate structural integrity and positive safety margins as shown in proposed revised Appendix 3.E.

f. The results of the analysis show that the shorter fuel spacer length is bounded by the longer fuel spacer length. The stresses on the new plate attachment are acceptable under all loading conditions. See Attachment 5 for proposed revised TSAR Appendix 3.J for details of this analysis.

g. The reduction in the amount of weld material allows for a more efficient fabrication process. The 3/16 inch minimum weld meets all structural design requirements as shown in proposed revised TSAR Appendix 3.AG.

h. See Section I of this attachment for justification.

Proposed Change No. 19

TSAR Chapter 4

a. Section 4.3 text and Tables 4.3.2, 4.3.3, 4.3.5, 4.3.6, and 4.3.7 are revised as conforming changes in support of changes proposed in Section I of this attachment to modify/add fuel assembly array/classes. These revisions address fuel cladding stress and temperature limits for the following fuel:

B&W 15x15 Mark B-11 (Entergy-ANO)
CE-14x14 (Millstone Unit 2)
GE 6x6 Dresden-1 Fuel (with TN Damaged Fuel Container)
Dresden Unit 1 Thoria Rod Canister
GE 7x7 (GPUN-Oyster Creek)
GE 8x8 (GPUN-Oyster Creek)
GE 8x8 QUAD+ (NYPA-Fitzpatrick)
GE 8x8 (TVA-Browns Ferry)
Seimens 9x9 SPC-5 (Entergy-Grand Gulf)

b. Subsection 4.4.1.1.2 text and Tables 4.4.5 through 4.4.7 are revised, and new Table 4.4.25 is added as a conforming changes in support of changes proposed in Section I of this attachment to modify/add fuel assembly array/classes (see list in Item 'a' above).

c. Subsection 4.4.1.1.11 is revised to clarify the last bullet in the subsection.

d. Subsection 4.4.1.1.15 is revised to change the units of "t" from "°F" to "hrs."

e. New Subsection 4.4.1.1.16 is added as a conforming change in support of changes proposed in Section I of this attachment to provide a discussion of Low Heat Emitting (LHE) fuel, including the TN/D-1 damaged fuel canister and the D-1 Thoria Rod Canister.

f. Subsection 4.4.4 and Table 4.4.15 are revised as conforming changes in support of changes proposed in Section I of this attachment to address the addition of non-fuel PWR hardware (BPRAs and TPDs).

Reason for Proposed Changes

a. This is a conforming change in support of changes to the CoC. See Section I of this attachment.

b. This is a conforming change in support of changes to the CoC. See Section I of this attachment.

c. Editorial.

d. Editorial.

e. This is a conforming change in support of changes to the CoC. See Section I of this attachment.

f. This is a conforming change in support of changes to the CoC. See Section I of this attachment.

Justification for Proposed Change

a. See thermal evaluation of this change in Section I of this attachment.

b. See thermal evaluation of this change in Section I of this attachment.

c. Editorial.

d. Editorial.

e. See thermal evaluation of this change in Section I of this attachment.

f. See thermal evaluation of this change in Section I of this attachment.

Proposed Change No. 20

TSAR Chapter 5

a. Section 5.0 is revised to add discussion the Antimony-beryllium sources, BPRAs, TPDs, and Thoria Rod Canister which are being added as allowable contents for storage in HI-STAR 100.

b. Section 5.0 is revised to change the wording of acceptance criterion 4.

c. Section 5.1 is revised to add Dresden Unit 1 antimony-beryllium neutron sources to the list of neutron sources.

d. Section 5.1 is revised to added a sentence to address burnup and cooling time for PWR fuel assemblies with BPRAs.

e. Subsection 5.1.1 is revised to add the word "critical" before the word organ in the item 1 discussion about 10CFR72.104 regulations.

f. Subsection 5.1.1 is revised to discuss Thoria Rod Canister, BPRAs, TPDs, and Dresden Unit 1 antimony-beryllium sources.

g. Subsection 5.1.2 is revised to change the wording in the discussion of 10CFR72.106.

h. Table 5.1.3 is revised to correct a typographical error.

i. Subsection 5.2.4 is revised to discuss permitting BPRAs and TPDs for storage in HI-STAR 100.

j. New subsection 5.2.4.1 is added to discuss the addition of BPRAs and TPDs to the allowable contents for HI-STAR 100.

k. Subsection 5.2.5.3 is revised to add discussion about heavy metal mass.

l. New Subsection 5.2.6 is added to discuss the source terms for the Dresden Unit 1 Thoria Rod Canister which is being added to the allowable contents for HI-STAR 100.

m. New Subsection 5.2.7 is added to discuss the source terms for the Dresden Unit 1 antimony-beryllium neutron sources which are being added to the allowable contents for HI-STAR 100.

n. New Tables 5.2.29 through 5.2.33 are added in support of additional Section 5.2.4.1 and 5.2.6 (BPRAs, TPDs, and Thoria Rod Canister).

o. Subsection 5.3.1.2 is revised to delete a word.

p. Figure 5.3.9 is revised to correct a typographical error.

q. Subsection 5.4.1 is revised to delete a word.

r. New Subsection 5.4.6 is added to discuss the addition of BPRAs and TPDs to the allowable contents for HI-STAR 100.

s. New Subsection 5.4.7 is added to discuss the source terms for the Dresden Unit 1 Antimony-beryllium neutron sources which are being added to the allowable contents for HI-STAR 100.

t. New Subsection 5.4.8 is added to discuss the source terms for the Dresden Unit 1 Thoria Rod Canister which is being added to the allowable contents for HI-STAR 100.

u. New Tables 5.4.15 through 5.4.17 are added.

v. References [5.2.2] and [5.2.3] are swapped.

Reason for Proposed Changes

a. This is a conforming change to support the addition of these items to the CoC for storage.

b. The wording of 10CFR72.104 and 10CFR72.106 has changed since Revision 10 of the HI-STAR TSAR.

c. This is a conforming change to support the addition of this item to the CoC for storage.

d. This is a conforming change to support the addition of this item to the CoC for storage.

e. The wording of 10CFR72.104 has changed since Revision 10 of the HI-STAR TSAR.

f. This is a conforming change to support the addition of these items to the CoC for storage.

g. The wording of 10CFR72.106 has changed since Revision 10 of the HI-STAR TSAR.

h. Editorial.

i. This is a conforming change to support the addition of these items to the CoC for storage.

j. This is a conforming change to support the addition of these items to the CoC for storage.

k. This is a conforming change to support the increase in allowable heavy metal mass for non-design basis fuel assemblies.

l. This is a conforming change to support the addition of the Dresden Unit 1 Thoria Rod Canister to the CoC for storage.

m. This is a conforming change to support the addition of the Dresden Unit 1 Antimony-beryllium neutron sources to the CoC for storage.

n. This is a conforming change to support the addition of the Dresden Unit 1 BPRAs, TPDs, and Thoria Rod Canister to the CoC for storage.

o. The word was deleted so as not to be misleading about the design of the shield plug.

p. Editorial.

q. The word was deleted so as not to be misleading about the design of the shield plug.

r. This is a conforming change to support the addition of these items to the CoC for storage.

s. This is a conforming change to support the addition of the Dresden Unit 1 Antimony-beryllium neutron sources to the CoC for storage.

t. This is a conforming change to support the addition of the Dresden Unit 1 Thoria Rod Canister to the CoC for storage.

u. This is a conforming change to support the addition of the Dresden Unit 1 BPRAs, TPDs, and Antimony-beryllium sources to the CoC for storage.

v. Editorial.

Justification for Proposed Changes

a. See shielding evaluation in Section I of this attachment.

b. This is a conforming change to bring the wording in the TSAR into agreement with the current regulations.

c. See shielding evaluation in Section I of this attachment.

d. See shielding evaluation in Section I of this attachment.

e. This is a conforming change to bring the wording in the TSAR into agreement with the current regulations.

f. See shielding evaluation in Section I of this attachment.

g. This is a conforming change to bring the wording in the TSAR into agreement with the current regulations.

h. Editorial.

i. through n.: Conforming changes. See shielding evaluation in Section I of this attachment.

o. The shield plug for the pocket trunnions can be made of either a solid piece of steel or a block of steel and Holtite-A. The word neutron might imply that the shield plug is to be made of only Holtite.

p. Editorial.

q. The shield plug for the pocket trunnions can be made of either a solid piece of steel or a block of steel and Holtite-A. The word neutron might imply that the shield plug is to be made of only Holtite.

r. through u.: See shielding evaluation in Section I of this attachment.

v. Editorial.

Proposed Change No. 21

TSAR Chapter 6

a. In Section 6.1, fourth paragraph, the second sentence is revised to change "NUREG-1536" to "10CFR72.124(b)", and delete ".. as required by 10CFR72.124(b)."

b. Tables 6.1.1 through 6.1.3 are revised to reflect changes to the authorized fuel contents for HI-STAR 100.

c. Table numbers in section 6.2 are revised as follows:

Tables 6.2.15 through 6.2.23 become Tables 6.2.16 through 6.2.24.
Tables 6.2.24 through 6.2.39 become Tables 6.2.26 through 6.2.41.

Table references in TSAR Subsections 6.2.2, 6.2.3 and 6.2.4 are updated accordingly

d. Tables 6.2.6, 20, 21, 23, 27, 29, 30, 31, 34, 37, 38 and 41 and Appendix 6.C are revised to reflect changes to the authorized fuel contents for HI-STAR 100.

e. Tables 6.2.15 and 6.2.25 are added to Section 6.2.

f. Subsection 6.2.4, after the third sentence is revised to add "Two different DFC types with slightly different cross sections are considered." At the end of the first paragraph "for both DFC types" is added.

g. Subsection 6.2.5 is added, together with Table 6.2.42. This subsection and table provides information about the Thoria Rod Canister (see Section I of this attachment).

h. Table 6.3.4, MOX fuel specification, is revised as follows:

   92235 Atom-Density from 1.659E-04 to 1.719E-04
   92235 Wtg.-Fraction from 6.150E-03 to 6.380E-03
   92238 Wtg.-Fraction from 8.586E-01 to 8.584E-01

i. Table 6.3.4, Specification for fuel in Thoria Rods is added.

j. Subsection 6.4.4, after the first sentence is revised to add "Two different DFC types with slightly different cross sections are considered." The third paragraph, after the first sentence is revised to add "There is no significant difference in reactivity between the two DFC types." In Table 6.4.5, a third column is added to show results of the criticality analyses for the TN/D-1 DFC.

k. Subsection 6.4.6 is added, discussing results of the criticality analyses for the Thoria Rod Canister.

l. Subsection 6.4.7 is added, discussing the impact of sealed water rods in BWR fuel assemblies on the reactivity of the cask.

m. Subsection 6.4.8 is added, discussing the impact of including non-fuel hardware with PWR fuel assemblies on the reactivity of the cask.

n. Subsection 6.4.9 is added, discussing the impact of neutron sources in BWR fuel assemblies on the reactivity of the cask.

Reason for Proposed Changes

a. To bring text in line with a recent change to 10CFR72.124(b) (FR publication date 6/22/99).

b. This is a conforming change to support the extended scope of fuel array classes (see Section I of this attachment).

d. This is a conforming change to support the two new fuel classes (see Section I of this attachment).

e. This is a conforming change to support the extended scope of fuel array classes (see Section I of this attachment).

e. This is a conforming change in support of adding two new fuel classes (see Section I of this attachment).

f. This is a conforming change to add the TN/D-1 Damaged Fuel Canister (see Section I of this attachment).

g. This is a conforming change to add the Thoria Rod Canister to the approved list of contents (see Section I of this attachment).

h. This is a conforming change to support the increase in the U-235 enrichment in the MOX fuel rods for fuel assembly array/class 6x6B (see Section I of this attachment).

i. This is a conforming change in support of adding the Thoria Rod Canister to the approved list of contents (see Section I of this attachment).

j. This is conforming change in support of adding the Transnuclear D-1 Damaged Fuel Canister to the authorized contents (see Section I of this attachment).

k. This is a conforming change in support of adding the Thoria Rod Canister to the approved list of contents (see Section I of this attachment).

l. This is a conforming change in support of adding BWR fuel assemblies with sealed water rods to the approved contents (see Section I of this attachment).

m. This is a conforming change in support of adding PWR non-fuel hardware (BPRAs and TPDs) to the approved contents (see Section. I of this attachment).

n. This is a conforming change in support of adding BWR assemblies with neutron sources to the approves contents (see Section I of this attachment).

Justification for Proposed Changes

a. 10 CFR 72.124(b) was amended in June, 1999 to no longer require continued verification of the efficacy of neutron absorbers in dry storage systems. This proposed TSAR text change is a conforming change in support of this change to the regulations.

b. See criticality evaluation for this change in Section I of this attachment.

c. Editorial.

d. through n. See criticality evaluations for these changes in Section I of this attachment.

Proposed Change No. 22

TSAR Chapter 7

a. Subsection 7.1.5 is revised to remove reference to Dresden Unit 1 and Humboldt Bay fuel debris.

b. The design pressures for the mechanical seals shown in Table 7.1.1 is revised from 10,000 psig to 1,000 psig.

c. Subsection 7.1.2 and 7.1.3 are revised to clarify that root pass PT is only required for multi-pass welds.

d. Table 7.1.2 is revised to change “full” to “partial” in describing the MPC closure ring segment to closure ring segment radial welds.

e. Table 7.1.3 is revised to clarify that root pass PT examination is only required for multi-pass welds.

f. Figure 7.1.3 is revised to remove the call-outs of the closure ring weld size and to correct the size of the MPC lid-to-shell (LTS) weld. A clarifying note is added regarding the LTS weld.

g. Section 7.2, first paragraph is revised to delete reference to TSAR Tables 4.4.15 and 4.4.22.

h. Subsection 7.2.3 is revised to include discussion of confinement analyses for off-normal conditions of storage and to add discussion of doses to all critical organs.

i. Subsection 7.2.3 is revised to add clarification that root pass PT examination is only required for multi-pass welds.

j. Subsection 7.2.7 is revised to change the leakage rate for normal conditions.

k. Subsection 7.2.8 is revised to discuss doses to all critical organs and to discuss doses due to contaminated soil.

l. Subsection 7.2.8.2 is revised to address doses to all critical organs.

m. Subsection 7.2.9 is renumbered to 7.2.10. New Subsection 7.2.9 is added to address doses to all critical organs and the TEDE at the controlled area boundary due to off-normal conditions of storage.

n. Re-numbered Subsection 7.2.10 is revised to address off-normal conditions of storage, to revise the assumption regarding capillary length, and to delete the assumption regarding I-129.

o. Section 7.3, second paragraph is revised to discuss doses to all critical organs.

p. Subsection 7.3.1 is revised to include the dose contribution from all actinides, regardless of each isotope's contribution to the inventory; to add discussion of the impact of thoria rods on the confinement analysis; and to address the Antimony-beryllium neutron sources.

q. Subsection 7.3.3.1 is revised to make Equation 7-2 and its resultant leak rate and capillary diameter consistent with that used in the HI-STORM confinement analysis (Docket 72-1014).

r. Subsection 7.3.4 is revised to discuss doses to all critical organs and the dose contribution from contaminated soil.

s. The title of Subsection 7.3.4.1 is revised to add "Total Effective Dose Equivalent."

t. The title of Subsection 7.3.4.2 is revised to "Critical Organ Dose" and the subsection is revised to address doses to all critical organs.

u. Subsection 7.3.5 is revised to add the doses to critical organs and the estimated TEDE at the controlled area boundary.

v. Subsection 7.3.6 is revised to change the assumption regarding capillary length, to delete the assumption that only I-129 is significant in estimating the dose to the thyroid, and to delete the assumption that the thyroid is the only organ to receive an appreciable dose.

w. Table 7.3.1 is revised to add all applicable isotopes of Pu, Am, Np, and Cm.

x. Table 7.3.2 is revised to reflect the updated confinement analyses for normal, off-normal, and hypothetical accident conditions for the MPC-24.

y. Tables 7.3.3 and 7.3.4 are re-numbered as Tables 7.3.5 and 7.3.6. Re-numbered Table 7.3.6 is revised to address off-normal conditions of storage.

z. New Tables 7.3.3 and 7.3.4 present the doses from the updated confinement analyses for normal, off-normal, and hypothetical accident conditions for the MPC-68 and –68F, respectively.

aa. Appendix 7.A is revised to reflect the updated confinement analyses.

Reason for Proposed Changes

a. Editorial.

b. The current design pressures stated for the mechanical seals are unnecessarily high.

c. This is a conforming change to reflect the reduction of closure ring weld sizes on the design drawings (see Attachment 4).

d. This is a conforming change to reflect the reduction of closure ring weld sizes on the design drawings (see Attachment 4).

e. This is a conforming change to reflect the reduction of closure ring weld sizes on the design drawings (see Attachment 4).

f. This closure ring weld size is not germane to the confinement analysis and is being changed on the design drawings (see Attachment 4). The MPC lid-to-shell weld size is corrected to reflect the weld size shown on the current design drawing (no change to the licensed weld size).

g. Editorial.

h. through aa. These changes are necessary to reflect the updated confinement analyses performed to demonstrate compliance with 10 CFR 72.104 and 72.106 as amended in October, 1998 (after HI-STAR 100 received its preliminary storage certification).

Justification for Proposed Changes

a. Editorial

b. The design pressures currently stated in the TSAR for these seals is 10,000 psig. The maximum design internal pressure for the HI-STAR 100 System is 125 psig. Reducing the design pressures for these seals to 1,000 psig increases the selection of seal available for use while still providing a safety margin of approximately an order of magnitude.

c. This is a conforming change to reflect the reduction of closure ring weld sizes on the design drawings (see Attachment 4).

d. This is a conforming change to reflect the reduction of closure ring weld sizes on the design drawings (see Attachment 4).

e. This is a conforming change to reflect the reduction of closure ring weld sizes on the design drawings (see Attachment 4).

f. Editorial change to remove duplicate, unnecessary information on the closure ring welds (see Attachment 4). Editorial change for the MPC LTS weld.

g. Editorial

h. through aa. The proposed changes to the discussion of the confinement analyses for HI-STAR 100 reflect the updated analyses performed to demonstrate compliance with 10 CFR 72.104 and 72.106 as amended in October, 1998. The results of the updated confinement analyses show continued compliance with the dose limits 10 CFR 72.104 and 72.106. These changes also bring the HI-STAR confinement analysis into accord with the HI-STORM confinement analysis, which was approved after the final rules cited above were effective (Docket 72-1014).

The confinement analyses supporting TSAR Chapter 7 were also revised to account for new isotopes added to the source inventory by a Thoria Rod Canister (see Section I of this attachment) and to address the fuel assemblies which contain Antimony-beryllium neutron sources.

Proposed Change No. 23

TSAR Chapter 8

a. Section 8.0 is revised to 1) correct cross-references to the CoC for the location of the Technical Specifications (TS) and the TS Bases, 2) clarify vacuum drying time information in Chapter 4, and 3) clarify that DFCs must be used for damaged fuel and fuel debris as defined in the TS, but the location where the fuel is placed in the DFC is determined by the user.

b. Table 8.0.1 is revised to make the text regarding the applicability of ANSI N14.6 match the requirements of LCO 2.1.3.b in the Technical Specifications.

c. Subsection 8.1.1 is revised to 1) delete the reference to Technical Specifications for MPC lid dose rates, 2) delete text referring to the need to measure the volume of water drained from the MPC for use with helium backfilling, 3) change "density" to "pressure" and 4) add clarification that root pass PT is only applicable for multi-pass welds.

d. Subsections 8.1.2, "HI-STAR 100 System Receiving and Handling Operations"; 8.1.3, "HI-STAR 100 Overpack and MPC Receipt Inspection and Loading Preparation"; 8.1.5, "MPC Closure", 8.1.6, "Preparation for Storage"; and 8.3.2, "HI-STAR 100 Overpack Recovery from Storage" are revised in a number of places as shown in the attached proposed TSAR revisions (Attachment 5) to incorporate editorial improvements, to reflect enhancements in the operating procedures, and as conforming changes to support the CoC change of MPC helium backfill from a density limit to a pressure limit.

e. Procedural step 8.1.5.32 is revised to recognize the smaller closure ring welds.

f. Tables 8.1.1 and 8.1.2 are revised to increase the weight of the lift yoke from 3200 lbs to 3600 lbs.

g. Tables 8.1.4 and 8.1.5 are revised to reflect a new description for the use of the water totalizer.

h. Table 8.1.6 is revised to correct the numbering of the inspections items.

i. Table 8.1.3 is revised to increase the torque requirement for the overpack vent and drain port plugs.

j. Subsection 8.3.1 and Subsection 8.3.2, Steps 11 and 12 are revised to reflect a different method of gaining access to the MPC vent and drain ports prior to fuel unloading.

k. Subsection 8.3.2, Step 14.h is revised to correct the cross-reference to the Fuel Cooldown Technical Specification, Limiting Condition for Operation 2.1.4.

Reason for Proposed Changes

a. 1) Editorial. 2) Clarification. 3) Clarification.

b. Editorial for consistency between the TSAR and the Technical Specifications.

c. 1) Only overpack dose rates, not MPC dose rates, have limits specified in the Technical Specifications. 2) and 3) These are conforming changes to support the CoC change from MPC helium backfill density to pressure. 4) For clarification in support of drawing changes which reduce the size of certain welds requiring PT examination (see Attachment 4).

d. To incorporate lessons learned from dry run activities for the first production HI-STAR 100 System at Plant Hatch.

e. This is a conforming change to reflect the reduction in closure ring weld sizes shown on the design drawings (see Attachment 4).

f. Editorial to correct the value based on actual lift yoke design. The lift yoke weight is provided for information to the users to determine total load on the plant crane hook.

g. This is a conforming change to support the change to MPC helium backfill pressure viz. density.

h. Editorial.

i. To provide sufficient compression for the seals located beneath the port plug heads.

j. This change reflects the actual type of weld removal system selected for use.

k. Editorial.

Justification for Proposed Changes

a. 1) Editorial. 2) Clarification. Actual limits on vacuum drying time are plant-specific, based on the actual burnup and cooling time of the fuel being loaded and the temperature of the spent fuel pool water. The TSAR provides examples for illustration which assume design basis decay heat values and a range of spent fuel pool temperatures. 3) Damaged fuel and fuel debris are defined terms in the TS and CoC Appendix B. Fuel meeting either of these definitions must be placed in a DFC prior to storage in accordance with the CoC. It is the user's responsibility to control the loading of the fuel assemblies into the DFCs such that the ready-for-storage configuration meets the CoC requirements. This may be accomplished by inserting an empty DFC into the MPC and then loading the fuel assembly into the DFC.

b. Editorial.

c. 1) Editorial change to reflect TS requirements. 2) and 3) These are conforming changes to reflect the change from MC helium backfill density to pressure. See Section I of this attachment. 4) This is a conforming change to reflect the reduction in weld size for the closure ring welds on the design drawings. See Attachment 4 for the drawing changes and Attachment 5 for the Chapter 3, Appendix 3.E TSAR text justifying this change.

d. The proposed revisions to the operating procedures are enhancements based on actual field experience during dry run activities with the first production Hi-STAR 100 System at Plant Hatch. These changes preserve the intent of the steps they modify while providing necessary guidance and/or flexibility for implementing the step. These changes do not increase stay times in the vicinity of the cask. Therefore, the occupational dose estimates in Chapter 10 remain bounding. Changing from density to pressure for MPC helium backfilling is justified in Section I of this attachment (see Proposed Change Number 2.

e. This is a conforming change to reflect the smaller closure ring weld size on the design drawings.

f. Editorial. The weight of the lift yoke is not used in any cask structural analysis.

g. These are conforming changes to reflect the change from MPC backfill density to pressure. The water totalizer is used in a limited role for measuring the amount of water removed from the MPC prior to helium leakage testing.

h. Editorial.

i. The seal manufacturer has recommended increasing the port plug torque to ensure sufficient compression of the seal. The depth of the seal groove machined under the heads of the port plugs ensure the seals seat at the higher torque without over-compression.

j. The weld removal system used to access the vent and drain ports during fuel unloading operations performs this operation differently, while achieving the same result. These changes do not increase stay times in the vicinity of the cask. Therefore, the occupational dose estimates in Chapter 10 remain bounding.

k. Editorial.

Proposed Change No. 24

TSAR Chapter 9

a. Subsection 9.1.1.4 is revised to add the words "or other site-specific, NRC-approved program for personnel qualification" after "SNT-TC-1A [9.1.3]."

b. Subsection 9.1.2.2.1, third sentence of the third paragraph is revised to add "or temporary test seal" before "installed."

c. Subsection 9.1.2.4 is revised to change the testing for the neutron shield enclosure vessel to require a pneumatic pressure test in lieu of a bubble test. A soap bubble method is retained for use in finding any leaks discovered during the pneumatic test. See attached proposed revised TSAR text in Attachment 5.

d. Subsection 9.1.3.1 is revised to 1) eliminate the specific pressure range required to be used for the overpack helium leakage test, 2) allow the flexibility to test the vent and drain port plugs in any order, and 3) to clarify that the *total* measured leakage rate from all tested penetrations must be within the prescribed acceptance limit.

e. Subsection 9.1.4.2 is revised to delete the requirement to perform testing of the neutron enclosure rupture disks in accordance with written and approved procedures.

f. Subsection 9.1.5.1 is revised regarding Holtite-A testing as shown in the attached proposed revised TSAR pages to re-define the frequency of testing to be every manufactured lot instead of every mixed batch. In addition, clarify that the material composition test is required to confirm the amount of aluminum and hydrogen and that specific gravity testing is equivalent to the density confirmation test.

g. Table 9.1.1 is revised in two places to add reference to the NF subsection of the ASME Section III Code.

h. Table 9.1.3 is revised to 1) delete the liquid penetrant (PT) examination requirement for the root pass of the closure ring welds (3 places) and 2) delete the PT examination requirement for the fuel spacers.

Reason for Proposed Changes

a. To recognize that some users may not be committed to SNT-TC-1A for personnel qualification.

b. To allow a suitable temporary test seal allows the fabricator to avoid destroying an engineered mechanical seal for the hydrotest.

c. Based on experience with fabrication of the first HI-STAR production unit, fabrication efficiency is increased if a pneumatic test of the neutron shield enclosure is performed in lieu of a soap bubble test.

d. 1) The specific pressure range used in the pressure test is a level of detail more appropriate for the implementing procedures than the TSAR. 2) This change is proposed to offer flexibility to the fabricator. 3) This change is made to be consistent with the intent of the acceptance limit being an allowed leak rate for the whole helium retention boundary.

e. To provide the appropriate language for the actual testing performed by the rupture disk supplier.

f. To provide an appropriate level of testing for the Holtite material while reducing unnecessary burden on the fabricator.

g. This is an editorial clarification. The NF Code is used for inspection of the fuel spacers, which are designed in accordance with Subsection NG (per TSAR Table 2.2.6).

h. 1) This is a conforming change based on a proposed drawing change to reduce the size of three closure ring welds to 1/8 inch. The proposed welds will not have a separate root and final pass. See Attachment 4. 2) A PT examination of the fuel spacer welds is not required by the NF Code.

Justification for Proposed Changes

a. A number of Part 50 license holders are not committed to SNT-TC-1A for personnel qualification. Provided whatever personnel qualification standard they use is part of an NRC-approved QA-plan, this is acceptable for use in implementing the applicable activities described in the HI-STAR TSAR. This change makes HI-STAR consistent with HI-STORM (Docket 72-1014).

b. Allowing a suitable temporary seal for the hydrotest allows the fabricator to avoid destroying an engineered mechanical seal for a test which is not designed to verify the integrity of the seal. The hydrotest verifies the integrity of the containment boundary welds. The integrity of the closure seals is verified during helium leak testing described in TSAR Section 9.1.3.1.

c. The neutron shield enclosure vessel is designed in accordance with ASME Section III, Subsection NF. Subsection NF does not require pressure testing of any kind. Pressure testing of this enclosure was a voluntary commitment. A pneumatic pressure test accomplishes the same objectives as the bubble test. A bubble solution will be used to find leaks if test pressure is unable to be held during the pneumatic test.

d. 1) In accordance with NUREG-1536, the TSAR is required to contain a commitment to perform testing, the acceptance criteria, and test sensitivity. These values remain in the TSAR. The test pressure range will be controlled via the implementing procedures. 2) This is editorial. There is no difference between testing one port plug before the other. 3) This is a clarification to reflect ANSI N14.5, which requires summing the individual leak rates for comparison against the overall overpack leakage rate limit.

e. The rupture disks are Important-to-Safety, Category C items which are purchased from a commercial supplier. The supplier is required to perform the testing and provide certification that the rupture disks meet the purchase order requirements. The testing may, or may not be performed in accordance with written an approved procedures, at the supplier's discretion.

f. Testing each mixed batch of Holtite is overly conservative and costly considering the controls used to mix and pour each batch. Sufficient confidence that each batch of as-poured Holtite-A is in compliance with the design requirements is provided by testing the total amount of material, (regardless of the number of mixed batches it produces) which contains the same constituent lots. Testing will be performed any time a new lot of constituent material is used in a mixed batch. Refer to the enclosed Holtec Standard Procedure HSP-107 for procedural controls imposed on Holtite-A mixing and pouring.

g. The stress analyses for the fuel spacers were performed in accordance with Subsection NG per current TSAR Table 2.2.6. This was done because they interface with the fuel basket, which is also designed to NG. The intent of the note in TSAR Table 2.2.6 is to clarify that Subsection NG applies *only* to the stress analyses. Functionally, the fuel spacers are more akin to piping and component supports than to core support structures. Therefore, Subsection NF was always intended to be the Code governing inspection of the fuel spacers. This, therefore, is a clarifying change to more clearly describe the scope of Code sections governing inspection of MPC components.

h. 1) This is a conforming change based on a drawing change proposed in Attachment 4 which reduces the size of three closure ring welds to 1/8 inch. One-eighth inch welds will not have separate root and final passes. Therefore, a PT of the final pass is the appropriate inspection in addition to visual inspection. 2) Article NF-5231 only requires PT examination of primary member welds greater than 1 inch. Other welds require visual examination. The fuel spacer welds do not meet either criterion requiring PT examination.

<u>Proposed Change No. 25</u>

<u>TSAR Chapter 11</u>

a. Subsection 11.1.1.3 text and calculation are revised as conforming changes to support the proposed addition of BPRAs to the authorized contents for HI-STAR 100.

b. Subsection 11.1.3 is revised to clarify that root pass PT examination is only performed on multi-pass welds.

c. Subsection 11.2.3.2 and Table 11.2.3 are revised as conforming changes to add discussion and data regarding the effect of BPRAs on post-fire MPC pressure. This subsection is also revised to make an editorial change to the title of Reference [11.2.7].

d. Subsection 11.2.12 text and calculation are revised as conforming changes to support the proposed addition of BPRAs to the authorized contents for HI-STAR 100.

e. Section 11.4 is revised to change Reference [11.2.7].

Reason for Proposed Changes

a. This is a conforming change to support the addition of BPRAs to the authorized contents of the cask (see Section I of this attachment). BPRAs contain helium fill gas which must be accounted for in the evaluation of off-normal conditions.

b. Editorial clarification. Also a conforming change in support of a drawing change to reduce the size of certain welds on the MPC closure ring. See Proposed Change Number 18.e

c. The first change is a conforming change to support the addition of BPRAs to the authorized contents of the cask (see Section I of this attachment). BPRAs contain helium fill gas which must be accounted for in the evaluation of a fire accident. The second change is editorial.

d. This is a conforming change to support the addition of BPRAs to the authorized contents of the cask (see Section I of this attachment). BPRAs contain helium fill gas which must be accounted for in the evaluation of burial under debris.

e. Editorial.

Justification for Proposed Changes

a. This is a conforming change to reflect helium backfill pressure adjustments made in new TSAR Subsection 4.4.1.1.16.

b. Editorial clarification and conforming change. See Proposed Change Number 18.e for justification welds size reduction.

c. The first change is a conforming change to reflect helium backfill pressure adjustments made in new TSAR Subsection 4.4.1.1.16. The second change is a correction to a reference document.

d. This is a conforming change to reflect helium backfill pressure adjustments made in new TSAR Subsection 4.4.1.1.16.

d. Editorial.

Proposed Change No. 26

TSAR Chapter 12

a. Section 12.3 is revised to delete reference to the Technical Specification Bases being provided in Appendix A to the CoC.

b. Appendix 12.A, Bases B 2.1.1, "Multi-Purpose Canister" is revised as a conforming change to reflect the change from helium density to pressure for the acceptance criterion for MPC backfilling. See Section I of this attachment.

c. Appendix 12.A, Bases B 2.1.3, "SFSC Lifting Requirements" is revised in the Surveillance Requirements section to add a note clarifying where measurements of lift height should be taken in order to confirm compliance with LCO 2.1.3.a.

d. Appendix 12.A the Surveillance Requirement number in Bases B.2.1.4 is changed from "SR 3.1.3.1" to SR 2.1.4.1."

Reason for Proposed Changes

a. Editorial.

b. Conforming change supporting the change of the MPC helium backfill acceptance criterion from density to pressure.

c. This change provides clarification as requested through user feedback.

d. Editorial.

Justification for Proposed Changes

a. Editorial.

b. The current acceptance criteria for MPC helium backfill *density* are based upon credit being taken in the thermal analysis for convection heat transfer, where the density of the helium in the MPC is an important input parameter. HI-STAR 100 was licensed assuming helium in the MPC, but without credit for convection heat transfer. Therefore, only the *presence* of helium in the MPC must be confirmed. A more appropriate acceptance criterion is helium backfill pressure. Accordingly, Table 2-1 in Appendix A to the CoC is proposed to be revised to provide a maximum pressure limit (see Section I of this attachment). This proposed change to TSAR Appendix 12.A (the TS Bases) is a conforming revision providing the technical basis for the new acceptance criterion in CoC Appendix A, Table 2-1. See Proposed Change Number 2.

c. The structural analyses of drop events assume a free-fall from the height limits in LCO 2.1.3.a to the impact surface. That height is measured from the lowest surface of the overpack with no intervening support or impact surfaces, which varies depending on the orientation of the overpack at the onset of the drop.

d. Editorial.

<u>**Proposed Change No. 27**</u>

<u>TSAR Chapter 13</u>

Revise Chapter 13 as shown in the attached marked-up pages of the chapter.

Reason for Proposed Change

To clarify the applicability of graded QA and to make the requirement for user distribution of "accept-as-is" and 'repair" dispositions consistent with NUREG-1536. These changes bring the HI-STAR QA chapter into agreement with the HI-STORM QA chapter.

Justification for Proposed Change

These changes are necessary to correctly reflect implementation of the Holtec QA program.

Section III – PROPOSED CHANGES TO DESIGN DRAWINGS

Proposed Change No. 28

Based on lessons learned during the fabrication of the HI-STAR 100 prototype and the first production unit for Plant Hatch, a number of drawings changes are proposed. Attachment 4 provides the revised drawings. The text below provides and overview of the drawing changes and categorizes them for review purposes.

Overview of Drawing Changes

The manufacturing effort on the HI-STAR 100 prototype and the first production HI-STAR 100 (overpack and MPC-68) for Plant Hatch uncovered a number of drafting errors, discrepancies, inconsistencies, and ambiguities in the Design Drawings which had to be resolved through a laborious "Engineering Change Order" (ECO) process by Holtec and by §72.48 evaluations by Southern Nuclear (Plant Hatch). In retrospect, the need to address these changes, in large measure, was inevitable given the fact that our HI-STAR 100 submittal was an industry pioneering effort which did not have the benefit of an established precedent for the level of specificity and prescriptiveness for Design Drawings.

The revised drawings submitted with this amendment request incorporate the "lessons learned" collectively by Holtec International, Southern Nuclear, and UST&D, Inc. The revisions address fabricability issues, eliminate inconsistencies, replace unverifiable or non-essential dimensions and tolerances, incorporate operationally significant dimensions/tolerances, and remove ambiguities in the verbiage of the drawing notes. As the SFPO is aware, most of the changes noted in the drawings were submitted in the pre-certification period, but the resources required for their review were, at that time, committed to SER preparation and the decision was made by the SFPO (and accepted by Holtec) that the drawing changes for HI-STAR 100 be deferred to a post-certification amendment. In the meantime, we have been forced to implement these changes through Engineering Change Orders. Their formal incorporation in the TSAR will alleviate the need for an arduous and paper-intensive ECO and §72.48 reconciliation process *for each and every licensee who deploys Hi-STAR 100.*. While the drawing changes, indicated by numbered triangles, are self-evident, a summary of the changes is provided in the following, under the categories (i) Non-Fabricable Details, (ii) Errors or Inconsistencies, (iii) Component Fit-up, (iv) Clarifications to Eliminate Ambiguities, and (v) Design Enhancements.

i. Non-Fabricable Details

The following examples illustrate changes in this category:

a. Change the angular location of the four bolt holes on the bottom flange of the overpack that are used for securing the bottom shield. The pocket trunnion location interferes with the currently defined hole locations.

b. Change the overpack inner diameter to 68-9/16" (min.). The tolerances on the inner diameter can not be guaranteed in the fabricated overpack because PWHT (which follows machining of the overpack I.D.) produces dimensional changes due to strain relief, which will vary from one unit to the next.

c. Define a maximum diameter of 68-1/2" for the MPC canister and eliminate the provision for shims on the outside of the MPC. The 68-1/2" maximum dimension assures that the MPC can be installed into the overpack, whose I.D, as stated above, is prescribed as 68-9/16" (min). The elimination of external shims reduces localized weld-induced distortion which would degrade hardware quality.

d. Change radial channel-to-radial panel weld size in the overpack to 3/16" in order to eliminate heat-induced warping of the radial plates.

e. The tolerances on the overpack (minimum) cavity length and MPC external envelope length are slightly adjusted such that welding-induced dimension changes in the as-fabricated hardware would not cause a physical interference during the worst case operating scenario (the postulated transport fire event).

ii. Errors or Inconsistencies

Examples of the changes that fall under this category are:

a. The rupture disk joining detail (in the overpack drawing) was inconsistent with the commercially available rupture disk assemblies. The detail is revised to eliminate this inconsistency.

b. The tolerances on the O-ring grooves in the overpack were based on one manufacturer's design and may not be consistent with other manufacturers' seal designs. The seal groove geometry specification is modified to permit use of competing equivalent O-rings available in the industry.

c. For the upper fuel spacers on the MPC, the diameter of item 24 is increased from 3-3/4" to 4" to assure there is sufficient base metal to make the required weld.

iii. Component Fit-Up

Dimensional tolerances and tolerance stack-ups can both aid and hinder the ability to fit up two components. In many cases, fit-up is confirmed during final inspection and thus, dimensional tolerances need to be set down to ensure that as-built components will fit together. Examples of the required changes that fall under this category are:

a. Change dimensions for drain line supports to reference dimensions. Actual size will be governed by the space from the MPC canister and basket supports in the as-fabricated equipment.

b. Identify the MPC closure ring dimensions as reference values. Allow closure ring to be made from one or more pieces. Since the closure ring shall be field welded, an actual fit-up to assure high quality welds can be made only if the ring dimensions can be adjusted to best fit its location in the as-built hardware. Fit-up at the site under high radiation conditions will be more efficient with use of multiple sections rather than one monolithic ring.

c. Change hole size on 1-3/4" holes on the overpack closure plate to 1-15/16". The increased hole size will reduce the time necessary to align the closure plate holes with the top flange holes and, thus, reduce dose to the personnel engaged in the cask loading operations.

iv. Clarifications to Eliminate Ambiguities

Examples of the changes that fall under this category are:

a. Delete the ambiguous term "surface hardened" from items 13A and 13B on the MPC Bill of Materials and add a note to the applicable MPC drawing which states that the threads of item 13A shall be surface hardened by flash chrome plating or similar. The intent of surface hardening is to protect integral parts of a component that cannot easily be replaced. Since 13B (threaded cap) is a removable item, by hardening the integral member (13A), the surface wear on the threads will be biased towards the removable member.

b. Clarify that the stainless steel overlay thickness for the overpack inner and outer seal is a reference dimension. Actual thickness of the stainless steel overlay does not affect joint sealability. Machining after weld overlay does not allow for final verification of overlay thickness.

c. The overpack internal surface is machined after rolling and welding to assure the inner diameter is met. Localized grinding of the overpack and MPC base metal surfaces may be required to address scratches, burrs, weld spatter, and the like, which are inevitable in a manufacturing process. The allowance for local grinding is based on limiting the characteristic dimension of the ground region to the value permitted by NB-3213.10 for local membrane stresses.

v. Design Enhancements

Sophisticated fixturing, improved fabrication process (i.e., welding) and lessons learned have prompted us to incorporate a variety of enhancements into the design drawings. Examples of the changes that fall under this category are:

a. An alternative design for MPC basket supports allows the fabricator improved dimensional control over the clearance between the basket supports welded to the inside surface of the MPC canister and the fuel basket over the length of the canister.

b. Eliminate MPC basket shims. Shims were permitted to give added flexibility to the manufacturer. Manufacturing experience gathered to date shows that the fixturing assures dimensions can be met and, thus, shimming is not required. Removal of shims will eliminate localized heat distortion.

c. Allow option to change sheathing weld (a non-structural weld) length and pitch from two-inch long welds at eight-inch pitches to one-inch long welds at four-inch pitches. The total amount of weld remains the same; however, the revised spacing minimizes the extent of waviness in the sheathing caused by basket panel welding.

d. In the overpack, the pocket trunnions are welded using a qualified weld procedure, directly to the overpack bottom plate, eliminating the requirement for overlay on the pocket trunnion. Elimination of the overlay reduces the distortion of the machined semi-circular recess in the trunnion, which serves as the bearing surface during the rotation operation on the overpack. The trunnion made of precipitation hardened stainless steel will receive the Code-specified hardening heat treatment at 1150° when the vessel is post-weld heat treated.

The above list, of course, is not exhaustive. It does, however, help illustrate the necessity and advisability of incorporating the changes to the Design Drawings through the amendment request submitted herewith.

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Document ID 5014354
Attachment 2

ATTACHMENT 2

MARK-UPS OF PROPOSED CHANGES TO COC 1008 APPENDICES A AND B (STRIKEOUT/ITALIC FORMAT)

1.0 USE AND APPLICATION

1.1 Definitions

---NOTE---

The defined terms of this section appear in capitalized type and are applicable throughout these Technical Specifications and Bases.

Term	Definition
ACTIONS	ACTIONS shall be that part of a Specification that prescribes Required Actions to be taken under designated Conditions within specified Completion Times.
DAMAGED FUEL ASSEMBLY	DAMAGED FUEL ASSEMBLIES are fuel assemblies with known or suspected cladding defects, *as determined by a review of records,* greater than pinhole leaks or hairline cracks, missing fuel rods that are not replaced with dummy fuel rods, or those that cannot be handled by normal means. Fuel assemblies which cannot be handled by normal means due to fuel cladding damage are considered FUEL DEBRIS.
DAMAGED FUEL CONTAINER (DFC)	DFCs are specially designed enclosures for DAMAGED FUEL ASSEMBLIES or FUEL DEBRIS which permit gaseous and liquid media to escape while minimizing dispersal of gross particulates. *DFCs authorized for use in the HI-STAR 100 System are the Holtec design or the Transnuclear Dresden Unit 1 design as shown on the applicable design drawings in the HI-STAR 100 Topical Safety Analysis Report.*
FUEL BUILDING	The FUEL BUILDING is the site-specific power plant facility, licensed pursuant to 10 CFR Part 50, where the loaded OVERPACK is transferred to or from the transporter.
FUEL DEBRIS	FUEL DEBRIS is ruptured fuel rods, severed rods, loose fuel pellets or fuel assemblies with known or suspected defects which cannot be handled by normal means due to fuel cladding damage.

2.1 SFSC INTEGRITY

2.1.1 Multi-Purpose Canister (MPC)

LCO 2.1.1 The MPC shall be dry and helium filled.

APPLICABILITY: During TRANSPORT OPERATIONS and STORAGE OPERATIONS.

ACTIONS

-----NOTE-----
Separate Condition entry is allowed for each MPC.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. MPC cavity vacuum drying pressure limit not met.	A.1 Perform an engineering evaluation to determine quantity of moisture left in MPC.	7 days
	AND	
	A.2 Determine and complete corrective actions necessary to return MPC to analyzed condition.	30 days
B. MPC helium backfill ~~density~~ *pressure* limit not met.	B.1 Perform an engineering evaluation to determine impact of helium differential.	72 hours
	AND	
	B.2 Determine and complete corrective actions necessary to return MPC to an analyzed condition.	14 days

CONDITION	REQUIRED ACTION	COMPLETION TIME
C. MPC helium leak rate limit not met.	C.1 Perform an engineering evaluation to determine impact of increased helium leak rate on heat removal capability and offsite dose release effects.	24 hours
	AND	
	C.2 Determine and complete corrective actions necessary to return MPC to an analyzed condition.	7 days
D. Required Actions and associated Completion Times not met.	D.1 Remove all fuel assemblies from the SFSC.	30 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 2.1.1.1	Verify MPC cavity vacuum drying pressure is within the limit specified in Table 2-1 for the applicable MPC model.	During LOADING OPERATIONS
SR 2.1.1.2	Verify MPC helium backfill ~~density~~ *pressure* is within the limit specified in Table 2-1 for the applicable MPC model.	During LOADING OPERATIONS
SR 2.1.1.3	Verify that the total helium leak rate through the MPC lid confinement weld and the drain and vent port confinement welds is within the limit specified in Table 2-1 for the applicable MPC model.	During LOADING OPERATIONS

Table 2-1
MPC Model-Dependent Limits

MPC MODEL	LIMITS
1. MPC-24	
a. MPC Cavity Vacuum Drying Pressure	≤ 3 torr for ≥ 30 min
b. OVERPACK Annulus Vacuum Drying Pressure	≤ 3 torr for ≥ 30 min
c. MPC Helium Backfill ~~Density~~ *Pressure*[1]	~~0.1212 g-moles/l +0% or -10%~~ ≤ *22.2 psig*
d. OVERPACK Annulus Helium Backfill Pressure	≥ 10 psig and ≤ 14 psig
e. MPC Helium Leak Rate	≤ 5.0E-6 std cc/sec (He)
f. OVERPACK Helium Leak Rate	≤ 4.3E-6 std cc/sec (He)
2. MPC-68	
a. MPC Cavity Vacuum Drying Pressure	≤ 3 torr for ≥ 30 min
b. OVERPACK Annulus Vacuum Drying Pressure	≤ 3 torr for ≥ 30 min
c. MPC Helium Backfill ~~Density~~ *Pressure*[1]	~~0.1212 g-moles/l +0% or -10%~~ ≤ *28.5 psig*
d. OVERPACK Annulus Helium Backfill Pressure	≥ 10 psig and ≤ 14 psig
e. MPC Helium Leak Rate	≤ 5.0E-6 std cc/sec (He)
f. OVERPACK Helium Leak Rate	≤ 4.3E-6 std cc/sec (He)
3. MPC-68F	
a. MPC Cavity Vacuum Drying Pressure	≤ 3 torr for ≥ 30 min
b. OVERPACK Annulus Vacuum Drying Pressure	≤ 3 torr for ≥ 30 min
c. MPC Helium Backfill ~~Density~~ *Pressure*[1]	~~0.1212 g-moles/l +0% or -10%~~ ≤ *28.5 psig*
d. OVERPACK Annulus Helium Backfill Pressure	≥ 10 psig and ≤ 14 psig
e. MPC Helium Leak Rate	≤ 5.0E-6 std cc/sec (He)
f. OVERPACK Helium Leak Rate	≤ 4.3E-6 std cc/sec (He)

[1] Helium used for backfill of MPC shall have a purity of ≥ 99.995%.

APPENDIX B DESIGN FEATURES

1.0 Definitions

NOTE

The defined terms of this section appear in capitalized type and are applicable throughout this Appendix

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Term	Definition
DAMAGED FUEL ASSEMBLY	DAMAGED FUEL ASSEMBLIES are fuel assemblies with known or suspected cladding defects, *as determined by a review of records,* greater than pinhole leaks or hairline cracks, missing fuel rods that are not replaced with dummy fuel rods, or those that cannot be handled by normal means. ~~A DAMAGED FUEL ASSEMBLY'S inability to~~ *Fuel assemblies which cannot* be handled by normal means ~~must be~~ due to ~~mechanical damage and must not be due to~~ fuel ~~rod~~ cladding damage *are considered FUEL DEBRIS.*
DAMAGED FUEL CONTAINER (DFC)	DFCs are specially designed enclosures for DAMAGED FUEL ASSEMBLIES or FUEL DEBRIS which permit gaseous and liquid media to escape while minimizing dispersal of gross particulates. *DFCs authorized for use in the HI-STAR 100 System are the Holtec design or the Transnuclear, Dresden Unit 1 design as shown on the applicable design drawings in the HI-STAR 100 Topical Safety Analysis Report.*
FUEL DEBRIS	FUEL DEBRIS is ruptured fuel rods, severed rods, loose fuel pellets or fuel assemblies with known or suspected defects which cannot be handled by normal means due to fuel cladding damage.
INTACT FUEL ASSEMBLY	INTACT FUEL ASSEMBLIES are fuel assemblies without known or suspected cladding defects greater than pinhole leaks or hairline cracks and which can be handled by normal means. Partial fuel assemblies, that is fuel assemblies from which fuel rods are missing, shall not be classified as INTACT FUEL ASSEMBLIES unless dummy fuel rods are used to displace an amount of water greater than or equal to that displaced by the original fuel rod(s).
PLANAR-AVERAGE INITIAL ENRICHMENT	PLANAR-AVERAGE INITIAL ENRICHMENT is the ~~simple~~ average of the distributed fuel rod *initial* enrichments within a given axial plane of the assembly lattice.

1.1 Fuel Specifications

1.1.1 Fuel To Be Stored In The HI-STAR 100 SFSC

a. INTACT FUEL ASSEMBLIES, DAMAGED FUEL ASSEMBLIES, ~~and~~ FUEL DEBRIS, *and certain non-fuel hardware* meeting the limits specified in Table 1.1-1 (which refers to Tables 1.1-2 through 1.1-~~5~~ *6*) may be stored in the HI-STAR 100 SFSC System.

b. For MPCs partially loaded with stainless steel clad fuel assemblies, all remaining fuel assemblies in the MPC shall meet the maximum decay heat generation limit for the stainless steel clad fuel assemblies.

c. For MPCs partially loaded with DAMAGED FUEL ASSEMBLIES or FUEL DEBRIS, all remaining Zircaloy clad INTACT FUEL ASSEMBLIES in the MPC shall meet the maximum decay heat generation limits for the DAMAGED FUEL ASSEMBLIES.

~~c.~~*d.* For MPC-68's partially loaded with array/class 6x6A, 6x6B, 6x6C, or 8x8A fuel assemblies, all remaining Zircaloy clad INTACT FUEL ASSEMBLIES in the MPC shall meet the maximum decay heat generation limits for the 6x6A, 6x6B, 6x6C, and 8x8A fuel assemblies.

1.1.2 Preferential Fuel Loading

Preferential fuel loading shall be used whenever fuel assemblies with significantly different post-irradiation cooling times (equal to or greater than one year) are to be loaded in the same MPC. That is, fuel assemblies with the longest post-irradiation cooling times shall be loaded into fuel storage locations at the periphery of the basket. Fuel assemblies with shorter post-irradiation cooling times shall be placed toward the center of the basket.

1.2 Functional and Operating Limits Violations

If any Fuel Specifications defined in Section 1.1 are violated, the following actions shall be completed:

a. The affected fuel assemblies shall be placed in a safe condition without delay and in a controlled manner.

b. Within 24 hours, notify the NRC Operations Center.

c. Within 30 days, submit a special report which describes the cause of the violation, and actions taken to restore compliance and prevent recurrence.

The above actions are not a substitute for the reporting requirements contained in 10 CFR 72.75.

1.3 Codes and Standards

The American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME), 1995 Edition with Addenda through 1997, is the governing Code for the HI-STAR 100 Cask System, as clarified in Specification 1.3.1 below.

1.3.1 Exceptions to Codes, Standards, and Criteria

Table 1.3-1 lists approved exceptions to the ASME Code for the design of the HI-STAR 100 Cask System.

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

Proposed alternatives to the ASME Code, Section III, 1995 Edition with Addenda through 1997 including exceptions allowed by Specification 1.3.1 may be used when authorized by the Director of the Office of Nuclear Material Safety and Safeguards or designee. The request for such alternative should demonstrate that:

1. The proposed alternatives would provide an acceptable level of quality and safety, or

2. Compliance with the specified requirements of the ASME Code, Section III, 1995 Edition with Addenda through 1997, would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Requests for exceptions shall be submitted in accordance with 10 CFR 72.4

1.4 Site Specific Parameters and Analyses

Site-specific parameters and analyses that need verification by the system user, as a minimum, are as follows:

1. The temperature of 80°F is the maximum allowed average yearly temperature.

2. The allowed temperature extremes, averaged over a three day period, shall be greater than -40°F, and less than 125°F.

3. The horizontal and vertical seismic acceleration levels are bounded by the values listed below in Table 1-4.

Table 1-4

Design-Basis Earthquake Input on the Top Surface of an ISFSI Pad

Horizontal g-level in each of two orthogonal directions	Horizontal g-level Vector Sum	Corresponding Vertical g-level (upward)
0.222 g	0.314 g	1.00 x 0.222 g = 0.222 g
0.235 g	0.332 g	0.75 x 0.235 g = 0.176 g
0.24 g	0.339 g	0.667 x 0.24 g = 0.160 g
0.25 g	0.354 g	0.500 x 0.25 g = 0.125 g

4. The analyzed flood condition of 12 fps water velocity and a height of 656 feet of water (full submergence of the loaded cask) are not exceeded.

5. The potential for fire and explosion shall be addressed, based on site-specific considerations. This includes the condition that the onsite transporter fuel tank will contain no more than 50 gallons of combustible transporter fuel.

6. In addition to the requirement of 10 CFR 72.212(b)(2)(ii), the cask storage pads and foundation shall include the following characteristics as applicable to the drop and tipover analyses:

    a. Concrete thickness: $\leq$ 36 inches

    b. Concrete compressive strength: $\leq$ 4,200 psi

    c. Reinforcement top and bottom (Both Directions):
        Reinforcement area and spacing determined by analysis
        Reinforcement yield strength: $\leq$ 60,000 psi

    d. Soil effective modulus of elasticity: $\leq$ 28,000 psi

        An acceptable method of defining the soil modulus of elasticity applicable to the drop and tipover analyses is provided in Table 13 of NUREG/CR-6608 with soil classification in accordance with ASTM-D2487-93, Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System USCS) and density determination in accordance with ASTM D1586-84, Standard Test Method for Penetration Test and Split/Barrel Sampling of Soils.

7. In cases where engineered features (i.e., berms, shield walls) are used to ensure that the requirements of 10 CFR 72.104(a) are met, such features are to be considered important to safety and must be evaluated to determine the applicable Quality Assurance Category.

1.5 Design Specifications

1.5.1 Specifications Important for Criticality Control

1.5.1.1 MPC-24

1. Minimum flux trap size: 1.09 in

2. Minimum ^{10}B loading in the Boral neutron absorbers: 0.0267 g/cm^2

1.5.1.2 MPC-68 and MPC-68F

1. Minimum fuel cell pitch: 6.43 in

2. Minimum ^{10}B loading in the Boral neutron absorbers: 0.0372 g/cm^2 in the MPC-68, and 0.01 g/cm^2 in the MPC-68F.

1.5.2 Specifications Important for Thermal Performance

1.5.2.1 OVERPACK

The ~~painted surface of~~ *paint used on* the HI-STAR 100 OVERPACK must have an emissivity no less than 0.85.

Table 1.1-1
Fuel Assembly Limits

I. MPC MODEL: MPC-24

A. Allowable Contents

1. Uranium oxide, PWR INTACT FUEL ASSEMBLIES, *with or without Burnable Poison Rod Assemblies (BPRAs) or Thimble Plug Devices (TPDs)* listed in Table 1.1-2 and meeting the following specifications:

a. Cladding Type:	Zircaloy (Zr) or Stainless Steel (SS) as specified in Table 1.1-2 for the applicable fuel assembly array/class
b. Initial Enrichment:	As specified in Table 1.1-2 for the applicable fuel assembly array/class.
c. Decay Heat Per Assembly:	
i. Zr Clad:	An assembly decay heat as specified in Table 1.1-4 for the applicable post-irradiation cooling time.
ii. SS Clad:	$\leq$ 575 Watts
g. Post-irradiation Cooling Time and Average Burnup Per Assembly	
i. Zr Clad:	An assembly post-irradiation cooling time and average burnup as specified in Table 1.1-5. *BPRA and TPD post-irradiation cooling time and average burnup as specified in Table 1.1-6.*
ii. SS Clad:	An assembly post-irradiation cooling time $\geq$ 9 years and an average burnup $\leq$ 30,000 MWD/MTU. <u>OR</u> An assembly post-irradiation cooling time $\geq$ 15 years and an average burnup $\leq$ 40,000 MWD/MTU.

e. Nominal Fuel Assembly Length: ≤ 176.8 inches

f. Nominal Fuel Assembly Width: ≤ 8.54 inches

g. Fuel Assembly Weight ≤ 1,680 lbs *(including non-fuel hardware)*

B. Quantity per MPC: Up to 24 fuel assemblies

C. Fuel assemblies shall not contain control components *except as specifically authorized by this CoC. BPRAs and TPDs are authorized for loading in the HI-STAR 100 System with their associated fuel assemblies provided the burnup and cooling time limits specified in Table 1.1-6 are met.*

D. DAMAGED FUEL ASSEMBLIES and FUEL DEBRIS are not authorized for loading into the MPC-24.

II. MPC MODEL: MPC-68

A. Allowable Contents

1. Uranium oxide, BWR INTACT FUEL ASSEMBLIES listed in Table 1.1-3, with or without Zircaloy channels, and meeting the following specifications:

a. Cladding Type:	Zircaloy (Zr) or Stainless Steel (SS) as specified in Table 1.1-3 for the applicable fuel assembly array/class.
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
d. Decay Heat Per Assembly	
i. Zr Clad:	An assembly decay heat as specified in Table 1.1-4 for the applicable post-irradiation cooling time, except for array/class 6x6A, 6x6C, and 8x8A fuel assemblies, which shall have a decay heat $\leq$ 115 Watts *and array/class 8x8F fuel assemblies, which shall have a decay heat $\leq$ 183.5 Watts*.
ii. SS Clad:	$\leq$ 95 Watts

e. Post-irradiation Cooling Time and Average Burnup Per Assembly

i. Zr Clad:	An assembly post-irradiation cooling time and average burnup as specified in Table 1.1-5, except for array/class 6x6A, 6x6C, and 8x8A fuel assemblies, which shall have a cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTU *and array/class 8x8F fuel assemblies, which shall have a cooling time ≥ 10 years and an average burnup ≤ 27,500 MWD/MTU.*
ii. SS Clad:	An assembly cooling time after discharge ≥ 10 years and an average burnup ≤ 22,500 MWD/MTU.

f. Nominal Fuel Assembly Length:	≤ 176.2 inches
g. Nominal Fuel Assembly Width:	≤ 5.85 inches
h. Fuel Assembly Weight	≤ 700 lbs, including channels

2. Uranium oxide, BWR DAMAGED FUEL ASSEMBLIES, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. BWR DAMAGED FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6A, 6x6C, 7x7A, or 8x8A, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
d. Decay Heat Per Assembly:	$\leq$ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time $\geq$ 18 years and an average burnup $\leq$ 30,000 MWD/MTU.
f. Nominal Fuel Assembly Length:	$\leq$ 135.0 inches
g. Nominal Fuel Assembly Width:	$\leq$ 4.70 inches
h. Fuel Assembly Weight:	$\leq$ 400 lbs, including channels

3. Mixed oxide (MOX) INTACT FUEL ASSEMBLIES, with or without Zircaloy channels. MOX BWR INTACT FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTIHM.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

4. Mixed oxide (MOX), BWR DAMAGED FUEL ASSEMBLIES, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. MOX BWR DAMAGED FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTIHM.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

5. *Thoria rods (ThO_2 and UO_2) placed in Dresden Unit 1 Thoria Rod Canisters and meeting the following specifications:*

a. Cladding Type:	*Zircaloy (Zr)*
b. Composition:	*98.2 wt.% ThO_2, 1.8 wt. % UO_2 with an enrichment of 93.5 wt. % ^{235}U.*
c. Number of Rods Per Thoria Rod Canister:	*$\leq$ 18*
d. Decay Heat Per Thoria Rod Canister:	*$\leq$ 115 Watts*
e. Post-irradiation Fuel Cooling Time and Average Burnup Per Thoria Rod Canister:	*A fuel post-irradiation cooling time $\geq$ 18 years and an average burnup $\leq$ 16,000 MWD/MTIHM.*
f. Initial Heavy Metal Weight:	*$\leq$ 27 kg/canister*
g. Fuel Cladding O.D.:	*$\geq$ 0.412 inches*
h. Fuel Cladding I.D.:	*$\leq$ 0.362 inches*
i. Fuel Pellet O.D.:	*$\leq$ 0.358 inches*
j. Active Fuel Length:	*$\leq$ 111 inches*
k. Canister Weight:	*$\leq$ 550 lbs, including fuel*

B. Quantity per MPC: *Up to one (1) Dresden Unit 1 Thoria Rod Canister plus any* ~~Any~~ combination of DAMAGED FUEL ASSEMBLIES in DAMAGED FUEL CONTAINERS, and INTACT FUEL ASSEMBLIES, up to a total of 68.

C. Fuel assemblies with stainless steel channels are not authorized for loading in the MPC -68.

D. Dresden Unit 1 fuel assemblies with one Antimony-Beryllium neutron source are authorized for loading in the MPC-68.

III. MPC MODEL: MPC-68F

A. Allowable Contents

1. Uranium oxide, BWR INTACT FUEL ASSEMBLIES, with or without Zircaloy channels. BWR INTACT FUEL ASSEMBLIES shall meet the criteria *specified* in Table 1.1-3 for fuel assembly array/class 6x6A, 6x6C, 7x7A, or 8x8A, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTU.
f. Nominal Fuel Assembly Length:	≤ 176.2 inches
g. Nominal Fuel Assembly Width:	≤ 5.85 inches
h. Fuel Assembly Weight:	≤ 700 lbs, including channels

2. Uranium oxide, BWR DAMAGED FUEL ASSEMBLIES, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. BWR DAMAGED FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6A, 6x6C, 7x7A, or 8x8A, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTU.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

3. Uranium oxide, BWR FUEL DEBRIS, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. The original fuel assemblies for the BWR FUEL DEBRIS shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6A, 6x6C, 7x7A, or 8x8A, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTU.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

4. Mixed oxide (MOX), BWR INTACT FUEL ASSEMBLIES, with or without Zircaloy channels. MOX BWR INTACT FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTIHM.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

5. Mixed oxide (MOX), BWR DAMAGED FUEL ASSEMBLIES, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. MOX BWR DAMAGED FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTIHM.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

6. Mixed oxide (MOX), BWR FUEL DEBRIS, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. The original fuel assemblies for the MOX BWR FUEL DEBRIS shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTIHM.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

7. *Thoria rods (ThO_2 and UO_2) placed in Dresden Unit 1 Thoria Rod Canisters and meeting the following specifications:*

a. *Cladding Type:*	*Zircaloy (Zr)*
b. *Composition:*	*98.2 wt.% ThO_2, 1.8 wt. % UO_2 with an enrichment of 93.5 wt. % ^{235}U.*
c. *Number of Rods Per Thoria Rod Canister:*	*$\leq$ 18*
d. *Decay Heat Per Thoria Rod Canister:*	*$\leq$ 115 Watts*
e. *Post-irradiation Fuel Cooling Time and Average Burnup Per Thoria Rod Canister:*	*A fuel assembly post-irradiation cooling time $\geq$ 18 years and an average burnup $\leq$ 16,000 MWD/MTIHM.*
f. *Initial Heavy Metal Weight:*	*$\leq$ 27 kg/canister*
g. *Fuel Cladding O.D.:*	*$\geq$ 0.412 inches*
h. *Fuel Cladding I.D.:*	*$\leq$ 0.362 inches*
i. *Fuel Pellet O.D.:*	*$\leq$ 0.358 inches*
j. *Active Fuel Length:*	*$\leq$ 111 inches*
k. *Canister Weight:*	*$\leq$ 550 lbs, including fuel*

B. Quantity per MPC:

Up to four (4) DFCs containing uranium oxide or MOX BWR FUEL DEBRIS. The remaining MPC-68F fuel storage locations may be filled with array/class 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A fuel assemblies of the following type, as applicable:

a. Uranium oxide BWR INTACT FUEL ASSEMBLIES;

b. MOX BWR INTACT FUEL ASSEMBLIES;

c. Uranium oxide BWR DAMAGED FUEL ASSEMBLIES placed in DFCs; ~~or~~

d. MOX BWR DAMAGED FUEL ASSEMBLIES placed in DFCs*; or*

e. Up to one (1) Dresden Unit 1 Thoria Rod Canister.

C. Fuel assemblies with stainless steel channels are not authorized for loading in the MPC-68F.

D. Dresden Unit 1 fuel assemblies with one Antimony-Beryllium neutron source are authorized for loading in the MPC-68F.

Table 1.1-2
PWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/Class	**14x14A**	**14x14B**	**14x14C**	**14x14D**	**15x15A**
Clad Material (Note 2)	Zr	Zr	Zr	SS	Zr
Design Initial U (kg/assy.) *(Note 3)*	~~≤ 402~~ *≤ 407*	~~≤ 402~~ *≤ 407*	~~≤ 410~~ *≤ 425*	≤ 400	~~≤ 420~~ *≤ 464*
Initial Enrichment (wt % ^{235}U)	≤ 4.6	≤ 4.6	≤ 4.6	≤ 4.0	≤ 4.1
No. of Fuel Rods	179	179	176	180	204
Clad O.D. (in.)	≥ 0.400	≥ 0.417	≥ 0.440	≥ 0.422	≥ 0.418
Clad I.D. (in.)	≤ 0.3514	≤ 0.3734	~~≤ 0.3840~~ *≤ 0.3880*	≤ 0.3890	≤ 0.3660
Pellet Dia. (in.)	≤ 0.3444	≤ 0.3659	~~≤ 0.3770~~ *≤ 0.3805*	≤ 0.3835	≤ 0.3580
Fuel Rod Pitch (in.)	≤ 0.556	≤ 0.556	≤ 0.580	≤ 0.556	≤ 0.550
Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 144	≤ 150
No. of Guide Tubes	17	17	5 (Note ~~3~~ *4*)	16	21
Guide Tube Thickness (in.)	≥ 0.017	≥ 0.017	~~≥ 0.040~~ *≥ 0.038*	≥ 0.0145	≥ 0.0165

Table 1.1-2 (continued)
PWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/Class	**15x15B**	**15x15C**	**15x15D**	**15x15E**	**15x15F**
Clad Material (Note 2)	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) *(Note 3)*	≤ 464	≤ 464	≤ 475	≤ 475	≤ 475
Initial Enrichment (wt % ^{235}U)	≤ 4.1	≤ 4.1	≤ 4.1	≤ 4.1	≤ 4.1
No. of Fuel Rods	204	204	208	208	208
Clad O.D. (in.)	≥ 0.420	≥ 0.417	≥ 0.430	≥ 0.428	≥ 0.428
Clad I.D. (in.)	≤ 0.3736	≤ 0.3640	≤ 0.3800	≤ 0.3790	≤ 0.3820
Pellet Dia. (in.)	≤ 0.3671	≤ 0.3570	≤ 0.3735	≤ 0.3707	≤ 0.3742
Fuel Rod Pitch (in.)	≤ 0.563	≤ 0.563	≤ 0.568	≤ 0.568	≤ 0.568
Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Guide Tubes	21	21	17	17	17
Guide Tube Thickness (in.)	≥ 0.015	≥ 0.0165	≥ 0.0150	≥ 0.0140	≥ 0.0140

Table 1.1-2 (continued)
PWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/ Class	**15x15G**	***15x15H***	**16x16A**	**17x17A**	**17x17B**	**17x17C**
Clad Material (Note 2)	SS	*Zr*	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) *(Note 3)*	≤ 420	*≤ 475*	~~≤ 430~~ *≤ 443*	~~≤ 450~~ *≤ 467*	~~≤ 464~~ *≤ 467*	~~≤ 460~~ *≤ 474*
Initial Enrichment (wt % ^{235}U)	≤ 4.0	*≤ 3.8*	≤ 4.6	≤ 4.0	≤ 4.0	≤ 4.0
No. of Fuel Rods	204	*208*	236	264	264	264
Clad O.D. (in.)	≥ 0.422	*≥ 0.414*	≥ 0.382	≥ 0.360	≥ 0.372	≥ 0.377
Clad I.D. (in.)	≤ 0.3890	*≤ 0.3700*	≤ 0.3320	≤ 0.3150	≤ 0.3310	≤ 0.3330
Pellet Dia. (in.)	≤ 0.3825	*≤ 0.3622*	≤ 0.3255	≤ 0.3088	≤ 0.3232	≤ 0.3252
Fuel Rod Pitch (in.)	≤ 0.563	*≤ 0.568*	≤ 0.506	≤ 0.496	≤ 0.496	≤ 0.502
Active Fuel Length (in.)	≤ 144	*≤ 150*	≤ 150	≤ 150	≤ 150	≤ 150
No. of Guide Tubes	21	*17*	5 (Note ~~3~~ *4*)	25	25	25
Guide Tube Thickness (in.)	≥ 0.0145	*≥ 0.0140*	≥ 0.0400	≥ 0.016	≥ 0.014	≥ 0.020

Notes:

1. ~~Initial Uranium weights and all~~ *All* dimensions are design nominal values. ~~Actual uranium weights may be up to 2.0% higher, within the manufacturer's tolerance.~~ Maximum and minimum dimensions are specified to bound variations in design nominal values within a given array/class.
2. Zr. Designates cladding material made of Zirconium or Zirconium alloys.
3. ~~Each guide tube replaces four fuel rods.~~ *Design initial uranium weight is the uranium weight specified for each assembly by the fuel manufacturer or reactor user. For each PWR fuel assembly, the total uranium weight limit specified in this table may be increased up to 2.0% for comparison with users' fuel records to account for manufacturer's tolerances.*
4. Each guide tube replaces four fuel rods.

Table 1.1-3
BWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/Class	**6x6A**	**6x6B**	**6x6C**	**7x7A**	**7x7B**	**8x8A**
Clad Material (Note 2)	Zr	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) *(Note 3)*	~~≤ 108~~ *110*	~~≤ 108~~ *110*	~~≤ 108~~ *110*	≤ 100	≤ 195	≤ 120
Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% ^{235}U)	≤ 2.7	≤ 2.7 for the UO_2 rods. See Note ~~3~~ *4* for MOX rods	≤ 2.7	≤ 2.7	≤ 4.2	≤ 2.7
Initial Maximum Rod Enrichment (wt.% ^{235}U)	≤ 4.0	≤ 4.0	≤ 4.0	~~≤ 4.0~~ *≤ 5.5*	≤ 5.0	≤ 4.0
No. of Fuel Rods	*35 or* 36	*35 or* 36 (up to 9 MOX rods)	36	49	49	*63 or* 64
Clad O.D. (in.)	≥ 0.5550	≥ 0.5625	≥ 0.5630	≥ 0.4860	≥ 0.5630	≥ 0.4120
Clad I.D. (in.)	~~≤ 0.4945~~ *≤ 0.5105*	≤ 0.4945	≤ 0.4990	~~≤ 0.4200~~ *≤ 0.4204*	≤ 0.4990	≤ 0.3620
Pellet Dia. (in.)	~~≤ 0.4940~~ *≤ 0.4980*	≤ 0.4820	≤ 0.4880	≤ 0.4110	~~≤ 0.4880~~ *≤ 0.4910*	≤ 0.3580
Fuel Rod Pitch (in.)	~~≤ 0.694~~ *≤ 0.710*	~~≤ 0.694~~ *≤ 0.710*	≤ 0.740	≤ 0.631	≤ 0.738	≤ 0.523
Active Fuel Length (in.)	~~≤ 110~~ *≤ 120*	~~≤ 110~~ *≤ 120*	≤ 77.5	~~≤ 79~~ *≤ 80*	≤ 150	~~≤ 110~~ *≤ 120*
No. of Water Rods *(Note 11)*	*1 or* 0	*1 or* 0	0	0	0	*1 or* 0
Water Rod Thickness (in.)	~~N/A~~ *> 0*	~~N/A~~ *> 0*	N/A	N/A	N/A	~~N/A~~ *≥ 0*
Channel Thickness (in.)	≤ 0.060	≤ 0.060	≤ 0.060	≤ 0.060	≤ 0.120	≤ 0.100

Table 1.1-3 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/Class	**8x8B**	**8x8C**	**8x8D**	**8x8E**	***8x8F***	**9x9A**	**9x9B**
Clad Material (Note 2)	Zr	Zr	Zr	Zr	*Zr*	Zr	Zr
Design Initial U (kg/assy.) *(Note 3)*	≤ 185	≤ 185	≤ 185	~~≤ 180~~ *≤ 185*	*≤ 185*	~~≤ 173~~ *≤ 177*	~~≤ 173~~ *≤ 177*
Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% ^{235}U)	≤ 4.2	≤ 4.2	≤ 4.2	≤ 4.2	*≤ 4.2*	≤ 4.2	≤ 4.2
Initial Maximum Rod Enrichment (wt.% ^{235}U)	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	*≤ 5.0*	≤ 5.0	≤ 5.0
No. of Fuel Rods	63 *or 64*	62	60 *or 61*	59	*64*	74/66 (Note ~~4~~ 5)	72
Clad O.D. (in.)	≥ 0.4840	≥ 0.4830	≥ 0.4830	≥ 0.4930	*≥ 0.4576*	≥ 0.4400	≥ 0.4330
Clad I.D. (in.)	~~≤ 0.4250~~ *≤ 0.4295*	≤ 0.4250	~~≤ 0.4190~~ *≤ 0.4230*	≤ 0.4250	*≤ 0.3996*	≤ 0.3840	≤ 0.3810
Pellet Dia. (in.)	~~≤ 0.4160~~ *≤ 0.4195*	≤ 0.4160	~~≤ 0.4110~~ *≤ 0.4140*	≤ 0.4160	*≤ 0.3913*	≤ 0.3760	≤ 0.3740
Fuel Rod Pitch (in.)	~~≤ 0.641~~ *≤ 0.642*	≤ 0.641	≤ 0.640	≤ 0.640	*≤ 0.609*	≤ 0.566	~~≤ 0.569~~ *≤ 0.572*
Design Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	*≤ 150*	≤ 150	≤ 150
No. of Water Rods *(Note 11)*	1 *or 0*	2	1 - 4 (Note ~~6~~ 7)	5	*N/A (Note 12)*	2	1 (Note ~~5~~ 6)
Water Rod Thickness (in.)	≥ 0.034	> 0.00	> 0.00	≥ 0.034	*≥ 0.0315*	> 0.00	> 0.00
Channel Thickness (in.)	≤ 0.120	≤ 0.120	≤ 0.120	≤ 0.100	*≤ 0.055*	≤ 0.120	≤ 0.120

Table 1.1-3 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/Class	**9x9C**	**9x9D**	**9x9E** *(Note 13)*	**9x9F** *(Note 13)*	**10x10A**
Clad Material (Note 2)	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) *(Note 3)*	~~≤ 173~~ *≤ 177*	~~≤ 170~~ *≤ 177*	~~≤ 170~~ *≤ 177*	~~≤ 170~~ *≤ 177*	~~≤ 182~~ *≤ 186*
Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% ^{235}U)	≤ 4.2	≤ 4.2	~~≤ 4.2~~ *≤ 4.1*	~~≤ 4.2~~ *≤ 4.1*	≤ 4.2
Initial Maximum Rod Enrichment (wt.% ^{235}U)	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
No. of Fuel Rods	80	79	76	76	92/78 (Note ~~7~~ *8*)
Clad O.D. (in.)	≥ 0.4230	≥ 0.4240	≥ 0.4170	≥ 0.4430	≥ 0.4040
Clad I.D. (in.)	≤ 0.3640	≤ 0.3640	~~≤ 0.3590~~ *≤ 0.3640*	~~≤ 0.3810~~ *≤ 0.3860*	≤ 0.3520
Pellet Dia. (in.)	≤ 0.3565	≤ 0.3565	~~≤ 0.3525~~ *≤ 0.3530*	≤ 0.3745	≤ 0.3455
Fuel Rod Pitch (in.)	≤ 0.572	≤ 0.572	≤ 0.572	≤ 0.572	≤ 0.510
Design Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Water Rods *(Note 11)*	1	2	5	5	2
Water Rod Thickness (in.)	≥ 0.020	~~≥ 0.0305~~ *≥ 0.0300*	~~≥ 0.0305~~ *≥ 0.0120*	~~≥ 0.0305~~ *≥ 0.0120*	≥ 0.0300
Channel Thickness (in.)	≤ 0.100	≤ 0.100	~~≤ 0.100~~ *≤ 0.120*	~~≤ 0.100~~ *≤ 0.120*	≤ 0.120

Table 1.1-3 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/Class	**10x10B**	**10x10C**	**10x10D**	**10x10E**
Clad Material (Note 2)	Zr	Zr	SS	SS
Design Initial U (kg/assy.) *(Note 3)*	~~≤ 182~~ *≤ 186*	~~≤ 180~~ *≤ 186*	≤ 125	≤ 125
Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% ^{235}U)	≤ 4.2	≤ 4.2	≤ 4.0	≤ 4.0
Initial Maximum Rod Enrichment (wt.% ^{235}U)	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5
No. of Fuel Rods	91/83 (Note ~~8~~ *9*)	96	100	96
Clad O.D. (in.)	≥ 0.3957	~~≥ 0.3790~~ *≥ 0.3780*	≥ 0.3960	≥ 0.3940
Clad I.D. (in.)	≤ 0.3480	≤ 0.3294	≤ 0.3560	≤ 0.3500
Pellet Dia. (in.)	≤ 0.3420	≤ 0.3224	≤ 0.3500	≤ 0.3430
Fuel Rod Pitch (in.)	≤ 0.510	≤ 0.488	≤ 0.565	≤ 0.557
Design Active Fuel Length (in.)	≤ 150	≤ 150	≤ 83	≤ 83
No. of Water Rods *(Note 11)*	1 (Note ~~5~~ *6*)	5 (Note ~~9~~ *10*)	0	4
Water Rod Thickness (in.)	> 0.00	~~≥ 0.034~~ *≥ 0.031*	N/A	≥ 0.022
Channel Thickness (in.)	≤ 0.120	≤ 0.055	≤ 0.080	≤ 0.080

1. ~~Initial Uranium weights and all~~ *All* dimensions are design nominal values. ~~Actual uranium weights may be up to 1.5% higher, within the manufacturer's tolerance.~~ Maximum and minimum dimensions are specified to bound variations in design nominal values within a given array/class.
2. Zr designates cladding material made from Zirconium or Zirconium alloys.
3. *Design initial uranium weight is the uranium weight specified for each assembly by the fuel manufacturer or reactor user. For each BWR fuel assembly, the total uranium weight limit specified in this table may be increased up to 1.5% for comparison with users' fuel records to account for manufacturer's tolerances.*
4. ≤ ~~0.612~~ *0.635* wt. % ^{235}U and ≤ 1.578 wt. % total fissile plutonium (^{239}Pu and ^{241}Pu), *(wt. % of total fuel weight, i.e., UO_2 plus PuO_2).*
5. This assembly class contains 74 *total fuel* rods; 66 full length rods and 8 partial length rods.
6. Square, replacing nine fuel rods.
7. Variable
8. This assembly class contains 92 total fuel rods; 78 full length rods and 14 partial length rods.
9. This assembly class contains 91 total fuel rods; 83 full length rods and 8 partial length rods.
10. One diamond-shaped water rod replacing the four center fuel rods and four rectangular water rods dividing the assembly into four quadrants.
11. *These rods may also be sealed at both ends and contain non-fissile material in lieu of water.*
12. *This assembly is known as "QUAD+." It has four rectangular water cross segments dividing the assembly into four quadrants.*
13. *For the SPC 9x9-5 fuel assembly, each fuel rod must meet either the 9x9E or 9x9F set of limits for clad O.D., clad I.D., and pellet diameter.*

Table 1.1-4
FUEL ASSEMBLY COOLING AND DECAY HEAT GENERATION *(Note 1)*

Post-irradiation Cooling Time (years)	**MPC-24 PWR Assembly Decay Heat (Watts)** *(Note 2)*	**MPC-68 BWR Assembly Decay Heat (Watts)**
≥ 5	≤ 792	≤ 272
~~≤~~ ≥ 6	≤ 773	≤ 261
~~≤~~ ≥ 7	≤ 703	≤ 238
~~≤~~ ≥ 8	≤ 698	≤ 236
~~≤~~ ≥ 9	≤ 692	≤ 234
~~≤~~ ≥ 10	≤ 687	≤ 232
~~≤~~ ≥ 11	≤ 683	≤ 231
~~≤~~ ≥ 12	≤ 678	≤ 229
~~≤~~ ≥ 13	≤ 674	≤ 228
~~≤~~ ≥ 14	≤ 669	≤ 227
~~> 14~~ ≥ *15*	≤ 665	≤ 226

Notes:
1. *Linear interpolation between points is permitted.*
2. *For assemblies with or without BPRAs or TPDs (assembly only).*

Table 1.1-5
FUEL ASSEMBLY COOLING AND AVERAGE BURNUP *(Note 1)*

Post-irradiation Cooling Time (years)	**MPC-24 PWR Assembly Burnup (MWD/MTU)** *(Note 2)*	*MPC-24 PWR Assembly Burnup (MWD/MTU) (Note 3)*	**MPC-68 BWR Assembly Burnup (MWD/MTU)**
≥ 5	≤ 28,700	*≤ 28,300*	≤ 26,000
≥ 6	*≤ 32,700*	*≤ 32,300*	≤ 29,100
≥ 7	≤ 33,300	*≤ 32,700*	≤ 29,600
≥ 8	*≤ 35,500*	*≤ 35,000*	≤ 31,400
≥ 9	≤ 37,000	*≤ 36,500*	≤ 32,800
≥ 10	*≤ 38,200*	*≤ 37,600*	≤ 33,800
≥ 11	≤ 39,300	*≤ 38,700*	≤ 34,800
≥ 12	*≤ 40,100*	*≤ 39,500*	≤ 35,500
≥ 13	*≤ 40,800*	*≤ 40,200*	≤ 36,200
≥ 14	≤ 41,500	*≤ 40,800*	≤ 36,900
≥ 15	≤ 42,100	*≤ 41,400*	≤ 37,600

Notes: 1. Linear interpolation between points is permitted.
2. For assemblies without BPRAs and with or without TPDs (assembly only).
3. For assemblies with BPRAs (assembly only).

Table 1.1-6
NON-FUEL HARDWARE COOLING AND AVERAGE BURNUP (Note 1)

Post-irradiation Cooling Time (years)	**MPC-24 BPRA BURNUP (MWD/MTU)**	**MPC-24 TPD BURNUP (MWD/MTU)**
≥ 3	≤ 20,000	NC (Note 2)
≥ 4	NC	≤ 20,000
≥ 5	≤ 30,000	NC
≥ 6	≤ 40,000	≤ 30,000
≥ 7	NC	≤ 40,000
≥ 8	≤ 50,000	NC
≥ 9	≤ 60,000	≤ 50,000
≥ 10	NC	≤ 60,000
≥ 11	NC	NC
≥ 12	NC	≤ 90,000
≥ 13	NC	≤ 180,000
≥ 14	NC	≤ 630,000

Notes:
1. Linear interpolation between points is permitted, except that TPD burnups > 180,000 MWD/MTU and ≤ 630,000 MWD/MTU must be cooled ≥ 14 years.
2. Not Calculated

LIST OF ASME CODE EXCEPTIONS FOR HI-STAR 100 SYSTEM
Table 1.3-1

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
MPC	NB-1100	Statement of requirements for Code stamping of components.	MPC enclosure vessel is designed and will be fabricated in accordance with ASME Code, Section III, Subsection NB to the maximum practical extent, but Code stamping is not required.
MPC	NB-2000	Requires materials to be supplied by ASME-approved material supplier.	Materials will be supplied by Holtec-approved suppliers with Certified Material Test Reports (CMTRs) in accordance with NB-2000 requirements.
MPC Lid and Closure Ring Welds	NB-4243	Full penetration welds required for Category C Joints (flat head to main shell per NB-3352.3).	MPC lid and closure ring are not full penetration welds. They are welded independently to provide a redundant seal. Additionally, a weld efficiency factor of 0.45 has been applied to the analyses of these welds.
MPC Lid to Shell Weld	*NB-5230*	*Radiographic (RT) or ultrasonic (UT) examination required.*	*Only UT or multi-layer liquid penetrant (PT) examination is permitted. If PT alone is used, at a minimum, it will include the root and final weld layers and each approximately 3/8 inch of weld depth.*
MPC Closure Ring, Vent and Drain Cover Plate Welds	NB-5230	Radiographic (RT) or ultrasonic (UT) examination required	Root *(if more than one weld pass is required)* and final liquid penetrant examination to be performed in accordance with NB-5245. The MPC vent and drain cover plate welds are leak tested. The closure ring provides independent redundant closure for vent and drain cover plates.

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
MPC Enclosure Vessel and Lid	NB-6111	All completed pressure retaining systems shall be pressure tested.	The MPC enclosure vessel is seal welded in the field following fuel assembly loading. The MPC enclosure vessel shall then be hydrostatically tested as defined in Chapter 9. Accessibility for leakage inspections preclude a Code compliant hydrostatic test. All MPC enclosure vessel welds (except the ~~lid-to-shell and~~ closure ring and vent/drain cover plate) are inspected by ~~RT or UT~~ *volumetric examination, except the MPC lid-to-shell weld shall be verified by volumetric or multi-layer PT examination. If PT alone is used, at a minimum, it must include the root and final layers and each approximately 3/8 inch of weld depth. For either UT or PT, the maximum undetectable flaw size must be demonstrated to be less than the critical flaw size. The critical flaw size must be determined in accordance with ASME XI methods. The critical flaw size shall not cause the primary stress limits of NB-3000 to be exceeded.* ~~The MPC lid-to-shell root and final weld layers are PT examined and the entire weld is either UT examined or multilayer PT examined.~~ The vent/drain cover plate weld is confirmed by liquid penetrant examination and the closure ring weld is confirmed by liquid penetrant examination. The inspection process, including findings, (indications) shall be made a permanent part of the certificate holder's records by video, photographic, or other means which provide an equivalent retrievable record of weld integrity. The video or photographic records should be taken during the final interpretation period described in ASME Section V, Article 6, T-676. The inspection of the weld must be performed by qualified personnel and shall meet the acceptance requirements of ASME

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
MPC Enclosure Vessel	NB-7000	Vessels are required to have overpressure protection.	No overpressure protection is provided. The function of the MPC enclosure vessel is to contain the radioactive contents under normal, off-normal, and accident conditions. The MPC vessel is designed to withstand maximum internal pressure considering 100% fuel rod failure and maximum accident temperatures.
MPC Enclosure Vessel	NB-8000	States requirements for nameplates, stamping and reports per NCA-8000.	The HI-STAR 100 System is to be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. Code stamping is not required. QA data package to be in accordance with Holtec approved QA program.
Overpack Helium Retention Boundary	NB-1100	Statement of requirements for Code stamping of components	Overpack helium retention boundary is designed, and will be fabricated in accordance with ASME Code, Section III, Subsection NB to the maximum practical extent, but Code stamping is not required.
Overpack Helium Retention Boundary	NB-2000	Requires materials to be supplied by ASME approved Material Supplier.	Material will be supplied by Holtec approved suppliers with CMTRs per NB-2000.
Overpack Helium Retention Boundary	NB-7000	Vessels are required to have overpressure protection.	No overpressure protection is provided. Function of overpack vessel is to contain helium contents under normal, off-normal, and accident conditions. Overpack vessel is designed to withstand maximum internal pressure and maximum accident temperatures.

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
Overpack Helium Retention Boundary	NB-8000	Statement of Requirements for nameplates, stamping and reports per NCA-8000.	The HI-STAR 100 System is to be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. Code stamping is not required. QA data package to be in accordance with Holtec approved QA program.
MPC Basket Assembly	NG-2000	Requires materials to be supplied by ASME approved Material Supplier.	Materials will be supplied by Holtec approved supplier with CMTRs per NG-2000 requirements.
MPC Basket Assembly	NG-8000	Statement of requirements for nameplates, stamping and reports per NCA-8000.	The HI-STAR 100 System is to be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. Code stamping is not required. QA data package to be in accordance with Holtec approved QA program.
Overpack Intermediate Shells	NF-4622	All welds, including repair welds, shall be post-weld heat treated (PWHT).	Intermediate shell-to-top flange welds and intermediate shell-to-bottom plate welds do not require PWHT. These welds attach non-pressure retaining parts to pressure retaining parts. The pressure retaining parts are >7 inches thick. Localized PWHT will cause material away from the weld to experience elevated temperatures which will have an adverse effect on the material properties.
Overpack Helium Retention Boundary	NG-2000	Perform radiographic examination after post-weld heat treatment (PWHT)	Radiography of the helium retention boundary welds after PWHT is not required. All welds (including repairs) will have passed radiographic examination prior to PWHT of the entire containment boundary. Confirmatory radiographic examination after PWHT is not necessary because PWHT is not known to introduce new weld defects in nickel steels.

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
Overpack Intermediate Shells	NF-2000	Requires materials to be supplied by ASME approved Material Supplier.	Materials will be supplied by Holtec approved supplier with CMTRs per NF-2000 requirements.
Overpack Helium Retention Boundary	NB-2330	Defines the methods for determining the T_{NDT} for impact testing of materials.	T_{NDT} shall be defined in accordance with Regulatory Guides 7.11 and 7.12 for the helium retention boundary components.

ATTACHMENT 3

PROPOSED REVISED COC 1008 APPENDICES A AND B (FINAL FORM)

1.0 USE AND APPLICATION

1.1 Definitions

---NOTE---
The defined terms of this section appear in capitalized type and are applicable throughout these Technical Specifications and Bases.

Term	Definition
ACTIONS	ACTIONS shall be that part of a Specification that prescribes Required Actions to be taken under designated Conditions within specified Completion Times.
DAMAGED FUEL ASSEMBLY	DAMAGED FUEL ASSEMBLIES are fuel assemblies with known or suspected cladding defects, as determined by a review of records, greater than pinhole leaks or hairline cracks, missing fuel rods that are not replaced with dummy fuel rods, or those that cannot be handled by normal means. Fuel assemblies which cannot be handled by normal means due to fuel cladding damage are considered FUEL DEBRIS.
DAMAGED FUEL CONTAINER (DFC)	DFCs are specially designed enclosures for DAMAGED FUEL ASSEMBLIES or FUEL DEBRIS which permit gaseous and liquid media to escape while minimizing dispersal of gross particulates. DFCs authorized for use in the HI-STAR 100 System are the Holtec design or the Transnuclear, Dresden Unit 1 design as shown on the applicable drawings in the HI-STAR 100 Topical Safety Analysis Report.
FUEL BUILDING	The FUEL BUILDING is the site-specific power plant facility, licensed pursuant to 10 CFR Part 50, where the loaded OVERPACK is transferred to or from the transporter.
FUEL DEBRIS	FUEL DEBRIS is ruptured fuel rods, severed rods, loose fuel pellets or fuel assemblies with known or suspected defects which cannot be handled by normal means due to fuel cladding damage.

2.1 SFSC INTEGRITY

2.1.1 Multi-Purpose Canister (MPC)

LCO 2.1.1 The MPC shall be dry and helium filled.

APPLICABILITY: During TRANSPORT OPERATIONS and STORAGE OPERATIONS.

ACTIONS

---NOTE---

Separate Condition entry is allowed for each MPC.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. MPC cavity vacuum drying pressure limit not met.	A.1 Perform an engineering evaluation to determine quantity of moisture left in MPC.	7 days
	<u>AND</u>	
	A.2 Determine and complete corrective actions necessary to return MPC to analyzed condition.	30 days
B. MPC helium backfill pressure limit not met.	B.1 Perform an engineering evaluation to determine impact of helium differential.	72 hours
	<u>AND</u>	
	B.2 Determine and complete corrective actions necessary to return MPC to an analyzed condition.	14 days

CONDITION	REQUIRED ACTION	COMPLETION TIME
C. MPC helium leak rate limit not met.	C.1 Perform an engineering evaluation to determine impact of increased helium leak rate on heat removal capability and offsite dose release effects. AND C.2 Determine and complete corrective actions necessary to return MPC to an analyzed condition.	24 hours 7 days
D. Required Actions and associated Completion Times not met.	D.1 Remove all fuel assemblies from the SFSC.	30 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 2.1.1.1	Verify MPC cavity vacuum drying pressure is within the limit specified in Table 2-1 for the applicable MPC model.	During LOADING OPERATIONS
SR 2.1.1.2	Verify MPC helium backfill pressure is within the limit specified in Table 2-1 for the applicable MPC model.	During LOADING OPERATIONS
SR 2.1.1.3	Verify that the total helium leak rate through the MPC lid confinement weld and the drain and vent port confinement welds is within the limit specified in Table 2-1 for the applicable MPC model.	During LOADING OPERATIONS

Table 2-1
MPC Model-Dependent Limits

MPC MODEL	LIMITS
1. MPC-24	
a. MPC Cavity Vacuum Drying Pressure	≤ 3 torr for ≥ 30 min
b. OVERPACK Annulus Vacuum Drying Pressure	≤ 3 torr for ≥ 30 min
c. MPC Helium Backfill Pressure[1]	≤ 22.2 psig
d. OVERPACK Annulus Helium Backfill Pressure	≥ 10 psig and ≤ 14 psig
e. MPC Helium Leak Rate	≤ 5.0E-6 std cc/sec (He)
f. OVERPACK Helium Leak Rate	≤ 4.3E-6 std cc/sec (He)
2. MPC-68	
a. MPC Cavity Vacuum Drying Pressure	≤ 3 torr for ≥ 30 min
b. OVERPACK Annulus Vacuum Drying Pressure	≤ 3 torr for ≥ 30 min
c. MPC Helium Backfill Pressure[1]	≤ 28.5 psig
d. OVERPACK Annulus Helium Backfill Pressure	≥ 10 psig and ≤ 14 psig
e. MPC Helium Leak Rate	≤ 5.0E-6 std cc/sec (He)
f. OVERPACK Helium Leak Rate	≤ 4.3E-6 std cc/sec (He)
3. MPC-68F	
a. MPC Cavity Vacuum Drying Pressure	≤ 3 torr for ≥ 30 min
b. OVERPACK Annulus Vacuum Drying Pressure	≤ 3 torr for ≥ 30 min
c. MPC Helium Backfill Pressure[1]	≤ 28.5 psig
d. OVERPACK Annulus Helium Backfill Pressure	≥ 10 psig and ≤ 14 psig
e. MPC Helium Leak Rate	≤ 5.0E-6 std cc/sec (He)
f. OVERPACK Helium Leak Rate	≤ 4.3E-6 std cc/sec (He)

[1] Helium used for backfill of MPC shall have a purity of ≥ 99.995%.

APPENDIX B DESIGN FEATURES

1.0 Definitions

NOTE

The defined terms of this section appear in capitalized type and are applicable throughout this Appendix

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Term	Definition
DAMAGED FUEL ASSEMBLY	DAMAGED FUEL ASSEMBLIES are fuel assemblies with known or suspected cladding defects as determined by a review of records greater than pinhole leaks or hairline cracks, missing fuel rods that are not replaced with dummy fuel rods, or those that cannot be handled by normal means. Fuel assemblies which cannot be handled by normal means due to fuel cladding damage are considered FUEL DEBRIS.
DAMAGED FUEL CONTAINER (DFC)	DFCs are specially designed enclosures for DAMAGED FUEL ASSEMBLIES or FUEL DEBRIS which permit gaseous and liquid media to escape while minimizing dispersal of gross particulates. DFCs authorized for use in the HI-STAR 100 System are the Holtec design or the Transnuclear Dresden Unit 1 design as shown on the applicable design drawings in the HI-STAR 100 Topical Safety Analysis Report.
FUEL DEBRIS	FUEL DEBRIS is ruptured fuel rods, severed rods, loose fuel pellets or fuel assemblies with known or suspected defects which cannot be handled by normal means due to fuel cladding damage.
INTACT FUEL ASSEMBLY	INTACT FUEL ASSEMBLIES are fuel assemblies without known or suspected cladding defects greater than pinhole leaks or hairline cracks and which can be handled by normal means. Partial fuel assemblies, that is fuel assemblies from which fuel rods are missing, shall not be classified as INTACT FUEL ASSEMBLIES unless dummy fuel rods are used to displace an amount of water greater than or equal to that displaced by the original fuel rod(s).
PLANAR-AVERAGE INITIAL ENRICHMENT	PLANAR-AVERAGE INITIAL ENRICHMENT is the average of the distributed fuel rod initial enrichments within a given axial plane of the assembly lattice.

1.1 Fuel Specifications

1.1.1 Fuel To Be Stored In The HI-STAR 100 SFSC

a. INTACT FUEL ASSEMBLIES, DAMAGED FUEL ASSEMBLIES, FUEL DEBRIS, and certain non-fuel hardware meeting the limits specified in Table 1.1-1 (which refers to Tables 1.1-2 through 1.1-5) may be stored in the HI-STAR 100 SFSC System.

b. For MPCs partially loaded with stainless steel clad fuel assemblies, all remaining fuel assemblies in the MPC shall meet the maximum decay heat generation limit for the stainless steel clad fuel assemblies.

c. For MPCs partially loaded with DAMAGED FUEL ASSEMBLIES or FUEL DEBRIS, all remaining Zircaloy clad INTACT FUEL ASSEMBLIES in the MPC shall meet the maximum decay heat generation limits for the DAMAGED FUEL ASSEMBLIES.

d. For MPC-68's partially loaded with array/class 6x6A, 6x6B, 6x6C, or 8x8A fuel assemblies, all remaining Zircaloy clad INTACT FUEL ASSEMBLIES in the MPC shall meet the maximum decay heat generation limits for the 6x6A, 6x6B, 6x6C, and 8x8A fuel assemblies.

1.1.2 Preferential Fuel Loading

Preferential fuel loading shall be used whenever fuel assemblies with significantly different post-irradiation cooling times (equal to or greater than one year are to be loaded in the same MPC. That is, fuel assemblies with the longest post-irradiation cooling times shall be loaded into fuel storage locations at the periphery of the basket. Fuel assemblies with shorter post-irradiation cooling times shall be placed toward the center of the basket.

1.2 Functional and Operating Limits Violations

If any Fuel Specifications defined in Section 1.1 are violated, the following actions shall be completed:

a. The affected fuel assemblies shall br placed in a safe condition without delay and in a controlled manner.

b. Within 24 hours, notify the NRC Operations Center.

c. Within 30 days, submit a special report which describes the cause of the violation, and actions taken to restore compliance and prevent recurrence.

The above actions are not a substitute for the reporting requirements contained in 10 CFR 72.75.

1.3 Codes and Standards

The American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME), 1995 Edition with Addenda through 1997, is the governing Code for the HI-STAR 100 Cask System, as clarified in Specification 1.3.1 below.

1.3.1 Exceptions to Codes, Standards, and Criteria

Table 1.3-1 lists approved exceptions to the ASME Code for the design of the HI-STAR 100 Cask System.

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

Proposed alternatives to the ASME Code, Section III, 1995 Edition with Addenda through 1997 including exceptions allowed by Specification 1.3.1 may be used when authorized by the Director of the Office of Nuclear Material Safety and Safeguards or designee. The request for such alternative should demonstrate that:

1. The proposed alternatives would provide an acceptable level of quality and safety, or

2. Compliance with the specified requirements of the ASME Code, Section III, 1995 Edition with Addenda through 1997, would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Requests for exceptions shall be submitted in accordance with 10 CFR 72.4

1.4 Site Specific Parameters and Analyses

Site-specific parameters and analyses that need verification by the system user, as a minimum, are as follows:

1. The temperature of 80°F is the maximum allowed average yearly temperature.

2. The allowed temperature extremes, averaged over a three day period, shall be greater than -40°F, and less than 125°F.

3. The horizontal and vertical seismic acceleration levels are bounded by the values listed below in Table 1-4.

Table 1-4

Design-Basis Earthquake Input on the Top Surface of an ISFSI Pad

Horizontal g-level in each of two orthogonal directions	Horizontal g-level Vector Sum	Corresponding Vertical g-level (upward)
0.222 g	0.314 g	1.00 x 0.222 g = 0.222 g
0.235 g	0.332 g	0.75 x 0.235 g = 0.176 g
0.24 g	0.339 g	0.667 x 0.24 g = 0.160 g
0.25 g	0.354 g	0.500 x 0.25 g = 0.125 g

4. The analyzed flood condition of 12 fps water velocity and a height of 656 feet of water (full submergence of the loaded cask) are not exceeded.

5. The potential for fire and explosion shall be addressed, based on site-specific considerations. This includes the condition that the onsite transporter fuel tank will contain no more than 50 gallons of combustible transporter fuel.

6. In addition to the requirement of 10 CFR 72.212(b)(2)(ii), the cask storage pads and foundation shall include the following characteristics as applicable to the drop and tipover analyses:

    a. Concrete thickness: ≤ 36 inches

    b. Concrete compressive strength: ≤ 4,200 psi

    c. Reinforcement top and bottom (Both Directions):
    Reinforcement area and spacing determined by analysis
    Reinforcement yield strength: ≤ 60,000 psi

    d. Soil effective modulus of elasticity: ≤ 28,000 psi

    An acceptable method of defining the soil modulus of elasticity applicable to the drop and tipover analyses is provided in Table 13 of NUREG/CR-6608 with soil classification in accordance with ASTM-D2487-93, Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System USCS) and density determination in accordance with ASTM D1586-84, Standard Test Method for Penetration Test and Split/Barrel Sampling of Soils.

7. In cases where engineered features (i.e., berms, shield walls) are used to ensure that the requirements of 10 CFR 72.104(a) are met, such features are to be considered important to safety and must be evaluated to determine the applicable Quality Assurance Category.

1.5 Design Specifications

1.5.1 Specifications Important for Criticality Control

1.5.1.1 MPC-24

1. Minimum flux trap size: 1.09 in
2. Minimum ^{10}B loading in the Boral neutron absorbers: 0.0267 g/cm^2

1.5.1.2 MPC-68 and MPC-68F

1. Minimum fuel cell pitch: 6.43 in
2. Minimum ^{10}B loading in the Boral neutron absorbers: 0.0372 g/cm^2 in the MPC-68, and 0.01 g/cm^2 in the MPC-68F.

1.5.2 Specifications Important for Thermal Performance

1.5.2.1 OVERPACK

The paint used on the HI-STAR 100 OVERPACK must have an emissivity no less than 0.85.

Table 1.1-1
Fuel Assembly Limits

I. MPC MODEL: MPC-24

A. Allowable Contents

1. Uranium oxide, PWR INTACT FUEL ASSEMBLIES, with or without Burnable Poison Rod Assemblies (BPRAs) or Thimble Plug Devices (TPDs), listed in Table 1.1-2 and meeting the following specifications:

a. Cladding Type:	Zircaloy (Zr) or Stainless Steel (SS) as specified in Table 1.1-2 for the applicable fuel assembly array/class
b. Initial Enrichment:	As specified in Table 1.1-2 for the applicable fuel assembly array/class.
c. Decay Heat Per Assembly:	
i. Zr Clad:	An assembly decay heat as specified in Table 1.1-4 for the applicable post-irradiation cooling time.
ii. SS Clad:	≤ 575 Watts
d. Post-irradiation Cooling Time and Average Burnup Per Assembly	
i. Zr Clad:	An assembly post-irradiation cooling time and average burnup as specified in Table 1.1-5. BPRA and TPD post-irradiation cooling time and average burnup as specified in Table 1.1-6.
ii. SS Clad:	An assembly post-irradiation cooling time ≥ 9 years and an average burnup ≤ 30,000 MWD/MTU. <u>OR</u> An assembly post-irradiation cooling time ≥ 15 years and an average burnup ≤ 40,000 MWD/MTU.

e. Nominal Fuel Assembly Length: ≤ 176.8 inches

f. Nominal Fuel Assembly Width: ≤ 8.54 inches

g. Fuel Assembly Weight ≤ 1,680 lbs (including non-fuel hardware)

B. Quantity per MPC: Up to 24 fuel assemblies

C. Fuel assemblies shall not contain control components except as specifically authorized by this CoC. BPRAs and TPDs are authorized for loading in the HI-STAR 100 System with their associated fuel assemblies provided the burnup and cooling time limits specified in Table 1.1-6 are met.

D. DAMAGED FUEL ASSEMBLIES and FUEL DEBRIS are not authorized for loading into the MPC-24.

II. MPC MODEL: MPC-68

A. Allowable Contents

1. Uranium oxide, BWR INTACT FUEL ASSEMBLIES listed in Table 1.1-3, with or without Zircaloy channels, and meeting the following specifications:

a. Cladding Type:	Zircaloy (Zr) or Stainless Steel (SS) as specified in Table 1.1-3 for the applicable fuel assembly array/class.
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
d. Decay Heat Per Assembly	
i. Zr Clad:	An assembly decay heat as specified in Table 1.1-4 for the applicable post-irradiation cooling time, except for array/class 6x6A, 6x6C, and 8x8A fuel assemblies, which shall have a decay heat ≤ 115 Watts and array/class 8x8F fuel assemblies, which shall have a decay heat ≤ 183.5 Watts.
ii. SS Clad:	≤ 95 Watts

e. Post-irradiation Cooling Time and Average Burnup Per Assembly

i. Zr Clad:	An assembly post-irradiation cooling time and average burnup as specified in Table 1.1-5, except for array/class 6x6A, 6x6C, and 8x8A fuel assemblies, which shall have a cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTU and array/class 8x8F fuel assemblies, which shall have a cooling time ≥ 10 years and an average burnup ≤ 27,500 MWD/MTU.
ii. SS Clad:	An assembly cooling time after discharge ≥ 10 years and an average burnup ≤ 22,500 MWD/MTU.
f. Nominal Fuel Assembly Length:	≤ 176.2 inches
g. Nominal Fuel Assembly Width:	≤ 5.85 inches
h. Fuel Assembly Weight	≤ 700 lbs, including channels

2. Uranium oxide, BWR DAMAGED FUEL ASSEMBLIES, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. BWR DAMAGED FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6A, 6x6C, 7x7A, or 8x8A, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTU.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

3. Mixed oxide (MOX) INTACT FUEL ASSEMBLIES, with or without Zircaloy channels. MOX BWR INTACT FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTIHM.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

4. Mixed oxide (MOX), BWR DAMAGED FUEL ASSEMBLIES, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. MOX BWR DAMAGED FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTIHM.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

5. Thoria rods (ThO_2 and UO_2) placed in Dresden Unit 1Thoria Rod Canisters and meeting the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Composition:	98.2 wt.% ThO_2, 1.8 wt. % UO_2 with an enrichment of 93.5 wt. % ^{235}U.
c. Number of Rods Per Thoria Rod Canister:	$\leq$ 18
d. Decay Heat Per Thoria Rod Canister:	$\leq$ 115 Watts
e. Post-irradiation Fuel Cooling Time and Average Burnup Per Thoria Rod Assembly:	A fuelpost-irradiation cooling time $\geq$ 18 years and an average burnup $\leq$ 16,000 MWD/MTIHM.
f. Initial Heavy Metal Weight:	$\leq$ 27 kg/canister
g. Fuel Cladding O.D.:	$\geq$ 0.412 inches
h. Fuel Cladding I.D.:	$\leq$ 0.362 inches
i. Fuel Pellet O.D.:	$\leq$ 0.358 inches
j. Active Fuel Length:	$\leq$ 111 inches
k. Canister Weight:	$\leq$ 550 lbs, including fuel

B. Quantity per MPC: Up to one (1) Dresden Unit 1Thoria Rod Canister plus any combination of DAMAGED FUEL ASSEMBLIES in DAMAGED FUEL CONTAINERS, and INTACT FUEL ASSEMBLIES, up to a total of 68.

C. Fuel assemblies with stainless steel channels are not authorized for loading in the MPC -68.

D. Dresden Unit 1 fuel assemblies with one Antimony-Beryllium neutron source are authorized for loading in the MPC-68.

III. MPC MODEL: MPC-68F

A. Allowable Contents

1. Uranium oxide, BWR INTACT FUEL ASSEMBLIES, with or without Zircaloy channels. BWR INTACT FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6A, 6x6C, 7x7A, or 8x8A, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTU.
f. Nominal Fuel Assembly Length:	≤ 176.2 inches
g. Nominal Fuel Assembly Width:	≤ 5.85 inches
h. Fuel Assembly Weight:	≤ 700 lbs, including channels

2. Uranium oxide, BWR DAMAGED FUEL ASSEMBLIES, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. BWR DAMAGED FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6A, 6x6C, 7x7A, or 8x8A, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTU.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

3. Uranium oxide, BWR FUEL DEBRIS, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. The original fuel assemblies for the BWR FUEL DEBRIS shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6A, 6x6C, 7x7A, or 8x8A, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for the applicable fuel assembly array/class.
d. Decay Heat Per Assembly:	$\leq$ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time $\geq$ 18 years and an average burnup $\leq$ 30,000 MWD/MTU.
f. Nominal Fuel Assembly Length:	$\leq$ 135.0 inches
g. Nominal Fuel Assembly Width:	$\leq$ 4.70 inches
h. Fuel Assembly Weight:	$\leq$ 400 lbs, including channels

4. Mixed oxide (MOX), BWR INTACT FUEL ASSEMBLIES, with or without Zircaloy channels. MOX BWR INTACT FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTIHM.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

5. Mixed oxide (MOX), BWR DAMAGED FUEL ASSEMBLIES, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. MOX BWR DAMAGED FUEL ASSEMBLIES shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
d. Decay Heat Per Assembly:	≤ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 30,000 MWD/MTIHM.
f. Nominal Fuel Assembly Length:	≤ 135.0 inches
g. Nominal Fuel Assembly Width:	≤ 4.70 inches
h. Fuel Assembly Weight:	≤ 400 lbs, including channels

6. Mixed oxide (MOX), BWR FUEL DEBRIS, with or without Zircaloy channels, placed in DAMAGED FUEL CONTAINERS. The original fuel assemblies for the MOX BWR FUEL DEBRIS shall meet the criteria specified in Table 1.1-3 for fuel assembly array/class 6x6B, and meet the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Maximum PLANAR-AVERAGE INITIAL ENRICHMENT:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
c. Initial Maximum Rod Enrichment:	As specified in Table 1.1-3 for fuel assembly array/class 6x6B.
d. Decay Heat Per Assembly:	$\leq$ 115 Watts
e. Post-irradiation Cooling Time and Average Burnup Per Assembly:	An assembly post-irradiation cooling time $\geq$ 18 years and an average burnup $\leq$ 30,000 MWD/MTIHM.
f. Nominal Fuel Assembly Length:	$\leq$ 135.0 inches
g. Nominal Fuel Assembly Width:	$\leq$ 4.70 inches
h. Fuel Assembly Weight:	$\leq$ 400 lbs, including channels

7. Thoria rods (ThO_2 and UO_2) placed in Dresden Unit 1 Thoria Rod Canisters and meeting the following specifications:

a. Cladding Type:	Zircaloy (Zr)
b. Composition:	98.2 wt.% ThO_2, 1.8 wt. % UO_2 with an enrichment of 93.5 wt. % ^{235}U.
c. Number of Rods Per Thoria Rod Canister:	≤ 18
d. Decay Heat Per Thoria Rod Canister:	≤ 115 Watts
e. Post-irradiation Fuel Cooling Time and Average Burnup Per Thoria Rod Assembly:	An assembly post-irradiation cooling time ≥ 18 years and an average burnup ≤ 16,000 MWD/MTIHM.
f. Initial Heavy Metal Weight:	≤ 27 kg/canister
g. Fuel Cladding O.D.:	≥ 0.412 inches
h. Fuel Cladding I.D.:	≤ 0.362 inches
i. Fuel Pellet O.D.:	≤ 0.358 inches
j. Active Fuel Length:	≤ 111 inches
k. Canister Weight:	≤ 550 lbs, including fuel

B. Quantity per MPC:

Up to four (4) DFCs containing uranium oxide or MOX BWR FUEL DEBRIS. The remaining MPC-68F fuel storage locations may be filled with array/class 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A fuel assemblies of the following type, as applicable:

a. Uranium oxide BWR INTACT FUEL ASSEMBLIES;

b. MOX BWR INTACT FUEL ASSEMBLIES;

c. Uranium oxide BWR DAMAGED FUEL ASSEMBLIES placed in DFCs; or

d. MOX BWR DAMAGED FUEL ASSEMBLIES placed in DFCs.

e. Up to one (1) Dresden Unit 1 Thoria Rod Canister.

C. Fuel assemblies with stainless steel channels are not authorized for loading in the MPC-68F.

D. Dresden Unit 1 fuel assemblies with one Antimony-Beryllium neutron source are authorized for loading in the MPC-68F.

Table 1.1-2
PWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/Class	14x14A	14x14B	14x14C	14x14D	15x15A
Clad Material (Note 2)	Zr	Zr	Zr	SS	Zr
Design Initial U (kg/assy.) (Note 3)	≤ 407	≤ 407	≤ 425	≤ 400	≤ 464
Initial Enrichment (wt % ^{235}U)	≤ 4.6	≤ 4.6	≤ 4.6	≤ 4.0	≤ 4.1
No. of Fuel Rods	179	179	176	180	204
Clad O.D. (in.)	≥ 0.400	≥ 0.417	≥ 0.440	≥ 0.422	≥ 0.418
Clad I.D. (in.)	≤ 0.3514	≤ 0.3734	< 0.3880	≤ 0.3890	≤ 0.3660
Pellet Dia. (in.)	≤ 0.3444	≤ 0.3659	≤ 0.3805	≤ 0.3835	≤ 0.3580
Fuel Rod Pitch (in.)	≤ 0.556	≤ 0.556	≤ 0.580	≤ 0.556	≤ 0.550
Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 144	≤ 150
No. of Guide Tubes	17	17	5 (Note 4)	16	21
Guide Tube Thickness (in.)	≥ 0.017	≥ 0.017	≥ 0.038	≥ 0.0145	≥ 0.0165

Table 1.1-2 (continued)
PWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/Class	**15x15B**	**15x15C**	**15x15D**	**15x15E**	**15x15F**
Clad Material (Note 2)	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) (Note 3)	≤ 464	≤ 464	≤ 475	≤ 475	≤ 475
Initial Enrichment (wt % ^{235}U)	≤ 4.1	≤ 4.1	≤ 4.1	≤ 4.1	≤ 4.1
No. of Fuel Rods	204	204	208	208	208
Clad O.D. (in.)	≥ 0.420	≥ 0.417	≥ 0.430	≥ 0.428	≥ 0.428
Clad I.D. (in.)	≤ 0.3736	≤ 0.3640	≤ 0.3800	≤ 0.3790	≤ 0.3820
Pellet Dia. (in.)	≤ 0.3671	≤ 0.3570	≤ 0.3735	≤ 0.3707	≤ 0.3742
Fuel Rod Pitch (in.)	≤ 0.563	≤ 0.563	≤ 0.568	≤ 0.568	≤ 0.568
Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Guide Tubes	21	21	17	17	17
Guide Tube Thickness (in.)	≥ 0.015	≥ 0.0165	≥ 0.0150	≥ 0.0140	≥ 0.0140

Table 1.1-2 (continued)
PWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/ Class	**15x15G**	**15x15H**	**16x16A**	**17x17A**	**17x17B**	**17x17C**
Clad Material (Note 2)	SS	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.)(Note 3)	≤ 420	≤ 475	≤ 443	≤ 467	≤ 467	≤ 474
Initial Enrichment (wt % ^{235}U)	≤ 4.0	≤ 3.8	≤ 4.6	≤ 4.0	≤ 4.0	≤ 4.0
No. of Fuel Rods	204	208	236	264	264	264
Clad O.D. (in.)	≥ 0.422	≥ 0.414	≥ 0.382	≥ 0.360	≥ 0.372	≥ 0.377
Clad I.D. (in.)	≤ 0.3890	≤ 0.3700	≤ 0.3320	≤ 0.3150	≤ 0.3310	≤ 0.3330
Pellet Dia. (in.)	≤ 0.3825	≤ 0.3622	≤ 0.3255	≤ 0.3088	≤ 0.3232	≤ 0.3252
Fuel Rod Pitch (in.)	≤ 0.563	≤ 0.568	≤ 0.506	≤ 0.496	≤ 0.496	≤ 0.502
Active Fuel Length (in.)	≤ 144	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Guide Tubes	21	17	5 (Note 4)	25	25	25
Guide Tube Thickness (in.)	≥ 0.0145	≥ 0.0140	≥ 0.0400	≥ 0.016	≥ 0.014	≥ 0.020

Notes:
1. All dimensions are design nominal values. Maximum and minimum dimensions are specified to bound variations in design nominal values within a given array/class.
2. Zr. Designates cladding material made of Zirconium or Zirconium alloys.
3. Design initial uranium weight is the uranium weight specified for each assembly by the fuel manufacturer or reactor user. For each PWR fuel assembly, the total uranium weight limit specified in this table may be increased up to 2.0% for comparison with users' fuel records to account for manufacturer's tolerances.
4. Each guide tube replaces four fuel rods.

Table 1.1-3
BWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/Class	**6x6A**	**6x6B**	**6x6C**	**7x7A**	**7x7B**	**8x8A**
Clad Material (Note 2)	Zr	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) (Note 3)	110	110	110	≤ 100	≤ 195	≤ 120
Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% ^{235}U)	≤ 2.7	≤ 2.7 for the UO_2 rods. See Note 4 for MOX rods	≤ 2.7	≤ 2.7	≤ 4.2	≤ 2.7
Initial Maximum Rod Enrichment (wt.% ^{235}U)	≤ 4.0	≤ 4.0	≤ 4.0	≤ 5.5	≤ 5.0	≤ 4.0
No. of Fuel Rods	35 or 36	35 or 36 (up to 9 MOX rods)	36	49	49	63 or 64
Clad O.D. (in.)	≥ 0.5550	≥ 0.5625	≥ 0.5630	≥ 0.4860	≥ 0.5630	≥ 0.4120
Clad I.D. (in.)	≤ 0.5105	≤ 0.4945	≤ 0.4990	≤ 0.4204	≤ 0.4990	≤ 0.3620
Pellet Dia. (in.)	≤ 0.4980	≤ 0.4820	≤ 0.4880	≤ 0.4110	≤ 0.4910	≤ 0.3580
Fuel Rod Pitch (in.)	≤ 0.710	≤ 0.710	≤ 0.740	≤ 0.631	≤ 0.738	≤ 0.523
Active Fuel Length (in.)	≤ 120	≤ 120	≤ 77.5	≤ 80	≤ 150	≤ 120
No. of Water Rods (Note 11)	1 or 0	1 or 0	0	0	0	1 or 0
Water Rod Thickness (in.)	> 0	> 0	N/A	N/A	N/A	≥ 0
Channel Thickness (in.)	≤ 0.060	≤ 0.060	≤ 0.060	≤ 0.060	≤ 0.120	≤ 0.100

Table 1.1-3 (continued)
BWR FUEL ASSEMVLY CHARACTERISTICS (note 1)

Fuel Assembly Array/Class	**8x8B**	**8x8C**	**8x8D**	**8x8E**	**8x8F**	**9x9A**	**9x9B**
Clad Material (Note 2)	Zr	Zr	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) (Note 3)	≤ 185	≤ 185	≤ 185	≤ 185	≤ 185	≤ 177	≤ 177
Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% ^{235}U)	≤ 4.2	≤ 4.2	≤ 4.2	≤ 4.2	≤ 4.2	≤ 4.2	≤ 4.2
Initial Maximum Rod Enrichment (wt.% ^{235}U)	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
No. of Fuel Rods	63 or 64	62	60 or 61	59	64	74/66 (Note 5)	72
Clad O.D. (in.)	≥ 0.4840	≥ 0.4830	≥ 0.4830	≥ 0.4930	≥ 0.4576	≥ 0.4400	≥ 0.4330
Clad I.D. (in.)	≤ 0.4295	≤ 0.4250	≤ 0.4230	≤ 0.4250	≤ 0.3996	≤ 0.3840	≤ 0.3810
Pellet Dia. (in.)	≤ 0.4195	≤ 0.4160	≤ 0.4140	≤ 0.4160	≤ 0.3913	≤ 0.3760	≤ 0.3740
Fuel Rod Pitch (in.)	≤ 0.642	≤ 0.641	≤ 0.640	≤ 0.640	≤ 0.609	≤ 0.566	≤ 0.572
Design Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Water Rods (Note 11)	1 or 0	2	1 - 4 (Note 7)	5	N/A (Note 12)	2	1 (Note 6)
Water Rod Thickness (in.)	≥ 0.034	> 0.00	> 0.00	≥ 0.034	≥ 0.0315	> 0.00	> 0.00
Channel Thickness (in.)	≤ 0.120	≤ 0.120	≤ 0.120	≤ 0.100	≤ 0.055	≤ 0.120	≤ 0.120

Table 1.1-3 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/Class	**9x9C**	**9x9D**	**9x9E (Note 13)**	**9x9F (Note 13)**	**10x10A**
Clad Material (Note 2)	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) (Note 3)	≤ 177	≤ 177	≤ 177	≤ 177	≤ 186
Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% ^{235}U)	≤ 4.2	≤ 4.2	≤ 4.1	≤ 4.1	≤ 4.2
Initial Maximum Rod Enrichment (wt.% ^{235}U)	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
No. of Fuel Rods	80	79	76	76	92/78 (Note 8)
Clad O.D. (in.)	≥ 0.4230	≥ 0.4240	≥ 0.4170	≥ 0.4430	≥ 0.4040
Clad I.D. (in.)	≤ 0.3640	≤ 0.3640	≤ 0.3640	≤ 0.3860	≤ 0.3520
Pellet Dia. (in.)	≤ 0.3565	≤ 0.3565	≤ 0.3530	≤ 0.3745	≤ 0.3455
Fuel Rod Pitch (in.)	≤ 0.572	≤ 0.572	≤ 0.572	≤ 0.572	≤ 0.510
Design Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Water Rods (Note 11)	1	2	5	5	2
Water Rod Thickness (in.)	≥ 0.020	≥ 0.0300	≥ 0.0120	≥ 0.0120	≥ 0.0300
Channel Thickness (in.)	≤ 0.100	≤ 0.100	≤ 0.120	≤ 0.120	≤ 0.120

Table 1.1-3 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS (note 1)

Fuel Assembly Array/Class	10x10B	10x10C	10x10D	10x10E
Clad Material (Note 2)	Zr	Zr	SS	SS
Design Initial U (kg/assy.) (Note 3)	$\leq$ 186	$\leq$ 186	$\leq$ 125	$\leq$ 125
Maximum PLANAR-AVERAGE INITIAL ENRICHMENT (wt.% ^{235}U)	$\leq$ 4.2	$\leq$ 4.2	$\leq$ 4.0	$\leq$ 4.0
Initial Maximum Rod Enrichment (wt.% ^{235}U)	$\leq$ 5.0	$\leq$ 5.0	$\leq$ 5.0	$\leq$ 5
No. of Fuel Rods	91/83 (Note 9)	96	100	96
Clad O.D. (in.)	$\geq$ 0.3957	$\geq$ 0.3780	$\geq$ 0.3960	$\geq$ 0.3940
Clad I.D. (in.)	$\leq$ 0.3480	$\leq$ 0.3294	$\leq$ 0.3560	$\leq$ 0.3500
Pellet Dia. (in.)	$\leq$ 0.3420	$\leq$ 0.3224	$\leq$ 0.3500	$\leq$ 0.3430
Fuel Rod Pitch (in.)	$\leq$ 0.510	$\leq$ 0.488	$\leq$ 0.565	$\leq$ 0.557
Design Active Fuel Length (in.)	$\leq$ 150	$\leq$ 150	$\leq$ 83	$\leq$ 83
No. of Water Rods (Note 11)	1 (Note 6)	5 (Note 10)	0	4
Water Rod Thickness (in.)	> 0.00	$\geq$ 0.031	N/A	$\geq$ 0.022
Channel Thickness (in.)	$\leq$ 0.120	$\leq$ 0.055	$\leq$ 0.080	$\leq$ 0.080

1. All dimensions are design nominal values. Maximum and minimum dimensions are specified to bound variations in design nominal values within a given array/class.
2. Zr designates cladding material made from Zirconium or Zirconium alloys.
3. Design initial uranium weight is the uranium weight specified for each assembly by the fuel manufacturer or reactor user. For each BWR fuel assembly, the total uranium weight limit specified in this table may be increased up to 1.5% for comparison with users' fuel records to account for manufacturer's tolerances.
4. $\leq$ 0.635 wt. % ^{235}U and $\leq$ 1.578 wt. % total fissile plutonium (^{239}Pu and ^{241}Pu)(wt.% of total fuel weight, i.e., UO_2 plus PuO_2).
5. This assembly class contains 74 total fuel rods; 66 full length rods and 8 partial length rods.
6. Square, replacing nine fuel rods.
7. Variable
8. This assembly class contains 92 total fuel rods; 78 full length rods and 14 partial length rods.
9. This assembly class contains 91 total fuel rods; 83 full length rods and 8 partial length rods.
10. One diamond-shaped water rod replacing the four center fuel rods and four rectangular water rods dividing the assembly into four quadrants.
11. These rods may also be sealed at both ends and contain non-fissile material in lieu of water.
12. This assembly is known as "QUAD+". It has four rectangular water cross segments dividing the assembly into four quadrants.
13. For the SPC 9x9-5 fuel assembly, each fuel rod must meet either the 9x9E or 9x9F set of limits for clad O.D., clad I.D., and pellet diameter.

Table 1.1-4
FUEL ASSEMBLY COOLING AND DECAY HEAT GENERATION (Note 1)

Post-irradiation Cooling Time (years)	**MPC-24 PWR Assembly Decay Heat (Watts)** (Note 2)	**MPC-68 BWR Assembly Decay Heat (Watts)**
≥ 5	≤ 792	≤ 272
≥ 6	≤ 773	≤ 261
≥ 7	≤ 703	≤ 238
≥ 8	≤ 698	≤ 236
≥ 9	≤ 692	≤ 234
≥ 10	≤ 687	≤ 232
≥ 11	≤ 683	≤ 231
≥ 12	≤ 678	≤ 229
≥ 13	≤ 674	≤ 228
≥ 14	≤ 669	≤ 227
≥ 15	≤ 665	≤ 226

Notes:
1. Linear interpolation between points is permitted.
2. For assemblies with or without BPRAs or TPDs (assembly only).

Table 1.1-5
FUEL ASSEMBLY COOLING AND AVERAGE BURNUP (Note 1)

Post-irradiation Cooling Time (years)	**MPC-24 PWR Assembly Burnup (MWD/MTU)** (Note 2)	MPC-24 PWR Assembly Burnup (MWD/MTU) (Note 3)	**MPC-68 BWR Assembly Burnup (MWD/MTU)**
≥ 5	≤ 28,700	≤ 28,300	≤ 26,000
≥ 6	≤ 32,700	≤ 32,300	≤ 29,100
≥ 7	≤ 33,300	≤ 32,700	≤ 29,600
≥ 8	≤ 35,500	≤ 35,000	≤ 31,400
≥ 9	≤ 37,000	≤ 36,500	≤ 32,800
≥ 10	≤ 38,200	≤ 37,600	≤ 33,800
≥ 11	≤ 39,300	≤ 38,700	≤ 34,800
≥ 12	≤ 40,100	≤ 39,500	≤ 35,500
≥ 13	≤ 40,800	≤ 40,200	≤ 36,200
≥ 14	≤ 41,500	≤ 40,800	≤ 36,900
≥ 15	≤ 42,100	≤ 41,400	≤ 37,600

Notes: 1. Linear interpolation between points is permitted.
2. For assemblies without BPRAs and with or without TPDs (assembly only).
3. For assemblies which contain BPRAs (assembly only).

Table 1.1-6
NON-FUEL HARDWARE COOLING AND AVERAGE BURNUP (Note 1)

Post-irradiation Cooling Time (years)	MPC-24 BPRA BURNUP (MWD/MTU)	MPC-24 TPD BURNUP (MWD/MTU)
≥ 3	≤ 20,000	NC (Note 2)
≥ 4	NC	≤ 20,000
≥ 5	≤ 30,000	NC
≥ 6	≤ 40,000	≤ 30,000
≥ 7	NC	≤ 40,000
≥ 8	≤ 50,000	NC
≥ 9	≤ 60,000	≤ 50,000
≥ 10	NC	≤ 60,000
≥ 11	NC	NC
≥ 12	NC	≤ 90,000
≥ 13	NC	≤ 180,000
≥ 14	NC	≤ 630,000

Notes:
1. Linear interpolation between points is permitted, except that TPD burnups > 180,000 MWD/MTU and ≤ 630,000 MWD/MTU must be cooled ≥ 14 years.
2. Not calculated.

LIST OF ASME CODE EXCEPTIONS FOR HI-STAR 100 SYSTEM
Table 1.3-1

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
MPC	NB-1100	Statement of requirements for Code stamping of components.	MPC enclosure vessel is designed and will be fabricated in accordance with ASME Code, Section III, Subsection NB to the maximum practical extent, but Code stamping is not required.
MPC	NB-2000	Requires materials to be supplied by ASME-approved material supplier.	Materials will be supplied by Holtec-approved suppliers with Certified Material Test Reports (CMTRs) in accordance with NB-2000 requirements.
MPC Lid and Closure Ring Welds	NB-4243	Full penetration welds required for Category C Joints (flat head to main shell per NB-3352.3).	MPC lid and closure ring are not full penetration welds. They are welded independently to provide a redundant seal. Additionally, a weld efficiency factor of 0.45 has been applied to the analyses of these welds.
MPC Lid to Shell Weld	NB-5230	Radiographic (RT) or ultrasonic (UT) examination required.	Only UT or multi-layer liquid penetrant (PT) examination is permitted. If PT alone is used, at a minimum, it will include the root and final weld layers and each approximately 3/8 inch of weld depth.
MPC Closure Ring, Vent and Drain Cover Plate Welds	NB-5230	Radiographic (RT) or ultrasonic (UT) examination required	Root (if more than one weld pass is required) and final liquid penetrant examination to be performed in accordance with NB-5245. The MPC vent and drain cover plate welds are leak tested. The closure ring provides independent redundant closure for vent and drain cover plates.

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
MPC Enclosure Vessel and Lid	NB-6111	All completed pressure retaining systems shall be pressure tested.	The MPC enclosure vessel is seal welded in the field following fuel assembly loading. The MPC enclosure vessel shall then be hydrostatically tested as defined in Chapter 9. Accessibility for leakage inspections preclude a Code compliant hydrostatic test. All MPC enclosure vessel welds (except the closure ring and vent/drain cover plate) are inspected by volumetric examination, except the MPC lid-to-shell shall be verified by volumetric or multi-layer PT examination. If PT alone is used, at a minimum, it must include the root and final layers and each approximately 3/8 inch of weld depth. For either UT or PT, the maximum undetectable flaw size must be demonstrated to be less than the critical flaw size. The critical flaw size must be determined in accordance with ASME XI methods. The critical flaw size shall not cause the primary stress limits of NB-3000 to be exceeded. The vent/drain cover plate weld is confirmed by liquid penetrant examination and the closure ring weld is confirmed by liquid penetrant examination. The inspection process, including findings, (indications) shall be made a permanent part of the certificate holder's records by video, photographic, or other means which provide an equivalent retrievable record of weld integrity. The video or photographic records should be taken during the final interpretation period described in ASME Section V, Article 6, T-676. The inspection of the weld must be performed by qualified personnel and shall meet the acceptance requirements of ASME Code Section III, NB-5350 for PT or NB-5332 for UT.

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
MPC Enclosure Vessel	NB-7000	Vessels are required to have overpressure protection.	No overpressure protection is provided. The function of the MPC enclosure vessel is to contain the radioactive contents under normal, off-normal, and accident conditions. The MPC vessel is designed to withstand maximum internal pressure considering 100% fuel rod failure and maximum accident temperatures.
MPC Enclosure Vessel	NB-8000	States requirements for nameplates, stamping and reports per NCA-8000.	The HI-STAR 100 System is to be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. Code stamping is not required. QA data package to be in accordance with Holtec approved QA program.
Overpack Helium Retention Boundary	NB-1100	Statement of requirements for Code stamping of components	Overpack helium retention boundary is designed, and will be fabricated in accordance with ASME Code, Section III, Subsection NB to the maximum practical extent, but Code stamping is not required.
Overpack Helium Retention Boundary	NB-2000	Requires materials to be supplied by ASME approved Material Supplier.	Material will be supplied by Holtec approved suppliers with CMTRs per NB-2000.
Overpack Helium Retention Boundary	NB-7000	Vessels are required to have overpressure protection.	No overpressure protection is provided. Function of overpack vessel is to contain helium contents under normal, off-normal, and accident conditions. Overpack vessel is designed to withstand maximum internal pressure and maximum accident temperatures.

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
Overpack Helium Retention Boundary	NB-8000	Statement of Requirements for nameplates, stamping and reports per NCA-8000.	The HI-STAR 100 System is to be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. Code stamping is not required. QA data package to be in accordance with Holtec approved QA program.
MPC Basket Assembly	NG-2000	Requires materials to be supplied by ASME approved Material Supplier.	Materials will be supplied by Holtec approved supplier with CMTRs per NG-2000 requirements.
MPC Basket Assembly	NG-8000	Statement of requirements for nameplates, stamping and reports per NCA-8000.	The HI-STAR 100 System is to be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. Code stamping is not required. QA data package to be in accordance with Holtec approved QA program.
Overpack Intermediate Shells	NF-4622	All welds, including repair welds, shall be post-weld heat treated (PWHT).	Intermediate shell-to-top flange welds and intermediate shell-to-bottom plate welds do not require PWHT. These welds attach non-pressure retaining parts to pressure retaining parts. The pressure retaining parts are >7 inches thick. Localized PWHT will cause material away from the weld to experience elevated temperatures which will have an adverse effect on the material properties.
Overpack Helium Retention Boundary	NG-2000	Perform radiographic examination after post-weld heat treatment (PWHT)	Radiography of the helium retention boundary welds after PWHT is not required. All welds (including repairs) will have passed radiographic examination prior to PWHT of the entire containment boundary. Confirmatory radiographic examination after PWHT is not necessary because PWHT is not known to introduce new weld defects in nickel steels.

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
Overpack Intermediate Shells	NF-2000	Requires materials to be supplied by ASME approved Material Supplier.	Materials will be supplied by Holtec approved supplier with CMTRs per NF-2000 requirements.
Overpack Helium Retention Boundary	NB-2330	Defines the methods for determining the T_{NDT} for impact testing of materials.	T_{NDT} shall be defined in accordance with Regulatory Guides 7.11 and 7.12 for the helium retention boundary components.

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Document ID: 5014354
Attachment 4

ATTACHMENT 4

REVISED HOLTEC DESIGN DRAWINGS AND

NEW DRESDEN UNIT 1 DRAWINGS OF TN DAMAGED FUEL CANISTER AND THORIA ROD CANISTER

BILL OF MATERIALS FOR HI-STAR 100 OVERPACK (BM-1476)

REF. DWGS. 1397,1398 & 1399.

REV. NO.	PREP. BY & DATE	CHECKED BY DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
13	S.GEE 11-18-99 INCORPORATED ECO/ SMOR/MISC. CHANGES	11/24/99	B.G. 11/24/99	MS 11/24/99

ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
1	1	SA-350 LF3	12" X 83 1/4" O.D. BASE PLATE	BOTTOM PLATE
2	1	SA-203-E	2 1/2" THK. X 223 7/8" X 174 1/8" PLATE	INNER SHELL
3	20	SA-515 GRADE 70	1/2" THK. X 172 1/8" X 8" APPROX. PLATE	ENCLOSURE SHELL PANELS
4	20	SA-515 GRADE 70	1/2" THK. X 172 1/8" X 17 1/2" LG. APPROX.	RADIAL CHANNELS
5	2	SA-705 630 17-4 PH OR SA-564 630 17-4 PH	11" THK. X 12 3/8" WIDE X 14" LG.	POCKET TRUNNION
6	4	SA-193 GRADE B7	5/8" - 11 UNC X 1 1/4" LG. SOCKET SET SCREW	CLOSURE PLATE PLUG
7	2	SB-637-N07718	7 1/4" O.D. X 9 1/4" LG. BAR	LIFTING TRUNNION
8	1	SA-350 LF3	68 3/4" I.D. X 86 1/4" O.D. X 24" LG. FORGING	TOP FLANGE
9	2	SA-203-E OR SA-350-LF3	1 1/2" THK. X 5 5/8" WIDE X 25" LG. BAR	REMOVEABLE SHEAR RING
10	1	SA-350 LF3	6" THK. X 77 3/8" O.D.	CLOSURE PLATE
11	2	SB-637-N07718	1 5/8" - 8 UN X 7 1/8" LG. 12 POINT CAP SCREW W/ 3 1/2" LG. THREAD (W/2.43" DIA. X 1 5/8" TOTAL HIGH HD. PER DET. DWG.1397 SHT.3)	CLOSURE PLATE SHORT BOLT
12	1	SA-516 GRADE 70	1 1/4" THK. X 174 1/8" X 235 5/8" APPROX. PLATE	INTERMEDIATE SHELL #1
13	1	SA-516 GRADE 70	1 1/4" THK. X 174 1/8" X 243 1/2" APPROX. PLATE	INTERMEDIATE SHELL #2
14	1	SA-516 GRADE 70	1 1/4" THK. X 174 1/8" X 251 3/8" APPROX. PLATE	INTERMEDIATE SHELL #3
15	1	SA-516 GRADE 70	1 1/4" THK. X 174 1/8" X 259 3/16" APPROX. PLATE	INTERMEDIATE SHELL #4
16	1	SA-516 GRADE 70	1" THK. X 173 7/8" X 266 1/4" APPROX. PLATE	INTERMEDIATE SHELL #5
17	2	SA-515 GRADE 70	1/2" THK. X 85 3/4" I.D. X 96" O.D. PLATE	ENCLOSURE SHELL RETURN
18	2	SA-193 GRADE B8	7/8" Ø X 4 7/16" LG. BAR (SEE DETAIL ON DWG. 1398 SHT. 3)	PORT PLUG
19	3	ALLOY X750	0.75 O.D. X 0.615 I.D. SPRING ENERGIZED SEAL, PART ASE50033 (AMERICAL SEAL) OR EQUIVALENT	PORT PLUG SEAL
20	4	SA-193 GRADE B7	1/4 - 20 UNC X 1/2 LG. SOCKET CAP SCREW	TRUNNION LOCKING PAD BOLT
21	2	SA-516 GRADE 70	1/2" THK. X 6 3/4" O.D PLATE	LIFTING TRUNNION END CAP
22	4	SA-193 GRADE B7	1/2" - 13 UNC X 1" LG. HEX. BOLTS	TRUNNION END CAP BOLT
23	2	SA-516 GRADE 70	3/8" THK. X 7 3/4" X 9 3/4" PLATE	LIFTING TRUNNION LOCKING PAD
24	AS REQ.	HOLTITE - A	HOLTITE-A WITH 1 WT. % B_4C	NEUTRON SHIELD
25	8	SA-193 GRADE B7	3/8" - 16 UNC X 1/2" LG. SOCKET SET SCREW	REMOVEABLE SHEAR RING PLUG
26	1	COMMERCIAL	3/8" X 71" O.D. SELF ENERGIZED SEAL, INTERNAL PRESSURE OR EQUIVALENT	CLOSURE PLATE INNER SEAL

BILL OF MATERIALS FOR HI-STAR 100 OVERPACK (BM-1476)

REF. DWGS. 1397,1398 & 1399.

REV. NO.	PREP. BY & DATE	CHECKED BY DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
15	S.GEE 11-2-99 INCORPORATED ECO/ SMDR/MISC CHANGES	[signature] 11/24/99	[signature] S.G. 11/24/99	[signature] MS 11/24/99

REV.	ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
15	27	1	COMMERCIAL	3/8" X 72.5" O.D. SELF ENERGIZED SEAL. INTERNAL PRESSURE OR EQUIVALENT	CLOSURE PLATE OUTER SEAL
	28	2	SA-350-LF3 OR SA-203-E	1 1/2" THK. X 5 1/2" Ø PLATE	PORT COVER
15	29	8	SA-193 GRADE B7	3/8 - 16 UNC X 5/8 LG. SOCKET CAP SCREW	PORT COVER BOLT
	30	2	ALLOY X750	2 1/2" O.D. SPRING ENERGIZED C-RING, INTERNAL PRESSURE (AMERICAL SEAL) OR EQUIVALENT	PORT COVER SEAL
15	31	--	---	DELETED	---
	32	52	SB-637-N07718	1 5/8" - 8 UN X 7 3/8" LG. 12 POINT CAP SCREW W/ 3 3/4" LG. THREAD. (W/2.43" DIA. X 1 5/8" TOTAL HIGH HD. PER DET.DWG.1397. SHT.3)	CLOSURE PLATE LONG BOLT
15	33	2	COMMERCIAL	RUPTURE DISK (RELIEVE AT 30 PSIG (±5 PSIG)) (1 1/2 IN^2 FLOW AREA)	RUPTURE DISK
15	34	8	SA-193 GRADE B7	3/8" - 16 UNC X 1 3/8" LG. SOCKET CAP SCREW	REMOVEABLE SHEAR RING BOLT
	35	1	SA-193 GRADE B8	7/8" Ø X 3 13/16" LG. BAR (SEE DETAIL ON DWG. 1398)	DRAIN PORT PLUG
	36	--	----	DELETED	----
	37	AS REQ.	SILICONE FOAM	TYPE HT-870 (BISCO PRODUCTS) OR EQUIVALENT	THERMAL EXPANSION FOAM
15	38	--	---	DELETED	---
15	39	2	SA-516 GRADE 70 OR A569	11 GAGE (1/8" THK.)	RUPTURE DISK PLATE
	40	1	SA 240 304	14 GAGE (0.0751" THK.) X 4" WIDE X 10" LG. SHEET	STORAGE MARKING NAME PLATE
	41	1	SA 240 304	14 GAGE (0.0751" THK.) X 6 1/2" WIDE X 10" LG. SHEET	TRANSPORTATION MARKING NAME PLATE
15	42	AS REQD	SA515-70	AS REQUIRED	BRIDGE
	43	2	SA 240 304	11 GAGE (1/8" THK.) X 6 1/8" WIDE X 7 11/16" LG. PLATE	POCKET TRUNNION PLUG PLATE
	44	2	SA 240 304	11 GAGE (1/8" THK.) X 1 1/2" WIDE X 9 1/2" LG. PLATE	POCKET TRUNNION PLUG PLATE
	45	2	SA 240 304	11 GAGE (1/8" THK.) X 3 1/2" WIDE X 18 7/8" LG. PLATE	POCKET TRUNNION PLUG PLATE
	46	2	SA 240 304	11 GAGE (1/8" THK.) X 3 3/4" WIDE X 6 1/8" LG. PLATE	POCKET TRUNNION PLUG PLATE
	47	2	SA 240 304	11 GAGE (1/8" THK.) X 6 1/8" WIDE X 7 11/16" LG. PLATE	POCKET TRUNNION PLUG PLATE
15	48	4	SA-193 GRADE B7	3/8 - 16 UNC X 1/2" LG. SOCKET CAP SCREW	POCKET TRUNNION PLUG SCREW
15	49	54	S/S	11 GAGE (1/8" THK.) X 1 3/4" ID. X 2 5/8" OD.	CLOSURE BOLT WASHER
	50	40	SA-193-B7	1 3/4"-5UNC X 1 1/8" LG. SOCKET SET SCREW	TOP FLG. LIP HOLE PLUGS
	51	20	SA-193-B7	1"-8UNC X 1 1/4" LG. SOCKET SET SCREW	TOP FLG. SIDE HOLE PLUGS
15	52	16	SA-193-B7	1 3/4"-8UNC X 2 1/4" LG. SOCKET SET SCREW	BOTTOM PLATE HOLE PLUGS
15	53	---	---	DELETED	---
	54	4	SA-193-B7	1/2-13UNC X 5/8" LG SOCKET SET SCREW	THREADED PLUG

NOTES:
1) ALL DIMENSIONS ARE APPROXIMATE.
2) HOLTITE IS A NEUTRON SHIELD MATERIAL WITH 1 WT. % B_4C, 6 WT. % H, AND A DENSITY OF 1.68g/cm^3.
3) ITEMS 12 THRU 16, MATERIAL SA-516-GR 70 IS TO BE NORMALIZED.
15 4) THICKNESS OF ITEM 16 MAY VARY DEPENDING ON THICKNESSES OF ITEMS 12-15.
5) ITEMS 2,12-17 MAY BE MADE FROM MORE THAN ONE PIECE.

BILL OF MATERIALS FOR 24-ASSEMBLY HI-STAR 100 PWR MPC.(BM-1478)

REF. DWG. 1395 & 1396.

REV.NO.	PREP. BY & DATE	CHECKED BY & DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
10	S.GEE 11-3-99 REVISED AS INDICATED	11/22/99	B.G. 11/23/99	MC 11/22/99

REV.	ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
	1A	2	ALLOY "X" SEE NOTE 1.	PLATE 5/16" THK.X 63.20" REF W. X 176 1/2" LG	BASKET CELL PLATE
	1B	1	↓	PLATE 5/16" THK X 60.57" REF W. X 176 1/2"LG.	BASKET CELL PLATE
	1C	2	↓	PLATE 5/16" THK X 43.42" REF W. X 176 1/2"LG.	BASKET CELL PLATE
	1D	1	↓	PLATE 5/16" THK X 20.402 " REF W. X 176 1/2"LG.	BASKET CELL PLATE
	1E	1	↓	PLATE 5/16" THK X 7.7175" REF W. X 176 1/2"LG.	BASKET CELL PLATE
	1F	22	↓	PLATE 5/16" THK X10.4625 " REF W. X 176 1/2"LG.	BASKET CELL PLATE
	1G	1	↓	PLATE 5/16" THK X 9.7445 " REF W. X 176 1/2"LG.	BASKET CELL PLATE
	1H	2	↓	PLATE 5/16" THK X 9.03 " REF W. X 176 1/2"LG.	BASKET CELL PLATE
	2	24	▽	PIPE 3"-SCH 80 LGTH AS REQD.	UPPER FUEL SPACER PIPE
	3A (3B)	84(12)	BORAL	.075"THK. X 7.5"W.(6 1/4") X 156" LG.PER DET.DWG.1395. SEE NOTE 2.	NEUTRON ABSORBER
	4A (4B)	84(12)	ALLOY "X" SEE NOTE 1.	.06" THK. SHEATHING PER DET. DWG. 1395.	SHEATHING
	5A	4	↓	PLATE 5/16"THK X 3" W. X 176 1/2"LG.	BASKET CELL PLATE
	5B	4	↓	PLATE 5/16"THK X 3 3/4" APPROX. W. X 176 1/2"LG.	BASKET CELL PLATE
	5C	4	↓	PLATE 1.5" APP. THK. X 3" W. X 168"LG.	BASKET SUPPORT
△10	5D	4	↓	2 1/2" W X 168" LG	BASKET SUPPORT
	5E	4	↓	2 "WIDE X 168"LG. THICKNESS AS REQD.	BASKET SUPPORT
△10	5F	-	↓	DELETED	---
△10	5G	4	↓	1 1/4" W X 1" THK X 168" LG.	BASKET SUPPORT SHIM
	5H	---	↓	DELETED	-----
	6	1	↓	1/2" THK X 68 3/8" O.D. X 187 5/8" LG. CYLINDER.	SHELL
	7	1	↓	BASEPLATE 2 1/2" THK X 68 3/8" O.D.	BASEPLATE
	8A	22	↓	9/32"THK. ANGLE X 176 1/2" LG. FROM PLATE PER DET. DWG.1395.	BASKET CELL ANGLE
	8B	2	↓	9/32"THK. CHANNEL X 176 1/2" LG. FROM PLATE PER DET.DWG. 1395.	BASKET CELL CHANNEL
	9A	1	↓	5/16" THK.X 10" W. APP. X 168" LG. PER DET.	BASKET SUPPORT
	9B	2	↓	5/16"THK. X 7 1/2" APP. W. X 168" LG. PER DET.	BASKET SUPPORT
	9C	1	↓	5/16"THK. X 5" APP. W. X 168" LG. PER DET.	BASKET SUPPORT
△10	9D	AS REQD	↓	AS REQUIRED	BASKET SUPPORT
	9E	----	↓	DELETED	---
	9F	---	↓	DELETED	---
	9G	---	↓	DELETED	---
	9H	---	↓	DELETED	---
	10	4	▽	PLATE 3/4" THK. X 3 1/2" WIDE X 8 3/4" LG.	LIFT LUG

BILL OF MATERIALS FOR 24-ASSEMBLY HI-STAR 100 PWR MPC.(BM-1478)

REF. DWG. 1395 & 1396.

REV.NO.	PREP. BY & DATE	CHECKED BY & DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
12	S.GEE 11-3-99 REVISED AS INDICATED	11/22/99	B.G. 11/22/99	MS 11/22/99

ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
11	4	ALLOY "X" SEE NOTE 1.	PLATE 3/4" THK. X 4" WIDE X 3" LG.	LIFT LUG BASEPLATE
12	1	ALLOY "X" SEE NOTE 1.	BAR 3.75" OD. X 5 7/8" LG.	DRAIN SHIELD BLOCK
13A	2	304 S/S	BAR 2 11/16" OD X 6.75" LG. DIMENSIONS AS SHOWN ON DWG 1396 SH 4	VENT AND DRAIN TUBE
13B	2	304 S/S	BAR 2 1/4 OD X 2 1/4 LG. DIMENSIONS AS SHOWN ON DWG 1396 SH 4	VENT AND DRAIN TUBE CAP
14	1	ALLOY "X" SEE NOTE 1.	9 1/2" THK. X 67 1/4" O.D.	MPC LID
15	1	↓	RING 3/8" THK.X 53 1/4" ID. X 67 5/8" O.D.	MPC CLOSURE RING
16	---	----	DELETED	---
17	----	----	DELETED	----
18	AS REQD	ALLOY "X" SEE NOTE 1.	AS REQUIRED	BASKET SUPPORT
19	2	ALLOY "X" SEE NOTE 1.	PLATE 3/8" THK. X 3 7/8"OD.	PORT COVER PLATE
20	24	A-193-B8 OR SIMILAR	3/4"-10UNC X 1 1/4"LG. HEX BOLT WITH FULL THRD.	UPPER FUEL SPACER BOLT
21	AS REQD	ALLOY "X" SEE NOTE 1.	3/4" X 2" X THICKNESS AS REQUIRED	LIFT LUG SHIM
22	---	---	DELETED	---
23	4	A-193-B8 OR SIMILAR	1 3/4"-5UNC X 2 3/4"LG SOCKET SET SCREW	LID LIFT HOLE PLUG
24	24	ALLOY "X" SEE NOTE 1.	PLATE 3/8" THK X 4" OD.	UPPER FUEL SPACER END PLATE
25	1 SET	ALLOY "X" SEE NOTE 1.	LENGTH, WIDTH AND THICKNESS OF SHIMS AS REQUIRED.	LID SHIM
26	1	S/S	COUPLING	COUPLING
27	AS REQD	ALLOY "X" SEE NOTE 1.	3/4" X 5" DIAM.	UPPER FUEL SPACER END PLATE
28	1	ALLOY "X" SEE NOTE 1.	BAR 3.75" OD. X 5.5"LG.	VENT QUICK DISCONN. CPLG.
29	4	ALLOY "X" SEE NOTE 1.	BAR 3/4" OD. X 1/2" LG.	VENT SHIELD BLOCK SPACER
30	1	ALLOY "X" SEE NOTE 1.	2"-SCH 10 PIPE X 173 1/2"APPROX. LG.	DRAIN LINE
31	--	-------	DELETED	-----
32	24	↓	6" SQ. TUBING X 1/4" WALL LENGTH AS REQ'D.	LOWER FUEL SPACER CLUMN
33A	24		PLATE 3/8" THK X 8.5" SQ.	LOWER FUEL SPCAER END PLATE
33B	24		PLATE 3/8" THK X 8.5" SQ.	LOWER FUEL SPCAER END PLATE
34	---	--------	DELETED	-------
35	AS REQ'D.	ALUM. ALLOY 1100 & S/S	1/8" THICK X 176 1/2" LG. ALUM. SHEET (153" LG (APP.) AT DRAIN PIPE LOCATION) WITH S/S SPRINGS	HEAT CONDUCTION ELEMENTS
36	2	ALUMINUM	0.065" THK 1.494 OD, 0.250" HOLE	SEAL WASHER
37	2	S/S	1/4" DIA X 3/8" LG	SEAL WASHER BOLT
38	2	ALLOY "X" SEE NOTE 1.	1/8" X 10 1/2" X 9 1/2" SHEET	DRAINLINE
39	8	ALLOY "X" SEE NOTE 1.	1/8" X 4" X 4 1/2" APPRPX SHEET	DRAINLINE

NOTES: (FOR SHEET 1 & 2)

1. ALLOY X IS ANY OF THE FOLLOWING ACCEPTABLE STAINLESS STEEL ALLOYS: ASME TYPE 316, 316LN, 304, 304LN. THE ALLOY TO BE USED SHALL BE SPECIFIED BY THE LICENSEE.
2. MINIMUM BORAL B-10 LOADING IS 0.0267 g/cm^2. BORAL TO BE PASSIVATED PRIOR TO INSTALLATION.
3. ALL DIMENSIONS ARE APPROXIMATE DIMENSIONS.
4. ITEMS 5C,5D,5E,5G 9A,9B,9C,9D,16,18, AND 35 MAY BE MADE FROM MORE THAN ONE PIECE. THE ENDS OF PIECES DO NOT NEED TO BE WELDED TOGETHER BUT THEY MUST NE FLUSH WITH EACH OTHER WHEN INSTALLED.

BILL OF MATERIALS FOR 68-ASSEMBLY HI-STAR 100 BWR MPC.(BM-1479)

REF. DWGS. 1401 & 1402.

REV. NO.	PREP. BY & DATE	CHECKED BY DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
11	S.GEE 11-3-99 REVISED AS INDICATED	[signature] 11/22/99	[signature] B.G. 11/22/99	[signature] MS 11/22/99

ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
1A	3	ALLOY "X" SEE NOTE 1.	PLATE 1/4" THK. X 65.65"W. X 176" LG PER DET. DWG.1401.	BASKET CELL PLATE
1B	4	↓	PLATE 1/4" THK. X 52.67"W. X 176" LG PER DET. DWG.1401.	BASKET CELL PLATE
1C	2		PLATE 1/4" THK. X 39.69W. X 176" LG PER DET. DWG.1401.	BASKET CELL PLATE
1D	2		PLATE 1/4" THK. X 13.73"W. X 176" LG PER DET. DWG.1401.	BASKET CELL PLATE
1E	78		PLATE 1/4" THK. X 6.24"W. X 176" LG PER DET. DWG.1401.	BASKET CELL PLATE
2	68	▽	3"- SCH 80 PIPE LGTH AS REQD.	UPPER FUEL SPCER CLUMN
3A	116	BORAL	.101"THK. X 4 3/4"W. X 156" LG.PER DET.DWG.1401. SEE NOTE 2.	NEUTRON ABSORBER
4A	116	ALLOY "X" SEE NOTE 1.	.075" THK. SHEATHING PER DET. DWG.1401.	SHEATHING
5	8	↓	BAR 1" WIDE X 168" LG X THICKNESS AS REQUIRED	BASKET SUPPORT SHIM
6	1		1/2" THK X 68 3/8" O.D. X 187 5/8" LG. CYLINDER.	SHELL
7	1		BASEPLATE 2 1/2" THK X 68 3/8" O.D.	BASEPLATE
8	8		PLATE 5/16"THK. X 10" APPROX.W.X 168 1/2" LG. PER DET. DWG.1401.	BASKET SUPPORT
9A	4		BAR 1" W. X .8" APPROX.THK. X 168 1/2" LG.	BASKET SUPPORT
9B	---		DELETED	---
9C	8		2 1/2" WIDE X 168 1/2" LG. THICKNESS AS REQD. ROLL TO SHELL I.D.	BASKET SUPPORT
9D	AS REQD		AS REQUIRED	BASKET SUPPORT
10	4		PLATE 3/4" THK. X 3 1/2" WIDE X 8 3/4" LG.	LIFT LUG
11	4		PLATE 3/4" THK. X 2 1/2" WIDE X 4" LG.	LIFT LUG BASEPLATE
12	1	▽	BAR 3.75"OD. X 5 7/8" LG.	DRAIN SHIELD BLOCK
13A	2	304 S/S	BAR 2 11/16" OD X 6 3/4" REF LG, DIMENSION ON DWG 1402 SHT 4	VENT AND DRAIN TUBE
13B	2	304 S/S	BAR 2 1/4" OD X 2 1/4" REF LG, DIMENSION ON DWG 1402 SHT 4	VENT AND DRAIN TUBE CAP
14	1	ALLOY "X" SEE NOTE 1.	10" THK. X 67 1/4" O.D. [MPC-68] 10" THK. X 66 1/4" O.D. [MPC-68F]	MPC LID
15	1	ALLOY "X" SEE NOTE 1.	RING 3/8" THK. X 53 1/4" ID. X 67 5/8" O.D. [MPC-68] RING 3/8" THK. X 53 1/4" ID. X 67 1/8" O.D. [MPC-68F]	MPC CLOSURE RING
16	---	---	DELETED	---

Revision triangles "11" at items 5, 9B, 9D, 13A, 13B, 14, 16.

BILL OF MATERIALS FOR 68-ASSEMBLY HI-STAR 100 BWR MPC.(BM-1479)

REF. DWGS. 1401 & 1402.

REV. NO.	PREP. BY & DATE	CHECKED BY DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
14	S. GEE 11-3-99 REVISED AS INDICATED	[signature] 11/22/99	[signature] B.G. 11/22/99	[signature] MS 11/22/99

ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
17	1	ALLOY "X" SEE NOTE 1.	1" THK X 68 3/8" OD X 11 5/8" LG. CYLINDER (MPC-68F)	SHELL
18	AS REQD	ALLOY "X" SEE NOTE 1.	AS REQUIRED	BASKET SUPPORT
19	2	ALLOY "X" SEE NOTE 1.	PLATE 3/8" THK X 3 7/8" OD.	PORT COVER PLATE
20	68	A-193-B8 OR SIMILAR	3/4"-10UNC X 1.25"LG. FULL THRD. HEX. BOLT	UPPER FUEL SPACER BOLT
21	AS REQD	ALLOY "X" SEE NOTE 1.	3/4" W X 2' LG X THICKNESS AS REQUIRED	LIFT LUG SHIM
22	---	---	DELETED	---
23	4	A-193-B8 OR SIMILAR	1 3/4"-5UNC X 2 3/4" LG. SOCKET SET SCREW.	LIFT HOLE PLUG
24	68	ALLOY "X" SEE NOTE 1.	PLATE 3/8" THK X 4" OD.	UPPER FUEL SPACER END PLATE
25	1 SET	ALLOY "X" SEE NOTE 1	LENGTH, WIDTH , THICKNESS AND QUANTITY AS REQD.	LID SHIM
26	1	S/S	COUPLING	COUPLING
27			DELETED	
28	1	ALLOY "X" SEE NOTE 1.	BAR 3.75" OD. X 5.5" LG.	VENT SHIELD BLOCK
29	4	ALLOY "X" SEE NOTE 1.	BAR .75"OD X .5"LG.	VENT SHIELD BLOCK SPACER
30	1	ALLOY "X" SEE NOTE 1.	2"-SCH 10 PIPE X 173" APPROX.LG.	DRAIN LINE
31	--	--	DELETED	---
32	--	--	DELETD	---
33	68	ALLOY "X" SEE NOTE 1.	4" SQ. TUBE X 1/4" WALL LENGTH AS REQD. (FOR SHORT FUEL ONLY)	LOWER FUEL SPACER CLUMN
34A	68	ALLOY "X" SEE NOTE 1.	3/8" THK. X 5 3/4" SQ. PLATE (FOR SHORT FUEL ONLY)	LOWER FUEL SPACER END PLATE
34B	68	ALLOY "X" SEE NOTE 1.	3/8" THK. X 5 3/4" SQ. PLATE (FOR SHORT FUEL ONLY)	LOWER FUEL SPACER END PLATE
35	----	----------	DELETED	
36	----	----------	DELETED	
37	AS REQD	ALUM. ALLOY 1100 & S/S	1/8" THK. X 176" LG. ALUM. SHEET (153" LG APP. AT DRAIN PIPE LOCATION.) W/S/S SPRINGS.	HEAT CONDUCTION ELEMENTS
38	2	ALUMINUM	.065" THK X 1.494 OD, .250 HOLE	SEAL WASHER
39	2	S/S	1/4" DIA X 3/8 LG	SEAL WASHER BOLT
40	2	ALLOY "X" SEE NOTE 1	1/8" THK. 6" X 6" APPROX. SHEET	DRAIN LINE
41	8	ALLOY "X" SEE NOTE 1.	1/8" THK. X 6" X 6" APPROX. SHEET	DRAIN LINE

NOTES: (FOR SHEET 1 & 2)

1. ALLOY X IS ANY OF THE FOLLOWING ACCEPTABLE STAINLESS STEEL ALLOYS: ASME TYPE 316, 316LN, 304, 304LN. THE ALLOY TO BE USED SHALL BE SPECIFIED BY THE LICENSEE.
2. MINIMUM BORAL B-10 LOADING IS 0.0372 g/cm^2. BORAL TO BE PASSIVATED PRIOR TO INSTALLATION. FOR MPC-68F, MINIMUM BORAL B-10 LOADING IS 0.01 g/cm^2.
3. ALL DIMENSIONS ARE APPROXIMATE DIMENSIONS.
4. ITEMS 5,8,9A,9C,9D,16,18, AND 37 MAY BE MADE FROM MORE THAN ONE PIECE. THE ENDS OF PIECES DO NOT NEED TO BE WELDED TOGETHER BUT THEY MUST BE FLUSH WITH EACH OTHER WHEN INSTALLED.

BILL OF MATERIALS HI-STAR 100 SYSTEM FAILED FUEL CANISTER (BM-1819)

REF. DWG. 1783 & 1784

SHEET 1 OF 1

REV.NO.	PREP. BY & DATE	CHECKED BY & DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
2	S.GEE 11-19-99 REVISED AS SHOWN	11/22/99	B.G. 11/22/99	MS 11/22/99

ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
1	1	SA430-WP304	3/4 X 1/2 CONCENTRIC REDUCER SCH. 160	LEAD IN
2	1	SA479-304	Ø 1 1/2 X 13/16 LG. ROUND BAR	LEAD IN COLLAR
3	1	SA479-304	Ø 3/8 X 2 LG. ROUND BAR	LOCK PIN
4	1	SA240-304	11 GA. X 1 1/2 X 2 5/8 LG. SHEET	ENGAGEMENT PIN
5	2	SA479-304	Ø 3/16 X 13/16 LG. ROUND BAR	ENGAGEMENT PIN
6	4	304 SST.	250 X 250 (.0016 WIRE Ø; .0024 WIDTH OPENING)	WIRE MESH
7	2	SA479-304 (or) SA240-304	3/16 X 1/2 X 5 7/16 LG. BAR	RIM BAR (LONG)
8	2	SA479-304 (or) SA240-304	3/16 X 1/2 X 4 7/16 LG. BAR	RIM BAR (SHORT)
9	2	SA479-304 (or) SA240-304	3/16 X 1 1/4 X 4 7/16 LG. BAR	SIDE (SHORT)
10	2	SA479-304 (or) SA240-304	3/16 X 1 1/4 X 4 13/16 LG. BAR	SIDE (LONG)
11	2	SA479-304 (or) SA240-304	1/2 SQ. X 2 3/16 LG. BAR	LOAD TAB
12	1	SA479-304	Ø 1 1/2 X 3/4 LG. ROUND BAR	LOAD TAB HUB
13	1	SA479-304	Ø 1 1/2 X 3 LG. ROUND BAR	LOCKING SHAFT
14	1	SA479-304	Ø 1/8 X 9/16 LG. ROUND BAR	LOCKING PIN
15	1	SA479-304	Ø 3/8 X 1 7/8 LG. ROUND BAR	SHEAR PIN
16	1	304 SST (or) 316 SST	COMPRESSION SPRING 13/16 I.D. X 1 LG.	LOCKING SPRING
17	1	SA240-304	3/16 X 4 13/16 SQ. PLATE	CLOSURE FRAME BASE PLATE
18	2	304 SST.	1/16 X 3/4 COTTER PIN	COTTER PIN
19	1	SA240-304	3/8 X 4 13/16 SQ. PLATE	FUEL SPACER TOP PLATE
20	1	304 SST.	1/4 WALL X 4 SQ. X 2 1/8 LG. TUBING	FUEL SPACER TUBING
21	1	304 SST.	250 X 250 (.0016 WIRE Ø; .0024 OPENING)	WIRE MESH
22	2	SA240-304	11 GA. X 10 3/8 APP. X 138 1/4 LG. SHEET	CANISTER SLEEVE
23	1	SA240-304	11 GA. X 21 3/4 APP. X 2 LG. SHEET	CANISTER COLLAR
24	1	SA240-304	11 GA. X 4 15/16 SQ. SHEET	CANISTER BOTTOM
25	1	SA240-304	11 GA. X Ø .61 PLUG	LEAD-IN CAP
26	1	SA240-304	11 GA. X 4 1/2 O.D. X 3 1/4 I.D. RING	SCREEN RING
27	4	SA240-304	11 GA. X 1 15/16 O.D. X 1 9/16 I.D. RING	SCREEN RING
28	1	SA312-304	3/4 STD. PIPE SCH 160	LEAD-IN EXTENSION

NOTE: DIMENSIONS ARE APPROXIMATE

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FIGURE WITHHELD AS SENSITIVE
UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 MPC-24 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1396	REV. 11
PROJECT No. 5014	DRAWING No.
P.O. No. N/A	1395 SHT 1 OF 4

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION		
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING	
DESCRIPTION HI-STAR 100 MPC-24 CONSTRUCTION		
CLIENT N/A		
COMPANION DRAWINGS 1396		REV. 10
PROJECT No. 5014	DRAWING No. 1395 SHT 2 OF 4	
P.O. No. N/A		

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION		
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING	
DESCRIPTION HI-STAR 100 MPC-24 CONSTRUCTION		
CLIENT N/A		
COMPANION DRAWINGS 1396		REV. 10
PROJECT No. 5014	DRAWING No.	
P.O. No. N/A	1395 SHT 3 OF 4	

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 MPC-24 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1396	REV. 9
PROJECT No. 5014	DRAWING No.
P.O. No. N/A	1395 SHT 4 OF 4

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 MPC-24 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1395	REV. 13
PROJECT No. 5014	DRAWING No. 1396 SHT 1 OF 6
P.O. No. N/A	

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

DESCRIPTION	BY:	BY:	ENG.	Q. A.

REVISION

HOLTEC INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-24 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS 1395 | REV. 10

PROJECT No. 5014 | DRAWING No.
P.O. No. N/A | 1396 SHT 2 OF 6

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REV.	DESCRIPTION	BY:	BY:	ENG.	Q. A.

REVISION

HOLTEC INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-24 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
1395

REV.
10

PROJECT No. 5014

P.O. No. N/A

DRAWING No.
1396 SHT 3 OF 6

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 MPC-24 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1395	REV. 9
PROJECT No. 5014	DRAWING No. 1396 SHT 4 OF 6
P.O. No. N/A	

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 MPC-24 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1395	REV. 8
PROJECT No. 5014 P.O. No. N/A	DRAWING No. 1396 SHT 5 OF 6

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN · ANALYSIS · CONSULTING
DESCRIPTION HI-STAR 100 MPC-24 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1395	REV. 8
PROJECT No. 5014	DRAWING No. 1396 SHT 6 OF 6
P.O. No. N/A	

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING	
DESCRIPTION CROSS SECTIONAL VIEW OF HI-STAR 100 OVERPACK		
CLIENT N/A		
COMPANION DRAWINGS 1398, 1399		REV. 16
PROJECT No. 5014	DRAWING No. 1397 SHT. 1 OF 7	
P.O. No. N/A		

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION DETAIL OF TOP FLANGE & BOTTOM PLATE OF HI-STAR 100 OVERPACK	
CLIENT N/A	
COMPANION DRAWINGS 1398, 1399	REV. 11
PROJECT No. 5014 P.O. No. N/A	DRAWING No. 1397 SHT. 2 OF 7

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION DETAIL OF BOLT HOLE & BOLT OF HI-STAR 100 OVERPACK	
CLIENT N/A	
COMPANION DRAWINGS 1398, 1399	REV. 11
PROJECT No. 5014	DRAWING No. 1397 SHT. 3 OF 7
P.O. No. N/A	

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
DETAIL OF CLOSURE PLATE TEST PORT
AND NAME PLATE DETAIL
OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS 1398, 1399

REV. 12

PROJECT No. 5014

P.O. No. N/A

DRAWING No. 1397 SHT. 4 OF 7

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION DETAIL OF LIFTING TRUNNION & LOCKING PAD OF HI-STAR 100 OVERPACK	
CLIENT N/A	
COMPANION DRAWINGS 1398, 1399	REV. 9
PROJECT No. 5014 P.O. No. N/A	DRAWING No. 1397 SHT. 5 OF 7

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION		
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING	
DESCRIPTION	DETAIL OF SHEAR RING AND CLOSURE PLATE BOLT INSTALLATION OF HI-STAR 100 OVERPACK	
CLIENT N/A		
COMPANION DRAWINGS 1398, 1399		REV. 9
PROJECT No. 5014	DRAWING No. 1397 SHT. 6 OF 7	
P.O. No. N/A		

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION DETAIL OF SHEAR RING OF HI-STAR 100 OVERPACK	
CLIENT N/A	
COMPANION DRAWINGS 1398, 1399	REV. 9
PROJECT No. 5014 P.O. No. N/A	DRAWING No. 1397 SHT. 7 OF 7

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION		
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING	
DESCRIPTION HI-STAR 100 OVERPACK ORIENTATION		
CLIENT N/A		
COMPANION DRAWINGS 1397, 1399		REV. 13
PROJECT No. 5014	DRAWING No. 1398 SHT. 1 OF 3	
P.O. No. N/A		

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION DETAIL OF DRAIN & RUPTURE DISK OF HI-STAR 100 OVERPACK	
CLIENT N/A	
COMPANION DRAWINGS 1397, 1399	REV. 10
PROJECT No. 5014	DRAWING No.
P.O. No. N/A	1398 SHT. 2 OF 3

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION DETAIL OF VENT & PORT PLUG OF HI-STAR 100 OVERPACK	
CLIENT N/A	
COMPANION DRAWINGS 1397, 1399	REV. 9
PROJECT No. 5014 P.O. No. N/A	DRAWING No. 1398 SHT. 3 OF 3

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
SECTION "G" "G"
OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS
1397, 1398

REV. 12

PROJECT No. 5014

DRAWING No.
1399 SHT. 1 OF 3

P.O. No. N/A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION SECTION "X"-"X" & VIEW "Y" OF HI-STAR 100 OVERPACK	
CLIENT N/A	
COMPANION DRAWINGS 1397, 1398	REV. 9
PROJECT No. 5014	DRAWING No.
P.O. No. N/A	1399 SHT. 2 OF 3

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION DETAIL OF TRUNNION POCKET FORGING OF HI-STAR 100 OVERPACK	
CLIENT N/A	
COMPANION DRAWINGS 1397, 1398	REV. 11
PROJECT No. 5014	DRAWING No.
P.O. No. N/A	1399 SHT 3 OF 3

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION		
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING	
DESCRIPTION HI-STAR 100 MPC-68 CONSTRUCTION		A
CLIENT N/A		
COMPANION DRAWINGS 1402	REV. 12	
PROJECT No. 5014	DRAWING No. 1401 SHT 1 OF 4	
P.O. No. N/A		

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION

HI-STAR 100 MPC-68 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
1402

REV.
9

PROJECT No. 5014

P.O. No. N/A

DRAWING No.
1401 SHT 2 OF 4

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION - HI-STAR 100 MPC-68 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1402	REV. 10
PROJECT No. 5014	DRAWING No. 1401 SHT 3 OF 4
P.O. No. N/A	

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION		
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING	
DESCRIPTION HI-STAR 100 MPC-68 CONSTRUCTION		
CLIENT N/A		
COMPANION DRAWINGS 1402		REV. 9
PROJECT No. 5014	DRAWING No. 1401 SHT 4 OF 4	
P.O. No. N/A		

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

DESCRIPTION	BY:	BY:	ENG.	Q. A.
REVISION				

HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 MPC-68 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1401	REV. 14
PROJECT No. 5014 P.O. No. N/A	DRAWING No. 1402 SHT 1 OF 6

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 MPC-68 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1401	REV. 12
PROJECT No. 5014	DRAWING No. 1402 SHT 2 OF 6
P.O. No. N/A	

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION		
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING	
DESCRIPTION HI-STAR 100 MPC-68 CONSTRUCTION		
CLIENT N/A		
COMPANION DRAWINGS 1401		REV. 12
PROJECT No. 5014	DRAWING No. 1402 SHT 3 OF 6	
P.O. No. N/A		

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION		
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING	
DESCRIPTION HI-STAR 100 MPC-68 CONSTRUCTION		
CLIENT N/A		
COMPANION DRAWINGS 1401		REV. 10
PROJECT No. 5014	DRAWING No. 1402 SHT 4 OF 6	
P.O. No. N/A		

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 MPC-68 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1401	REV. 9
PROJECT No. 5014 P.O. No. N/A	DRAWING No. 1402 SHT 5 OF 6

2

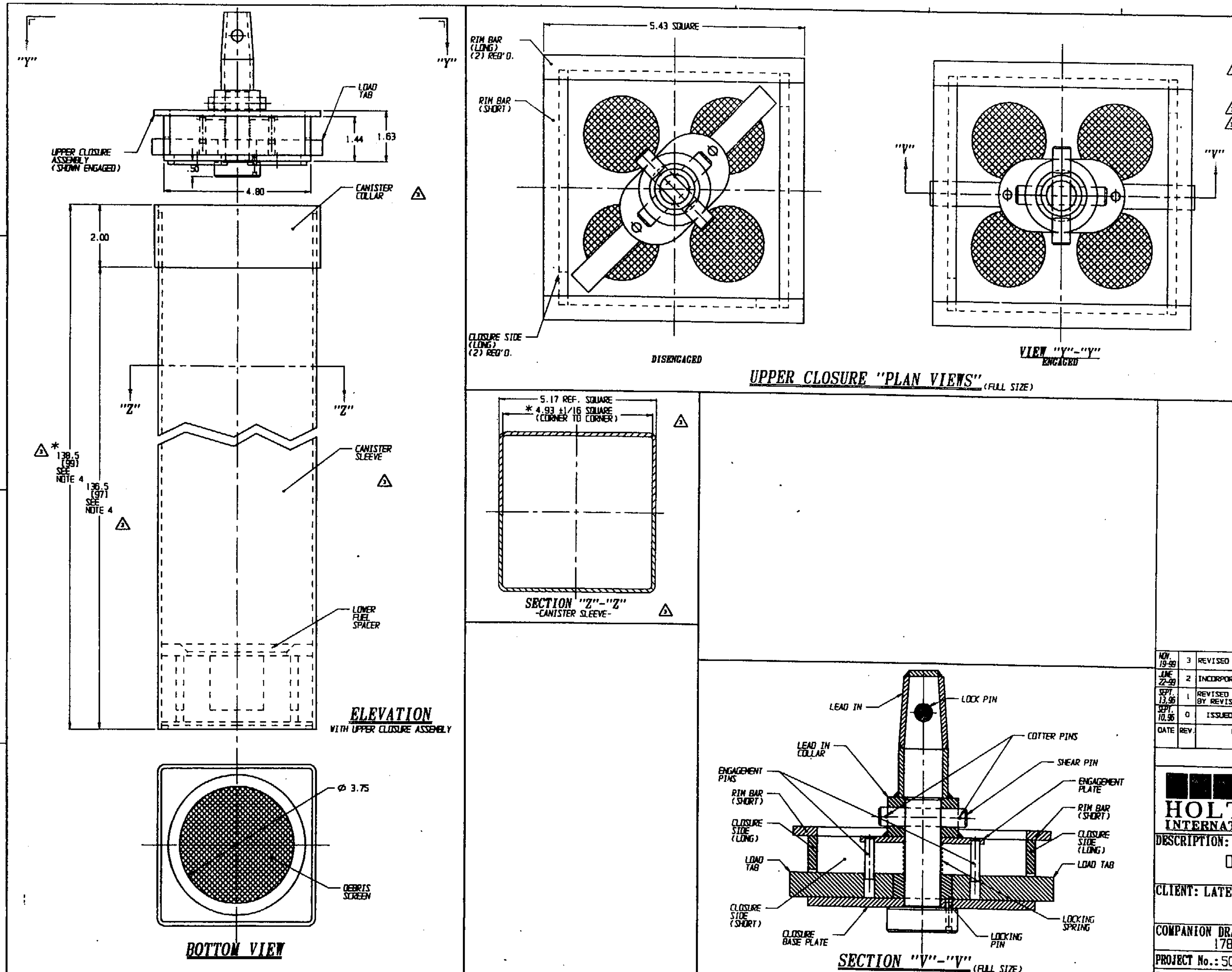
FIGURE WITHHELD AS
SENSITIVE UNCLASSIFIED
INFORMATION

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 MPC-68 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1401	REV. 8
PROJECT No. 5014 P.O. No. N/A	DRAWING No. 1402 SHT 6 OF 6

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 ASSEMBLY	
CLIENT N/A	
COMPANION DRAWINGS ---	REV. 4
PROJECT No. 5014 P.O. No. N/A	DRAWING No. 1763



NOTES:
1. - SEE DWG. 1784 FOR INDIVIDUAL PARTS AND SUB-ASSEMBLIES.
2. - TOLERANCES, UNLESS OTHERWISE NOTED:

RANGE	TOLERANCE
0" to 2"	±1/16
2" to <3'	±1/8
3' and >	±3/16

3. - ALL WELDS REQUIRE VISUAL EXAMINATION.
4. - LENGTH OF CANISTER IS DEPENDENT ON FUEL ASSEMBLY LENGTH.
5. - CRITICAL DIMENSIONS (INDICATED BY AN "*") ARE ESSENTIAL TO ASSURE EQUIPMENT FUNCTIONALITY.

DATE	REV.	DESCRIPTION	PREP. BY:	CHECKED BY:	ENG. APP.	Q.A.
NOV. 19-99	3	REVISED AS INDICATED	S.GEE 11-19-99	[illegible]	[illegible]	[illegible]
JUNE 22-99	2	INCORPORATED DCR 5014-132	J.O.A.	B.G.U. 6-22-99	B.G. 6-22-99	Y. G. 6-22-99
SEPT. 13,96	1	REVISED TYPO INDICATED BY REVISION MARKER	P.J.N.	MARK SOLER 9-13-96	MARK SOLER 9-13-96	VIC GUPTA 9-13-96
SEPT. 10,96	0	ISSUED FOR FABRICATION	P.J.N.	MARK SOLER 9-10-96	MARK SOLER 9-10-96	VIC GUPTA 9-10-96

REVISION

HOLTEC INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION: GENERAL ARRANGEMENT DAMAGED FUEL CONTAINER

CLIENT: LATER

COMPANION DRAWINGS: 1784

PROJECT No.: 5014
P.O. No.: LATER

DRAWING No.: 1783
REV.: 3

=\DRAWINGS\5014\5014\MPC\1783R3

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION			
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING		
DESCRIPTION: DAMAGED FUEL CONTAINER DETAILS			
CLIENT: LATER			
COMPANION DRAWINGS: 1783		PREP. BY: P.J.N. 8-12-96	
PROJECT No.: 5014	SCALE: FULL	DRAWING No.: 1784	REV.: 2
P.O. No.: LATER			SHEET:

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.

APPROVALS	DATE	
PROJ GTT/KG	9/2/83	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A [illegible]	9/2/83	D-1 CANISTER ASSEMBLY
EDO CK'D. BY	24 AUG 83	
DWN. BY PGB	05 AUG 83	

SCALE	SIZE	DWG. NO.	REV.
NONE	B	9317.1-120-2	0

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

APPROVALS	DATE	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.			
PROJ. GTT/KG	9/2/83	D-1 CANISTER LID ASSEMBLY			
Q/A	9/2/83				
CK'D. BY EDO	2 SEPT 83				
DWN. BY PGJ	02 SEP 83	1/1 SCALE	B SIZE	9317.1-120-3 DWG. NO.	1 REV.

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.

APPROVALS	DATE
PROJ. GTT/KL	9/2/83
Q/A [signature]	9/2/83
CK'D. BY EDO	
DWN. BY PGS	02 SEP 83

TRANSNUCLEAR, INC.
WHITE PLAINS, N.Y.

D-1 CANISTER BODY

SCALE	SIZE	DWG. NO.	REV.
NONE	B	9317.1-120-4	0

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.
1	05 OCT 83	SEE DCN 9317.1-120-5	PGG	EDO			

APPROVALS	DATE
PROJ. GTT/KG	9/2/83
Q/A	9/2/83
EDO CK'D. BY	
Z. DURAS DWN. BY PGG	02 SEP 83

TRANSNUCLEAR, INC.
WHITE PLAINS, N.Y.

D-1 CANISTER
BOTTOM ASSEMBLY

SCALE	SIZE	DWG. NO.	REV.
1/2	B	9317.1-120-5	1

STANPAT PRODUCTS INC. PORT WASHINGTON, N.

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.
1	11 OCT 85	SEE DCN 9317.1-120-7		EDO			KG

APPROVALS	DATE
PROJ. GTT/KG	9/2/83
Q/A	9/2/83
CK'D. BY EDO	24 AUG 83
DWN. BY Z. DURAS	8-5-83

TRANSNUCLEAR, INC.
WHITE PLAINS, N.Y.

D-1 CANISTER
LOWER LID BOX ASSY

SCALE	SIZE	DWG. NO.	REV.
1/1	B	9317.1-120-6	1

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.

APPROVALS	DATE	
PROJ. GTT/KG	9/2/83	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A [signature]	9/2/83	D-1 CANISTER BUMPER PLATE
EDO CK'D. BY	24 AUG 83	
Z. DURAS DWN. BY	8-5-83	SCALE 1/1 · SIZE B · DWG. NO. 9317.1-120-7 · REV. 0

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

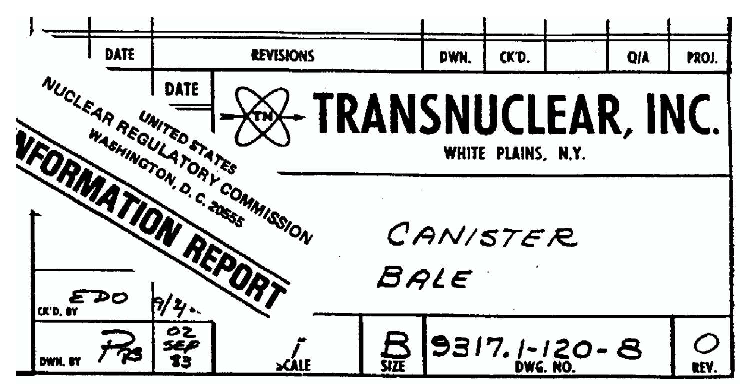


FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.
1	OCT 83	SEE DCN 9317.1-120-8	PGB	EDO		[illegible]	KG

APPROVALS	DATE	
PROJ. GTT/KG	9/2/83	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A [illegible]	9/4/83	D-1 CANISTER HANGER
CK'D. BY EDO	24 AUG 83	
DWN. BY Z. DURAS	8-5-83	

SCALE	SIZE	DWG. NO.	REV.
1/1	B	9317.1-120-9	1

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.
1	9/11/85	SEE DCN 9317.1-120-9	PGB	EDO		[signature]	KG

APPROVALS	DATE	
PROJ. GTT/KG	9/2/83	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A [signature]	9/4/83	D-1 CANISTER LID BOX
CK'D. BY EDO	24 AUG 83	
DWN. BY PGB	05 AUG 83	

SCALE	SIZE	DWG. NO.	REV.
1/2	B	9317.1-120-10	1

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.
1	03 OCT 83	SEE DCN 9317.1-120-4	[signature]	EDO		[signature]	[signature]

APPROVALS	DATE	
		TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
PROJ. GTT/KL	9/2/83	D-1 CANISTER LID FRAME
Q/A [signature]	9/2/83	
CK'D. BY EDO	9/2/83	
DWN. BY [signature]	02 SEP 83	SCALE 1/1 · SIZE B · DWG. NO. 9317.1-120-11 · RE 1

STANPAT PRODUCTS INC. PORT WASHINGTON

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.

APPROVALS	DATE	
PROJ. GTT/KG	9/2/83	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A	9/2/83	D-1 CANISTER GUIDE BAR
EDO CK'D. BY	24 AUG 83	
Z. DURAS DWN. BY	7-29-83	

SCALE	SIZE	DWG. NO.	REV.
1/1	B	9317.1-120-13	0

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.

APPROVALS	DATE	
PROJ. GTT/KG	4/2/83	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A	9/2/83	D-1 CANISTER FUEL SUPPORT PLATE
EDO CK'D. BY	9/2/83	
Z. DURAS DWN. BY	02 SEP 83	SCALE 1/1 · SIZE B · DWG. NO. 9317.1-120-14 · REV. 0

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

TRANSNUCLEAR, INC.
WHITE PLAINS, N.Y.

D-1 CANISTER
SCREEN SUPPORT PLATE

NO.	DATE	REVISIONS	DWN.	CK'D.	Q/A	PROJ.

APPROVALS	DATE
PROJ. GTT/KE	9/2/93
Q/A	9/7/93
CK'D. BY EDO	24 AUG 93
DWN. BY	18 AUG 93

SCALE 1/1 · SIZE B · DWG. NO. 9317.1-120-15 · REV. 0

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.

APPROVALS	DATE	
PROJ. GTT/KL	9/2/83	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A	9/2/83	D-1 CANISTER STRUT
CK'D. BY EDO	24 AUG 83	
DWN. BY PGS	18 AUG 83	

SCALE	SIZE	DWG. NO.	REV.
1/1	B	9317.1-120-17	0

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.
1	11 OCT 83	SEE DCN 9317-1-120-10	PGB	EDO		[signature]	KG

APPROVALS	DATE	
PROJ. GTT/KG	9/6/83	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A [signature]	9/6/83	D-1 CANISTER SCREEN
CK'D. BY EDO	6 SEPT 83	
DWN. BY Buchholtz	6 SEPT. '83	SCALE 1/1 · SIZE B · DWG. NO. 9317-120-18 · REV. 1

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.
2	9/7/84	SEE DCN 9317.1-120-38	AG	[illegible]		[illegible]	[illegible]
1	11 OCT 83	SEE DCN 9317.1-120-11	PGB	EDO		[illegible]	KG.

APPROVALS	DATE	
PROJ. GTT/KG	9/2/83	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A [illegible]	9/2/83	D-1 CANISTER THIN (INNER) WIPER
CK'D. BY EDO	24 AUG 83	
Buchholtz DWN. BY	24 AUG. '83	SCALE 1/1 · SIZE B · DWG. NO. 9317.1-120-19 · REV. 2

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ

APPROVALS	DATE	
PROJ. GTT/KG	9/2/83	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A	9/2/83	D-1 CANISTER SPACER
EDU CK'D. BY	9/2/83	
DWN. BY PCB	02 SEP 83	

SCALE	SIZE	DWG. NO.	REV
1/2	B	9317.1-120-20	C

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.

APPROVALS	DATE	
PROJ. [illegible]	2/17/84	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A		D-2/3 FUEL SPACER FOR TN-9 CASK
CK'D. BY EDO	17 FEB 84	
DWN. BY P93	20 OCT 83	

SCALE	SIZE	DWG. NO.	REV.
1/2	B	9317.1-120-21	0

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.

APPROVALS	DATE	
PROJ.	9/6/84	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A	9/6/84	D-1 CANISTER THICK WIPER
CK'D. BY	9/6/84	
DWN. BY AG	5 SEPT 84	

SCALE	SIZE	DWG. NO.	REV.
1/1	B	9317.1-120-22	0

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

APPROVALS	DATE	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.			
PROJ.	9/6/84	D-1 CANISTER LID ASSEMBLY FOR FAILED FUEL			
Q/A	9/6/84				
CK'D. BY	9/6/84				
DWN. BY AG	5 SEP 84	SCALE 1/1	SIZE B	DWG. NO. 9317.1-120-23	REV. 0

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.
1	02 NOV 84	SEE DCN 9317.1-182-5		EDO			

APPROVALS	DATE	
PROJ.	8/14/84	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A	8/14/84	THORIA ROD CANISTER ASSEMBLY
CK'D. BY EDO	9 JULY 84	
A.GALASSO DWN. BY	2 JULY 84	

SCALE	SIZE	DWG. NO.	REV.
NONE	B	9317.1-182-1	1

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.
1	8/28/84	SEE DCN 9317.1-183-2	AG	EDO			

APPROVALS	DATE	
PROJ.	8/11/84	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A	8/14/84	THORIA ROD CANISTER SPACER
CK'D. BY EDO	9 JULY 84	
DWN. BY A. GALASSO	9 JULY 84	SCALE: FULL; SIZE: B; DWG. NO.: 9317.1-182-2; REV.: 1

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.
1	8/24/84	SEE DCN 9317.1-182-1	AG	EDO		[signature]	[signature]

APPROVALS	DATE	
PROJ. [signature]	[illegible]	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A [signature]	8/14/84	THORIA ROD CANISTER SEPARATOR PLATE ASSEMBLY
CK'D. BY EDO	9 JULY 84	
A.GALASSO DWN. BY	5 JULY 84	

SCALE	SIZE	DWG. NO.	REV.
NONE	B	9317.1-182-3	1

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.
1	02 NOV 84	SEE DCN 9317.1-182-6	[illegible]	EDO		[illegible]	[illegible]

APPROVALS	DATE	
PROJ. [illegible]	8/1/84	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A [illegible]	8/14/84	THORIA ROD CANISTER RETAINING PLATE ASSEMBLY
CK'D. BY EDO	9 JULY 84	
DWN. BY A. GALASSO	5 JULY 84	SCALE: NONE; SIZE: B; DWG. NO.: 9317.1-182-4; REV.: 1

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A	PROJ.
1	8/28/84	SEE DCN 9317.1-182-3	AG	EDO			

APPROVALS	DATE	
PROJ.	8/1/84	TRANSNUCLEAR, INC. WHITE PLAINS, N.Y.
Q/A	8/14/84	THORIA ROD CANISTER RETAINING PLATE DETAILS
EDO CK'D. BY	9 JULY 84	
A.GALASSO DWN. BY	3 JULY 84	SCALE: NONE; SIZE: B; DWG. NO.: 9317.1-182-5; REV.: 1

PARTS LIST

ITEM NO	QTY	TITLE	DESCRIPTION	MATL
1	4	SEP PLATE ASSY	9317.1-182-3 REV 1	12 GA ASTM 240
2	1	SPACER	9317.1-182-2 REV 1	ASTM 240
3	1	RETAINING PLATE ASSY	9317.1-182-4 REV 1	12 GA ASTM 240
3.1	1	RETAINING PLATE	9317.1-182-5 REV 1	12 GA ASTM 240
3.2	4	RETAINING PLATE CLIP	9317.1-182-5 REV 1	12 GA ASTM 240
3.3	4	SCREW	#10-32UNC-2A FLAT HEAD SLOTTED X.62 LG	3xx SS
3.4	4	LOCKWASHER	#10	3xx SS
3.5	4	NUT	#10-32 UNC-2B HEX HEAD	3xx SS
3.6	1	BALE	9317.1-182-7, REV. 0	(SSTP 304)

NO.	DATE	REVISIONS	DWN.	CK'D.		Q/A.	PROJ.
2	02 NOV 84	SEE DCN 9317.1-182-7	PGB	EFD		[signature]	K6b-GT
~~1~~	~~8/28/84~~	~~SEE DCN 9317.1-182-4~~	~~AG~~	~~EFD~~		[signature]	[signature]

APPROVALS	DATE
PROJ [signature]	8/14/84
Q/A [signature]	8/14/84
CK'D. BY [signature]	8/14/84
A. GALASSO (DWN. BY)	9 AUG 84

TRANSNUCLEAR, INC.
WHITE PLAINS, N.Y.

THORIA ROD CANISTER
PARTS LIST

SCALE	SIZE	DWG. NO.	REV.
NONE	B	9317.1-182-6	2

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Document ID 5014354
Attachment 5

ATTACHMENT 5

PROPOSED REVISION 11 CHANGES TO THE HI-STAR 100 TOPICAL SAFETY ANALYSIS REPORT (HI-941184)

A Safety Analysis Report (SAR) has been submitted to the NRC (Docket No. 71-9261) requesting issuance of a Certificate of Compliance under provisions of 10CFR71, Subpart D [1.0.4] for the HI-STAR 100 as a Type B(U)F-85 packaging for transport by exclusive use shipment (10CFR71.47).

Within this report, all figures, tables and references cited are identified by the double decimal system m.n.i, where m is the chapter number, n is the section number, and i is the sequential number. Thus, for example, Figure 1.2.3 is the third figure in Section 1.2 of Chapter 1.

Revision of this document to Revision ~~8~~ *11* was made on a ~~subsection (e.g., 4.3 or 11.2) and appendix~~ *page level.* Therefore, if any change occurs in a ~~subsection or appendix~~ *page*, ~~the whole subsection or appendix~~ *only that page* was updated to Revision ~~8~~ *11.* ~~The sole exception is the figures, which were updated to Revision 8 only if a change was made specifically to that figure.~~ *In addition, only modified figures were updated to Revision 11.*

Table 1.0.1

TERMINOLOGY AND NOTATION

ALARA is an acronym for As Low As Reasonably Achievable.

Boral is a generic term to denote an aluminum-boron carbide cermet manufactured in accordance with U.S. Patent No. 4027377. The individual material supplier may use another trade name to refer to the same product.

Boral™ means Boral manufactured by AAR Advanced Structures.

BWR is an acronym for boiling water reactor.

C.G. is an acronym for center of gravity.

Confinement Boundary means the outline formed by the sealed, cylindrical enclosure of the multi-purpose canister (MPC) shell welded to a solid baseplate, a lid welded around the top circumference of the shell wall, the port cover plates welded to the lid, and the closure ring welded to the lid and MPC shell.

Confinement System means the HI-STAR 100 multi-purpose canister (MPC) which encloses and confines the spent nuclear fuel during storage.

Controlled Area means that area immediately surrounding an ISFSI for which the owner/user exercises authority over its use and within which operations are performed.

DBE means Design Basis Earthquake.

DCSS is an acronym for Dry Cask Storage System.

Damaged Fuel Assembly is defined as a fuel assembly with known or suspected cladding defects, *as determined by a review of records,* greater than pinhole leaks ~~and~~ *or* hairline cracks, ~~or~~ missing fuel rods that are not replaced with dummy fuel rods, ~~and which may have mechanical damage which would not allow it to be handled by normal means; however, there shall be no loose components.~~ *or those that cannot be handled by normal means. Fuel assemblies which cannot be handled by normal means due to fuel cladding damage are considered fuel debris.*

Damaged Fuel Container means a specially designed enclosure for damaged fuel or fuel debris which permits gaseous and liquid media to escape while minimizing dispersal of gross particulates. *DFCs authorized for use in the HI-STAR 100 System are the Holtec design or the Transnuclear Dresden Unit 1 design as shown on the applicable design drawings in Section 1.5.*
~~The Damaged Fuel Container (DFC) features a lifting location which is suitable for remote handling of a loaded or unloaded DFC.~~

Table 1.0.1 (continued)

TERMINOLOGY AND NOTATION

Enclosure Vessel means the pressure vessel defined by the cylindrical shell, baseplate, port cover plates, lid, and closure ring which provides confinement for the helium gas contained within the MPC. The Enclosure Vessel (EV) and the fuel basket together constitute the multi-purpose canister.

Fuel Basket means a honeycomb structural weldment with square openings which can accept a fuel assembly of the type for which it is designed.

Fuel Debris is defined as ~~a fuel assembly with known or suspected cladding defects greater than pinhole leaks and hairline cracks such as~~ ruptured fuel rods, severed fuel rods, ~~or~~ loose fuel pellets, ~~and~~ *or fuel assemblies with known or suspected defects* which cannot be handled by normal means *due to fuel cladding damage.*

Helium Retention Boundary means the enclosure formed by the overpack inner shell welded to a bottom plate and top main flange plus the bolted closure plate and port plugs with metallic seals. The helium retention boundary is an additional independent confinement boundary, however, no credit is taken for this additional barrier. The helium retention boundary maintains an inert helium atmosphere around the MPC.

HI-STAR 100 MPC means the sealed spent nuclear fuel container which consists of a honeycombed fuel basket contained in a cylindrical canister shell which is welded to a baseplate, lid with welded port cover plates, and closure ring. MPC is an acronym for multi-purpose canister. There are different MPCs with different fuel basket geometries for storing PWR or BWR fuel, but all MPCs have identical exterior dimensions. The MPC is the confinement boundary for storage conditions.

HI-STAR 100 overpack or overpack means the cask which receives and contains the sealed multi-purpose canisters containing spent nuclear fuel. It provides the retention boundary for the helium atmosphere, gamma and neutron shielding, and a set each of lifting and pocket trunnions. It is not defined as the confinement boundary for the radioactive material during storage.

HI-STAR 100 System consists of the HI-STAR 100 MPC sealed within the HI-STAR 100 overpack.

Holtite™ is a trade name denoting an approved neutron shield material for use in the HI-STAR 100 System. In this application, Holtite-A is the only approved neutron shield material.

Holtite™-A is a commercially available neutron shield material developed by Bisco, Inc., and currently sold under the trade name NS-4-FR. The neutron shield material is specified with a ~~minimum~~ *nominal* B_4C loading of 1 weight percent. An equivalent neutron shield material with equivalent neutron shielding properties and composition, but not sold under the trade name NS-4-FR, may be used.

Table 1.0.1 (continued)

TERMINOLOGY AND NOTATION

Important to Safety (ITS) means a function or condition required to store spent nuclear fuel safely; to prevent damage to spent nuclear fuel during handling and storage, and to provide reasonable assurance that spent nuclear fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

Independent Spent Fuel Storage Installation (ISFSI) means a facility designed, constructed, and licensed for the interim storage of spent nuclear fuel and other radioactive materials associated with spent fuel storage in accordance with 10CFR72.

Intact Fuel Assembly is defined as a fuel assembly without known or suspected cladding defects greater than pinhole leaks and hairline cracks, and which can be handled by normal means. *Partial fuel assemblies, that is fuel assemblies from which fuel rods are missing, shall not be classified as intact fuel assemblies unless dummy fuel rods used to displace an amount of water greater than or equal to that displaced by the original fuel rod(s).*

Maximum Reactivity means the highest possible k-effective including bias, uncertainties, and calculational statistics evaluated for the worst-case combination of fuel basket manufacturing tolerances.

MGDS is an acronym for Mined Geological Depository System.

Multi-Purpose Canister (MPC) means the sealed canister which consists of a honeycombed fuel basket for spent nuclear fuel storage, contained in a cylindrical canister shell which is welded to a baseplate, lid with welded port cover plates, and closure ring. There are different MPCs with different fuel basket geometries for storing PWR or BWR fuel, but all MPCs have identical exterior dimensions. The MPC is the confinement boundary for storage conditions. MPC is an acronym for multi-purpose canister. The MPCs used as part of the HI-STORM 100 System (Docket No. 72-1014) are identical to the HI-STAR 100 MPCs evaluated in the HI-STAR 100 storage (Docket No. 72-1008) and transport (Docket No. 71-9261) applications.

MPC Fuel Basket means the honeycombed composite cell structure utilized to maintain subcriticality of the spent nuclear fuel. The number and size of the storage cells depends on the type of spent nuclear fuel to be stored. Each MPC fuel basket has sheathing welded to the storage cell walls for retaining the Boral neutron absorber. Boral is a commercially-available thermal neutron poison material composed of boron carbide and aluminum.

Neutron Shielding means Holtite, a material used in the HI-STAR overpack to thermalize and capture neutrons emanating from the radioactive spent nuclear fuel.

PWR is an acronym for pressurized water reactor.

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM TSAR REGULATORY COMPLIANCE
CROSS-REFERENCE MATRIX

Regulatory Guide 3.61 Section and Content	Associated NUREG-1536 Review Criteria	Applicable 10CFR72 or 10CFR20 Requirement	HI-STAR TSAR
6.4.2 Fuel Loading or Other Contents Loading Optimization	6.V.3.a Configuration	--	6.4.2
6.4.3 Criticality Results	6.IV Acceptance Criteria	10CFR72.24(d) 10CFR72.124 10CFR72.236(c)	6.1, 6.2, 6.3.1, 6.3.2
6.5 Critical Benchmark Experiments	6.V.4.c Benchmark Comparisons	--	6.5, Appendix 6.A, 6.4.3
6.6 Supplemental Data	6.V.5 Supplemental Info.	--	Appendices 6.B, 6.C, and 6.D
7. Confinement			
7.1 Confinement Boundary	7.III.1 Description of Structures, Systems, and Components Important to Safety	10CFR72.24(c)(3) 10CFR72.24(l)	7.0, 7.1
7.1.1 Confinement Vessel	7.III.2 Protection of Spent Fuel Cladding	10CFR72.122(h)(l)	7.1, 7.1.1, 7.2.2
7.1.2 Confinement Penetrations	--	--	7.1.2
7.1.3 Seals and Welds	--	--	7.1.3
7.1.4 Closure	7.III.3 Redundant Sealing	10CFR72.236(e)	7.1.1, 7.1.4
7.2 Requirements for Normal Conditions of Storage	7.III.7 Evaluation of Confinement System	10CFR72.24(d) 10CFR72.236(l)	7.2

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM TSAR REGULATORY COMPLIANCE
CROSS-REFERENCE MATRIX

Regulatory Guide 3.61 Section and Content	Associated NUREG-1536 Review Criteria	Applicable 10CFR72 or 10CFR20 Requirement	HI-STAR TSAR
7.2.1 Release of Radioactive Material	7.III.6 Release of Nuclides to the Environment	10CFR72.24(~~i~~l)(1)	7.2.1
	7.III.4 Monitoring of Confinement System	10CFR72.122(h)(4) 10CFR72.128(a)(l)	7.1.4
	7.III.5 Instrumentation	10CFR72.24(l) 10CFR72.122(i)	7.1.4
	7.III.8 Annual Dose	10CFR72.104(a)	7.3.5
7.2.2 Pressurization of Confinement Vessel	--	--	7.2.2
7.3 Confinement Requirements for Hypothetical Accident Conditions	7.III.7 Evaluation of Confinement System	10CFR72.24(d) 10CFR72.122(b) 10CFR72.236(l)	7.3
7.3.1 Fission Gas Products	--	--	7.3.1
7.3.2 Release of Contents	--	--	7.3.3
NA	--	10CFR72.106(b)	7.3
7.4 Supplemental Data	7.V Supplemental Info.	--	--

1.2 GENERAL DESCRIPTION AND OPERATING FEATURES OF HI-STAR 100

1.2.1 System Characteristics

The complete HI-STAR 100 System for storage of spent nuclear fuel is comprised of two discrete components:

- the multi-purpose canister (MPC), and
- the storage/transport overpack

Necessary auxiliaries required to deploy the HI-STAR 100 System for storage are:

- lifting and handling systems
- welding equipment
- vacuum drying system and helium backfill system with leak detector
- a heavy haul transfer device (to move the cask from the fuel building to the cask pad)

The HI-STAR 100 System consists of interchangeable MPCs which constitute the confinement boundary for BWR or PWR spent nuclear fuel, and an overpack which provides the helium retention boundary. Tables 1.2.1 and 1.2.2 contain the key parameters for the HI-STAR 100 MPCs. Figure 1.2.1 provides a cross sectional elevation view of the HI-STAR 100 System in storage.

All MPCs have identical exterior dimensions which render them interchangeable. The outer diameter of the MPC is *nominally* 68-3/8 inches and the length is *approximately* 190-1/2 inches. Due to the differing storage contents of each of the MPCs, the maximum loaded weight differs between each MPC. However, the maximum weight of a loaded MPC is approximately 44-1/2 tons.

A single overpack design is provided which is capable of storing each type of MPC. The inner diameter of the overpack is *approximately* 68-3/4 inches and the height of the cavity is *nominally* 191-1/8 inches. The overpack inner cavity is sized to accommodate the MPCs. The outer diameter of the overpack is *approximately* 96 inches and the height is *approximately* 203-1/8 inches. The weight of the overpack without an MPC is approximately 77 tons.

Before proceeding to present detailed physical data on the HI-STAR 100 System, it is contextual to summarize the design attributes which set it apart from the prior generation of casks. There are several features in the HI-STAR 100 System design which increase its effectiveness with respect to the safe storage and transport of spent nuclear fuel (SNF). Some of the principal features of the HI-STAR 100 System which enhance its effectiveness as an SNF storage device and a safe SNF confinement structure are:

- the honeycomb design of the MPC fuel basket

The construction features of the PWR MPC-24 and the BWR MPC-68 are similar. However, the PWR MPC-24 canister in Figure 1.2.4, which is designed for highly enriched PWR fuel without credit for soluble boron, differs in construction from the MPC-68 in one important aspect: The fuel storage cells are physically separated from one another by a "flux trap" between each storage cell for criticality control. All MPC baskets are formed from an array of plates welded to each other, such that a honeycomb structure is created which resembles a multiflanged, closed-section beam in its structural characteristics.

The MPC fuel basket is positioned and supported within the MPC shell by a basket support structure welded to the inside of the MPC shell. Between the periphery of the basket, the MPC shell, and the basket supports, heat conduction elements are installed. These heat conduction elements are fabricated from thin aluminum alloy 1100 in shapes *and a design* which allow ~~sufficient flexibility to enable~~ a snug fit in the confined spaces and ~~for~~ ease of installation. The heat conduction elements are installed along the full length of the MPC basket, *except at the drain pipe location,* to create a nonstructural thermal connection which facilitates heat transfer from the basket to shell. In their ~~installed~~ *operating* condition, the heat conduction elements will conform to and contact the MPC shell and basket walls.

Lifting lugs attached to the inside surface of the MPC canister shell serve to permit lifting and placement of the empty MPC into the overpack. The lifting lugs also serve to axially locate the lid prior to welding. These internal lifting lugs are not used to handle a loaded MPC. Since the MPC lid is installed prior to any handling of the loaded MPC, there is no access to the lifting lugs once the MPC is loaded.

The top end of the HI-STAR 100 MPC incorporates a redundant closure system. Figure 1.2.6 provides a sketch of the MPC closure details. The MPC lid is a circular plate edge-welded to the MPC outer shell. This plate is equipped with vent and drain ports which are utilized to remove moisture and air from the MPC, and backfill the MPC with a specified ~~mass~~ *pressure* of inert gas (helium). The vent and drain ports are covered and welded before the closure ring is installed. The closure ring is a circular ring edge-welded to the MPC shell and lid. The MPC lid provides sufficient rigidity to allow the entire MPC loaded with SNF to be lifted by threaded holes in the MPC lid.

To maintain a constant exterior axial length between the MPC-24 and MPC-68, the thickness of the MPC-24 lid is a ½ inch thinner than the MPC-68 lid to accomodate the longest PWR fuel assembly which is approximately a ½ inch longer than the longest BWR fuel assembly. For fuel assemblies that are shorter than the design basis length, upper and lower fuel spacers (as appropriate) maintain the axial position of the fuel assembly within the MPC basket. The upper fuel spacers are threaded into the underside of the MPC lid as shown in Figure 1.2.5. The lower fuel spacers are placed in the bottom of each fuel basket cell. The upper and lower fuel spacers are designed to withstand normal, off-normal, and accident conditions of storage. An axial clearance of approximately 2 inches is provided to account for the irradiation and thermal growth of the fuel assemblies. The *suggested values for the* upper and lower fuel spacer lengths are listed in Tables 2.1.9 and 2.1.10 for each fuel assembly type.

The MPC is constructed entirely from stainless steel alloy materials (except for the neutron absorber and aluminum heat conduction elements). No carbon steel parts are permitted in the MPC. Concerns stipulated minimum loading. Furthermore, the surveillance, coupon testing, and material tracking processes which have so effectively controlled the quality of Boral are expected to continue to yield Boral of similar quality in the future. Nevertheless, to add another layer of insurance, only 75% ^{10}B credit of the fixed neutron absorber is assumed in the criticality analysis in compliance with Chapter 6.0, IV, 4.c of NUREG-1536, Standard Review Plan for Dry Cask Storage Systems.

1.2.1.3.2 Holtite™ Neutron Shielding

The specification of the overpack neutron shield material is predicated on functional performance criteria. These criteria are:

- Attenuation of neutron radiation and associated neutron capture to appropriate levels;
- Durability of the shielding material under normal conditions, in terms of thermal, chemical, mechanical, and radiation environments;
- Stability of the homogeneous nature of the shielding material matrix;
- Stability of the shielding material in mechanical or thermal accident conditions to the desired performance levels; and
- Predictability of the manufacturing process under adequate procedural control to yield an in-place neutron shield of desired function and uniformity.

Other aspects of a shielding material, such as ease of handling and prior nuclear industry use, are also considered, within the limitations of the main criteria. Final specification of a shield material is a result of optimizing the material properties with respect to the main criteria, along with the design of the shield system, to achieve the desired shielding results.

In the current submittal, Holtite-A is the only approved neutron shield material which fulfills the aforementioned criteria. Holtite-A is a poured-in-place solid borated synthetic neutron-absorbing polymer. Holtite-A is a commercially available neutron shield material under the trade name NS-4-FR and is specified with a ~~minimum~~ *nominal* B_4C loading of 1 weight percent for the HI-STAR 100 System. Appendix 1.B provides the Holtite-A material properties. Holtec has performed confirmatory qualification tests on Holtite-A under the company's QA program.

In the following, a brief summary of the performance characteristics and properties of Holtite-A is provided.

Density

The specific gravity of Holtite-A is 1.68 g/cm^3 as specified in Appendix 1.B. To conservatively bound any potential weight loss at the design temperature and any inability to reach the theoretical density, the density is reduced by 4% to 1.61 g/cm^3. The density used for the shielding analysis is conservatively assumed to be 1.61 g/cm^3 to underestimate the shielding capabilities of the neutron shield.

Hydrogen

The weight concentration of hydrogen is 6.0%. However, all shielding analyses conservatively assume 5.9% hydrogen by weight in the calculations.

Boron Carbide

Boron carbide dispersed within Holtite-A in finely dispersed powder form is present in 1% ~~(minimum)~~ weight concentration. Holtite-A may be specified with a B_4C content of up to 6.5 weight percent. For the HI-STAR 100 System, Holtite-A is specified with a ~~minimum~~ *nominal* B_4C weight percent of 1%.

Design Temperature

The design temperature of Holtite-A is set at 300°F. The maximum spatial temperature of Holtite-A under all normal operating conditions must be demonstrated to be below this design temperature.

Thermal Conductivity

It is evident from Figure 1.2.9 that Holtite-A is directly in the path of heat transmission from the inside of the overpack to its outside surface. For conservatism, however, the design basis thermal conductivity of Holtite-A under heat rejection conditions is set equal to zero. The reverse condition occurs under a postulated fire event when the thermal conductivity of Holtite-A aids in the influx of heat to the stored fuel in the fuel basket. The thermal conductivity of Holtite-A is conservatively set at 1 Btu/hr-ft-°F for all fire event evaluations.

The Holtite-A neutron shielding material is stable below the design temperature for long-term use and provides excellent shielding properties for neutrons. Technical papers provided in Appendix 1.B validate the neutron shield material's long-term stability within the design temperature and the material's ability to resist the effects of a fire accident. Holtite-A has been utilized in similar applications and has been licensed for use in a transportation cask under Docket No. 71-9235.

1.2.1.3.3 Gamma Shielding Material

For gamma shielding, HI-STAR 100 utilizes carbon steel in plate stock form. Instead of utilizing a thick forging, the gamma shield design in the HI-STAR 100 overpack borrows from the concept of layered vessels from the field of ultra-high pressure vessel technology. The shielding is made from successive layers of plate stock. The fabrication of the shell begins by rolling the inner shell plate and making the longitudinal weld seam. Each layer of the intermediate shells are constructed from two halves. The two halves of the shell shall be precision sheared, bevelled, and rolled to the construction with a long proven history in the nuclear industry and specifying materials known to withstand their operating environments with little to no degradation. A maintenance program, as specified in Chapter 9, is also implemented to ensure the HI-STAR 100 System will exceed its design life of 40 years. The design considerations that assure the HI-STAR 100 System performs as designed throughout the service life include the following:

HI-STAR Overpack

- Exposure to Environmental Effects
- Material Degradation
- Maintenance and Inspection Provisions

MPC

- Corrosion
- Structural Fatigue Effects
- Maintenance of Helium Atmosphere
- Allowable Fuel Cladding Temperatures
- Neutron Absorber Boron Depletion

The adequacy of the HI-STAR 100 System for its design life is discussed in Sections 3.4.10 and 3.4.11.

1.2.2 Operational Characteristics

1.2.2.1 Design Features

The HI-STAR 100 System is engineered to store different types of MPCs for varying PWR and BWR fuel characteristics.

The HI-STAR 100 System can safely store spent nuclear fuel with minimum cooling times. The maximum thermal decay heat load and SNF enrichments for each of the MPCs are identified in Chapter 2. The decay heat emitted by the spent nuclear fuel is dissipated in an entirely passive mode without any mechanical or forced cooling.

Both the free volume of the HI-STAR 100 MPCs and the annulus between the external surface of the MPC and the inside surface of the overpack are inerted with 99.995% pure helium gas during the spent nuclear fuel loading operations. Table 1.2.2 specifies the helium ~~fill mass~~ *pressure* to be placed in the MPC internal cavity ~~as a function of the free volume. As instructed in the operating procedures of Chapter 8, the water drained from the loaded MPC is measured to determine the free volume in the MPC internal cavity with fuel. As a fill pressure is highly dependent on the MPC internal temperature, which increases over time because of the decay heat coupled by the vacuum drying process, it is more accurate to measure the mass placed in the MPC internal cavity rather than pressure.~~

The primary heat transfer mechanisms are metal conduction and surface radiation for the HI-STAR 100 System. The MPC internal helium atmosphere, in addition to providing a noncorrosive dry atmosphere for the fuel cladding, provides for heat transfer through helium conduction. The most adverse temperature profiles and thermal gradients for the HI-STAR 100 System with each of the MPCs are discussed in detail in Chapter 4.

The criticality control features of the HI-STAR 100 are designed to maintain the neutron multiplication factor k-effective (including uncertainties and calculational bias) at less than 0.95 under all normal, off-normal, and accident conditions of storage as analyzed in Chapter 6.

1.2.2.2 Sequence of Operations

Table 1.2.6 provides the basic sequence of operations necessary to defuel a spent fuel pool using the HI-STAR 100 System. The detailed sequence of steps for storage-related loading and handling operations is provided in Chapter 8 and is supported by the Design Drawings in Section 1.5. A summary of ~~the~~ *general actions needed for the* loading and unloading operations is provided below. Figures 1.2.11 and 1.2.12 provide a pictorial view of the loading and unloading operations, respectively.

Loading Operations

At the start of loading operations, the overpack is configured with the closure plate removed. The lift yoke is used to position the overpack in the designated preparation area or setdown area for overpack inspection and MPC insertion. The annulus is filled with plant demineralized water and an inflatable annulus seal is installed. The inflatable seal prevents contact between spent fuel pool water and the MPC shell reducing the possibility of contaminating the outer surfaces of the MPC. The MPC is then filled with spent fuel pool water or plant demineralized water. The overpack and MPC are lowered into the spent fuel pool for fuel loading using the lift yoke. Pre-selected assemblies are loaded into the MPC and a visual verification of the assembly identification is performed.

While still underwater, a thick shielding lid (the MPC lid) is installed. The lift yoke is remotely engaged to the overpack lifting trunnions and is used to lift the overpack close to the spent fuel pool surface. As an ALARA measure, dose rates are measured on the top of the overpack and MPC prior to removal from the pool to check for activated debris on the top surface. The MPC lift bolts (securing the MPC lid to the lift yoke) are removed. As the overpack is removed from the spent fuel pool, the lift yoke and overpack are sprayed with demineralized water to help remove contamination.

The overpack is removed from the pool and placed in the designated preparation area. The top surfaces of the MPC lid and the top flange of the overpack are decontaminated. The inflatable annulus seal is removed, and an annulus shield is installed. The annulus shield provides additional personnel shielding at the top of the annulus and also prevents small items from being dropped into the annulus. Dose rates are measured to ensure that the dose rates are within expected values. The Automated Welding System baseplate shield is installed to reduce dose rates around the top of the cask. The MPC water level is lowered slightly and the MPC lid is seal-welded using the Automated Welding System (AWS). Liquid penetrant examinations are performed on the root and final passes.

A volumetric (or multi-layer liquid penetrant) examination is also performed on the MPC lid-to-shell weld. The water level is raised to the top of the MPC and the weld is hydrostatically tested. Then a small volume of the water is displaced with helium gas. The helium gas is used for leakage testing. A helium leakage rate test is performed on the MPC lid confinement weld (lid-to-shell) to verify weld integrity and to ensure that required leakage rates are within acceptance criteria. The ~~water level is raised to the top of the MPC again and then the~~ MPC water is displaced from the MPC by blowing pressurized helium or nitrogen gas into the vent port of the MPC, thus displacing the water through the drain line. ~~The volume of water displaced from the MPC is measured to determine the free volume inside the MPC. This information is used to determine the helium backfill requirements for the MPC.~~

The Vacuum Drying System (VDS) is connected to the MPC and is used to remove all residual water from the MPC in a stepped evacuation process. The stepped evacuation process is used to preclude the formation of ice in the MPC and VDS lines. The internal pressure is reduced and held for a duration to ensure that all liquid water has evaporated.

Following this dryness test, the VDS is disconnected, the Helium Backfill System (HBS) is attached, and the MPC is backfilled with a predetermined amount of helium gas. The helium backfill ensures adequate heat transfer during storage, provides an inert atmosphere for long-term fuel integrity, and provides the means of future leakage rate testing of the MPC confinement boundary welds. Cover plates are installed and seal-welded over the MPC vent and drain ports with liquid penetrant examinations performed on the root and final passes. The cover plates are helium leakage tested to confirm that they meet the established leakage rate criteria.

The MPC closure ring is then placed on the MPC, aligned, tacked in place, and seal welded, providing redundant closure of the MPC confinement cavity closure welds. Tack welds are visually examined, and the root and final welds are inspected using the liquid penetrant examination technique to ensure weld integrity. The annulus shield is removed and the remaining water in the annulus is drained. The AWS Baseplate shield is removed. The MPC lid and accessible areas of the top of the MPC shell are smeared for removable contamination and overpack dose rates are measured. The overpack closure plate is installed and the bolts are torqued. The overpack annulus is dried using the VDS, and backfilled with helium gas for heat transfer and seal testing. Concentric metallic seals in the overpack closure plate prevent the leakage of the helium gas from the annulus and provide an additional confinement boundary to the release of radioactive materials. The seals on the overpack vent and drain port plugs are leak tested along with the overpack closure plate inner seal. Cover plates with metallic seals are installed over the overpack vent and drain ports to provide redundant closure of the overpack penetrations. A port plug with a metallic seal is installed in the overpack closure plate test port to provide fully-redundant closure of all potential leakage paths in the overpack penetrations.

The overpack is secured to the transporter and moved to the ISFSI pad. The overpack may be moved using a number of methods as long as the handling height limitations listed in the Technical Specifications are not exceeded.

The HI-STAR 100 System can also be remotely loaded at a specially-designed dry loading facility

~~At this time, failed fuel assemblies discharged from Dresden Unit 1 and Humboldt Bay reactors have been evaluated and this application requests approval of these two types of damaged fuel assemblies and fuel debris as contents for storage in the MPC-68.~~ *Fuel assemblies classified as damaged fuel or fuel debris (assembly array/class 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A as specified in Table 1.2.11) have been evaluated.* Damaged fuel assemblies and fuel debris shall be placed in damaged fuel containers (see Figure 1.2.10) prior to loading into the MPC to facilitate handling and contain loose components. Damaged fuel assemblies in damaged fuel containers may be stored in the standard MPC-68. The MPC-68 design to store fuel debris is identical to the MPC-68 design to store intact or damaged fuel. The sole additional restriction imposed on an MPC-68 to load damaged fuel containers with fuel assemblies classified as fuel debris is a stricter leakage rate criteria prior to shipment. Therefore, an MPC-68 which is to store damaged fuel containers with fuel assemblies classified as fuel debris must be designated during fabrication to ensure the proper leakage rate criteria is applied. To distinguish an MPC-68 which is fabricated to store damaged fuel containers with fuel assemblies classified as fuel debris, the MPC shall be designated as an "MPC-68F".

Up to 4 damaged fuel containers ~~with Dresden 1 and Humboldt Bay zircaloy clad BWR fuel assemblies classified as~~ *containing specified* fuel debris may be stored within an MPC-68F. The quantity of damaged fuel containers with fuel debris is limited to meet the off-site transportation requirements of 10CFR71, specifically, 10CFR71.63(b).

Table 1.2.2
KEY PARAMETERS FOR HI-STAR 100 MULTI-PURPOSE CANISTERS

	PWR	BWR
Pre-disposal service life (years)	40	40
Design temperature, max./min. (°F)	725°†/-40°††	725°†/-40°††
Design internal pressure (psig) Normal conditions Off-normal conditions Accident Conditions	 100 100 125	 100 100 125
Total heat load, max. (kW)	19.0 (MPC-24)	18.5 (MPC-68)
Maximum permissible peak fuel cladding temperature: Normal (°F) Short Term & Accident (°F)	 See Table 2.2.3 1058°	 See Table 2.2.3 1058°
MPC internal environment Helium fill (~~g-moles/l of free space~~ *psig*)	 ~~0.1212 (MPC-24)~~ *≤ 22.2*	 ~~0.1218 (MPC-68)~~ *≤ 28.5*
MPC external environment/overpack internal pressure Helium fill initial pressure (psig, at STP)	 10	 10
Maximum permissible reactivity including all uncertainties and biases	<0.95	<0.95
Boral ^{10}B Areal Density (g/cm^2)	0.0267 (MPC-24)	0.0372 (MPC-68) 0.01 (MPC-68F)
End closure(s)	Welded	Welded
Fuel handling	Opening compatible with standard grapples	Opening compatible with standard grapples
Heat dissipation	Passive	Passive

† Maximum normal condition design temperature for the MPC fuel basket. A complete listing of design temperatures for all components is provided in Table 2.2.3.

†† Temperature based on off-normal minimum environmental temperatures specified in Table 2.2.2 and no fuel decay heat load.

1.5 GENERAL ARRANGEMENT DRAWINGS and BILLS-OF-MATERIAL

The following detailed HI-STAR 100 System design drawings are provided in this section:

Drawing Number/Sheet	Description	Rev.
5014-1395 Sht 1/4	HI-STAR 100 MPC-24 Construction	1~~0~~*1*
5014-1395 Sht 2/4	HI-STAR 100 MPC-24 Construction	~~9~~*10*
5014-1395 Sht 3/4	HI-STAR 100 MPC-24 Construction	~~9~~*10*
5014-1395 Sht 4/4	HI-STAR 100 MPC-24 Construction	~~8~~*9*
5014-1396 Sht 1/6	HI-STAR 100 MPC-24 Construction	1~~2~~*3*
5014-1396 Sht 2/6	HI-STAR 100 MPC-24 Construction	~~9~~*10*
5014-1396 Sht 3/6	HI-STAR 100 MPC-24 Construction	~~9~~*10*
5014-1396 Sht 4/6	HI-STAR 100 MPC-24 Construction	~~8~~*9*
5014-1396 Sht 5/6	HI-STAR 100 MPC-24 Construction	8
5014-1396 Sht 6/6	HI-STAR 100 MPC-24 Construction	~~7~~*8*
5014-1397 Sht 1/7	Cross Sectional View of HI-STAR 100 Overpack	1~~5~~*6*
5014-1397 Sht 2/7	Detail of Top Flange & Bottom Plate of HI-STAR 100 Overpack	1~~0~~*1*
5014-1397 Sht 3/7	Detail of Bolt Hole & Bolt of HI-STAR 100 Overpack	1~~0~~*1*
5014-1397 Sht 4/7	Detail of Closure Plate Test Port and Name Plate Detail of HI-STAR 100 Overpack	1~~1~~*2*
5014-1397 Sht 5/7	Detail of Lifting Trunnion & Locking Pad of HI-STAR 100 Overpack	~~8~~*9*
5014-1397 Sht 6/7	Detail of Shear Ring and Closure Plate Bolt Installation of HI-STAR 100 Overpack	~~8~~*9*
5014-1397 Sht 7/7	Detail of Shear Ring of HI-STAR 100 Overpack	~~8~~*9*
5014-1398 Sht 1/3	HI-STAR 100 Overpack Orientation	1~~2~~*3*
5014-1398 Sht 2/3	Detail of Drain & Rupture Disk of HI-STAR 100 Overpack	~~9~~*10*

Drawing Number/Sheet	Description	Rev.
5014-1398 Sht 3/3	Detail of Vent & Port Plug of HI-STAR 100 Overpack	~~8~~9
5014-1399 Sht 1/3	Section "G" - "G" of HI-STAR 100 Overpack	1~~1~~2
5014-1399 Sht 2/3	Section "X"-"X" & View "Y" of HI-STAR 100 Overpack	~~8~~9
5014-1399 Sht 3/3	Detail of Trunnion Pocket Forging of HI-STAR 100 Overpack	1~~0~~1
5014-1401 Sht 1/4	HI-STAR 100 MPC-68 Construction	1~~1~~2
5014-1401 Sht 2/4	HI-STAR 100 MPC-68 Construction	~~8~~9
5014-1401 Sht 3/4	HI-STAR 100 MPC-68 Construction	~~9~~10
5014-1401 Sht 4/4	HI-STAR 100 MPC-68 Construction	~~8~~9
5014-1402 Sht 1/6	HI-STAR 100 MPC-68 Construction	1~~3~~4
5014-1402 Sht 2/6	HI-STAR 100 MPC-68 Construction	1~~1~~2
5014-1402 Sht 3/6	HI-STAR 100 MPC-68 Construction	1~~1~~2
5014-1402 Sht 4/6	HI-STAR 100 MPC-68 Construction	~~9~~10
5014-1402 Sht 5/6	HI-STAR 100 MPC-68 Construction	9
5014-1402 Sht 6/6	HI-STAR 100 MPC-68 Construction	~~7~~8
5014-1763 Sht 1/1	HI-STAR 100 Assembly	3
5014-1783 Sht 1/1	General Arrangement Damaged Fuel Container	~~1~~3
5014-1784 Sht 1/1	Damaged Fuel Container Details	~~0~~2
BM-1476, Sht 1/2	Bills-of-Material for HI-STAR 100 Overpack	1~~2~~3
BM-1476, Sht 2/2	Bills-of-Material for HI-STAR 100 Overpack	1~~4~~5
BM-1478, Sht 1/2	Bills-of-Materials for 24-Assembly HI-STAR 100 PWR MPC	~~9~~10
BM-1478, Sht 2/2	Bills of Material for 24-Assembly HI-STAR 100 PWR MPC	1~~1~~2
BM-1479, Sht 1/2	Bills-of-Material for 68-Assembly HI-STAR 100 BWR MPC	1~~0~~1

Drawing Number/Sheet	Description	Rev.
BM-1479, Sht 2/2	Bills-of-Material for 68-Assembly HI-STAR 100 BWR MPC	1~~3~~4
BM-1819, Sht 1/1	Bills-of-Materials for HI-STAR 100 System Failed Fuel Canister	~~1~~2
9317.1-120-2	*D-1 Canister Assembly*	*0*
9317.1-120-3	*D-1 Canister Lid Assembly*	*1*
9317.1-120-4	*D-1 Canister Body*	*0*
9317.1-120-5	*D-1 Canister Bottom Assembly*	*1*
9317.1-120-6	*D-1 Canister Lower Lid Box Assy*	*1*
9317.1-120-7	*D-1 Canister Bumper Plate*	*0*
9317.1-120-8	*D-1 Canister Bale*	*0*
9317.1-120-9	*D-1 Canister Hanger*	*1*
9317.1-120-10	*D-1 Canister Lid Box*	*1*
9317.1-120-11	*D-1 Canister Lid Frame*	*1*
9317.1-120-13	*D-1 Canister Guide Bar*	*0*
9317.1-120-14	*D-1 Canister Fuel Support Plate*	*0*
9317.1-120-15	*D-1 Canister Screen Support Plate*	*0*
9317.1-120-17	*D-1 Canister Strut*	*0*
9317.1-120-18	*D-1 Canister Screen*	*1*
9317.1-120-19	*D-1 Canister Thin (Inner) Wiper*	*2*
9317.1-120-20	*D-1 Canister Spacer*	*0*
9317.1-120-21	*D-2/3 Fuel Spacer for TN-9 Cask*	*0*
9317.1-120-22	*D-1 Canister Thick Wiper*	*0*
9317.1-120-23	*D-1 Canister Lid Assembly For Failed Fuel*	*0*
9317.1-182-1	*Thoria Rod Canister Assembly*	*1*
9317.1-182-2	*Thoria Rod Canister Spacer*	*1*

Drawing Number/Sheet	Description	Rev.
9317.1-182-3	*Thoria Rod Canister Separator Plate Assembly*	*1*
9317.1-182-4	*Thoria Rod Canister Retaining Plate Assembly*	*1*
9317.1-182-5	*Thoria Rod Canister Retaining Plate Details*	*1*
9317.1-182-6	*Thoria Rod Canister Parts List*	*2*

Table 1.B.1

PROPERTIES OF HOLTITE-A NEUTRON SHIELD

PHYSICAL PROPERTIES (Reference: NAC International Brochure)	
% ATH	62 maximum (confirmed by Holtec in independent analyses)
Specific Gravity	1.68 g/cc ~~maximum~~ *nominal*
Thermal Conductivity	0.373 Btu/hr/ft-°F
Max. Continuous Operating Temperature	300°F
Specific Heat†	0.39 Btu/lb-°F
Hydrogen Density	0.096 g/cc minimum (confirmed by Holtec in independent analyses)
Radiation Resistance	Excellent
Ultimate Tensile Strength	4,250 psi
Tensile elongation	0.65%
Ultimate Compression Strength	10,500 psi
Compression Yield Strength	8,780 psi
Compression Modulus	561,000 psi
CHEMICAL PROPERTIES (Nominal)	
wt% Aluminum	21.5 (confirmed by Holtec)
wt% Hydrogen	6.0 (confirmed by Holtec)
wt% Carbon	27.7
wt% Oxygen	42.8
wt% Nitrogen	2.0
wt% B_4C	up to 6.5 (Holtite-A uses 1% B_4C)

† BISCO Products Data from Docket M-55, NAC-STC TSAR.

APPENDIX 1.C: MISCELLANEOUS MATERIAL DATA (Total of 8 Pages Including This Page)

The information provided in this appendix specifies the thermal expansion foam (silicone sponge), paint, and anti-seize lubricant properties and demonstrates their suitability for use in spent nuclear fuel storage casks. The following is a listing of the information provided.

- HT-800 Series, Silicone Sponge, Bisco Products Technical Data Sheet
- Thermaline 450, Carboline, Product Data Sheet and Application Instructions
- Carboline 890, Carboline, Product Data Sheet and Application Instructions
- FEL-PRO Technical Bulletin, N-5000 Nickel Based-Nuclear Grade Anti-Seize Lubricant

HT-870 silicone sponge is specified as a thermal expansion foam to be placed in the overpack outer enclosure with the neutron shield. Due to differing thermal expansion of the neutron shield and outer enclosure carbon steel, the silicone sponge is provided to compress and allow the neutron shield material to expand. The compression-deflection physical properties are provided for the silicone sponge.

Silicone has a long and proven history in the nuclear industry. Silicone is highly resistant to degradation as a result of radiation at the levels required for the HI-STAR 100 System. Silicone is inherently inert and stable and will not react with the metal surfaces or neutron shield material. Additionally, typical operating temperatures for silicone sponges range from -50°F to 400°F.

Thermaline 450 is specified to coat the inner cavity of the overpack and Carboline 890 is specified to coat the external surfaces of the overpack. As can be seen from the product data sheets, the paints are suitable for the design temperatures (see Table 2.2.3) and chemical environment.

Nuclear grade anti-seize lubricant, N-5000, from FEL-PRO is specified as the lubricant for the overpack closure bolts. The lubricant is formulated to have the lowest practical levels of halogens, sulfur, and heavy metals. *NEVER-SEEZ NGBT provides equivalent properties to FEL-PRO N-5000 and is also acceptable for use on the HI-STAR 100 System.*

presented in Chapter 3. The MPC lid and closure ring welds are inspected by performing a liquid penetrant examination of the root pass and final weld surface, in accordance with the Design Drawings contained in Section 1.5. The integrity of the MPC lid weld is further verified by performing a volumetric (or multi-layer liquid penetrant) examination, a hydrostatic pressure test and a helium leak test, in accordance with the Design Drawings and Technical Specification requirements.

The structural analysis of the MPC, in conjunction with the redundant closures and nondestructive examination, hydrostatic pressure testing, and helium leak testing performed during MPC fabrication and MPC closure, provides assurance of canister closure integrity in lieu of the specific weld joint requirements of the ASME Code, Section III, Subsection NB.

Compliance with the ASME Code as it is applied to the design and fabrication of the MPC, and the associated justification, are discussed in Section 2.2.4. Compliance with the ASME Code is fully consistent with that used by other canister-based dry storage systems previously approved by the NRC.

The MPC is designed for all design basis normal, off-normal, and postulated accident conditions, as defined in Section 2.2. These design loadings include the postulated drop accidents while in the cavity of the HI-STAR Overpack. The load combinations for which the MPC is designed are defined in Section 2.2.7. In addition, the maximum allowable weight and dimensions of a fuel assembly to be stored in the MPC are limited in accordance with Section 2.1.4.

Thermal

The allowable fuel cladding temperatures imposed to prevent cladding degradation during long-term dry storage conditions for the MPC are based on the PNL Report [2.0.5], and LLNL Report [2.0.6]. The allowable cladding temperatures which correspond to varying cooling times for the SNF to be stored in the MPCs are provided in Table 2.2.3.

The short-term allowable cladding temperature that is applicable to off-normal and accident conditions of storage, as well as the fuel loading, canister closure, and transfer operations, is 570°C (1058°F) based on PNL-4835 [2.0.7]. Further, the MPC is backfilled with 99.995% pure helium at a ~~mass~~ *pressure* specified in Chapter 12 during canister sealing operations to promote heat transfer and prevent cladding degradation.

The design temperatures for the structural steel components of the MPC are based on the temperature limits provided in ASME Section II, Part D, tables referenced in ASME Section III, Subsection NB and NG, for those load conditions under which material properties are relied on for a structural load combination. The specific design temperatures for the components of the MPC are provided in Table 2.2.3.

The MPCs are designed for a bounding thermal source term, as described in Section 2.1.5. The maximum allowable fuel assembly heat load for each MPC is limited in accordance with the Technical Specifications.

Table 2.0.1

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	TSAR Reference
Design Life:			
Design	40 yrs.	-	Table 1.2.2
Regulatory	20 yrs.	10CFR72.42(a) and 10CFR72.236(g)	-
Structural:			
Design ~~& Fabrication~~ Codes:			
Enclosure Vessel	ASME Code, Section III, Subsection NB	10CFR72.24(c)(4)	Section 2.0.1
Fuel Basket	ASME Code, Section III, Subsection NG	10CFR72.24(c)(4)	Section 2.0.1
MPC Lifting Points	ANSI N14.6/NUREG-0612	10CFR72.24(c)(4)	Section 1.2.1.4
Design Dead Weights:			
Max. Loaded Canister (dry)	79,987 lb. (MPC-24) 87,241 lb. (MPC-68)	ANSI/ANS 57.9	Table 3.2.1
Empty Canister (dry)	39,667 lb. (MPC-24) 39,641 lb. (MPC-68)	ANSI/ANS 57.9	Table 3.2.1
Design Cavity Pressures:			
Normal:	100 psig	ANSI/ANS 57.9	Section 2.2.1.3
Off-Normal:	100 psig	ANSI/ANS 57.9	Section 2.2.2.1
Accident (Internal)	125 psig	ANSI/ANS 57.9	Section 2.2.3.8

Table 2.0.1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	TSAR Reference
BWR Fuel Cladding:			
5-year cooled	749°F	PNL-6189	Section 4.3
6-year cooled	720°F	PNL-6189	Section 4.3
7-year cooled	676°F	PNL-6189	Section 4.3
10-year cooled	665°F	PNL-6189	Section 4.3
15-year cooled	653°F	PNL-6189	Section 4.3
Canister Backfill Gas	Helium	-	Chapter 12
Canister Backfill ~~Mass~~ *Pressure*	Varies by MPC	-	Chapter 12
Short-Term Allowable Fuel Cladding Temperature	1058°F	PNL-4835	Sections 2.0.1 & 4.3
Insolation	Protected by Overpack	10CFR71.71	-
Confinement:		10CFR72.128(a)(3) and 10CFR72.236(d) and (e)	
Closure Welds:			
Shell Seams and Shell-to-Baseplate	Full Penetration	-	Section 1.5 and Table 9.1.3
MPC Lid	Multi-pass Partial Penetration	10CFR72.236(e)	Section 1.5 and Table 9.1.3
MPC Closure Ring	Multi-pass Partial Penetration		
Port Covers	Full Penetration		

Table 2.0.1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	TSAR Reference
Spent Fuel Specification:			
Assemblies/Canister	Up to 24 (MPC-24) Up to 68 (MPC-68)	-	Table 1.2.1
Type of Cladding	Zircaloy*	-	Table 2.1.6
Fuel Condition	Intact*	-	Section 2.1.2 & Table 2.1.6
* Also designed to accommodate failed fuel, stainless clad fuel, and MOX fuel (Tables 2.1.7 and 2.1.11 and Appendix B to CoC 72-1008)			
PWR Fuel Assemblies:			
Type/Configuration	Various**	-	Table 2.1.3
** ~~No control components are permitted.~~			
Max. Burnup	42,100 MWD/MTU (MPC-24)	-	Figure 2.1.6
Max. Enrichment	Varies by fuel design	-	Table 2.1.3
Max. Decay Heat/Assembly:			
5-year cooled	791.6 W (MPC-24)	-	Figure 2.1.8
6-year cooled	773 W (MPC-24)	-	Figure 2.1.8
7-year cooled	703 W (MPC-24)	-	Figure 2.1.8
10-year cooled	687 W (MPC-24)	-	Figure 2.1.8
15-year cooled	665 W (MPC-24)	-	Figure 2.1.8
Minimum Cooling Time:	5 years (Intact Zr Clad Fuel) 9 years (Intact SS Clad Fuel)	-	Chapter 12

Table 2.0.1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	TSAR Reference
Away from Attachment Acceptance Criteria	ASME Code Level A	ASME Code	Section 2.2.1.2
Wet/Dry Loading	Wet or Dry	-	Section 1.2.2.2
Transfer Orientation	Vertical or Horizontal	-	Section 1.2.2.2
Storage Orientation	Vertical	-	Section 1.2.2.2
Fuel Rod Rupture Releases:			
Fuel Rod Failures	1%	NUREG-1536	Section 2.2.1.3
Fill Gases	100%	NUREG-1536	Section 2.2.1.3
Fission Gases	30%	NUREG-1536	Section 2.2.1.3
Snow and Ice	Protected by Overpack	ASCE 7-88	Section 2.2.1.6
Off-Normal Design Event Conditions:		10CFR72.122(b)(1)	
Ambient Temperature	See Table 2.0.2	ANSI/ANS 57.9	Section 2.2.2.2
Leakage of One Seal	No Loss of Confinement	ANSI/ANS 57.9	Section 2.2.2.4
Fuel Rod Rupture Releases:			
Fuel Rod Failures	10%	NUREG-1536	Section 2.2.2.1
Fill Gases	100%	NUREG-1536	Section 2.2.2.1
Fission Gases	30%	NUREG-1536	Section 2.2.2.1
Design-Basis (Postulated) Accident Design Events and Conditions:		10CFR72.24(d)(2) & 10CFR72.94	

Table 2.0.1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	TSAR Reference
Tip Over	See Table 2.0.2	-	Section 2.2.3.2
End Drop	See Table 2.0.2	-	Section 2.2.3.1
Side Drop	See Table 2.0.2	-	Section 2.2.3.1
Fire	See Table 2.0.2	10CFR72.122(c)	Section 2.2.3.3
Fuel Rod Rupture Releases:			
Fuel Rod Failures	100%	NUREG-1536	Section 2.2.3.8
Fill Gases	100%	NUREG-1536	Section 2.2.3.8
Fission Gases	30%	NUREG-1536	Section 2.2.3.8
Particulates & Volatiles	See Table 7.3.1	-	Sections 2.2.3.9 and 7.3
Confinement Boundary Leakage	$5x10^{-6}$ cm^3/sec (helium)	-	Sections 2.2.3.9 and 7.3
Explosive Overpressure	Protected by Overpack	10CFR72.122(c)	Section 2.2.3.10
Design Basis Natural Phenomenon Design Events and Conditions:		10CFR72.92 & 10CFR72.122(b)(2)	
Flood Water Depth	125 ft.	ANSI/ANS 57.9	Section 2.2.3.6
Seismic	See Table 2.0.2	10CFR72.102(f)	Section 2.2.3.7
Wind	Protected by Overpack	ASCE-7-88	Section 2.2.3.5
Tornado & Missiles	Protected by Overpack	RG 1.76 & NUREG-0800	Section 2.2.3.5
Burial Under Debris	Adiabatic Heat-Up	-	Section 2.2.3.12

Table 2.0.1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	TSAR Reference
Lightning	See Table 2.0.2	NFPA 78	Section 2.2.3.11
Partial Blockage of MPC Basket Vent Holes	Crud Depth (Table 2.2.8)	ESEERCO Project EP91-29	Section 2.2.3.4
Extreme Environmental Temperature	See Table 2.0.2	-	Section 2.2.3.13

Table 2.0.1 (continued)

MPC DESIGN CRITERIA SUMMARY

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Table 2.0.2

HI-STAR OVERPACK DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	TSAR Reference
Design Life:			
Design	40 yrs.	-	Section 2.0.2
Regulatory	20 yrs.	10CFR72.42(a) & 10CFR72.236(g)	
Structural:			
Design ~~& Fabrication~~ Codes:			
Inner Shell, Closure Plate, Top Flange, Bottom Plate, and Closure Plate Bolts			
Design	ASME Code Section III, Subsection NB	10CFR72.24(c)(4)	Section 2.0.2
Fabrication	ASME Code Section III, Subsection NB	10CFR72.24(c)(4)	Section 2.0.2
Remainder of Structural Steel			
Design	ASME Code Section III, Subsection NF	10CFR72.24(c)(4)	Section 2.0.2
Fabrication	ASME Code Section III, Subsection NF	10CFR72.24(c)(4)	Section 2.0.2
Design Weights:			

Fuel debris is defined as fuel assemblies with known or suspected defects greater than pinhole leaks or hairline cracks such as ruptured fuel rods, severed fuel rods, or loose fuel pellets, and which cannot be handled by normal means.

To aid in loading and unloading, damaged fuel assemblies and fuel debris will be loaded into stainless steel damaged fuel containers (DFCs) provided with 250 micron fine mesh screens, prior to placement in the HI-STAR 100 System. This application requests approval of Dresden Unit 1 (UO_2 rods and MOX fuel rods) and Humboldt Bay fuel arrays (Assembly Classes 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A) as damaged fuel assembly contents for storage in the MPC-68 and fuel debris as contents for storage in the MPC-68F. The design characteristics bounding Dresden Unit 1 and Humboldt Bay SNF are given in Table 2.1.7. The placement of a single damaged fuel assembly in an MPC-68 or a single fuel debris damaged fuel container in an MPC-68F necessitates that all fuel assemblies (intact, damaged, or debris) stored in that MPC meet the maximum heat generation requirements specified in Table 2.1.7. The fuel characteristics specified in Table 2.1.4 for Dresden 1 and Humboldt Bay fuel arrays have been evaluated in this TSAR and are acceptable for storage as damaged fuel or fuel debris in the HI-STAR 100 System. The DFC design is illustrated in Figure 2.1.1 and the Design Drawings are provided in Section 1.5. Because of the long cooling time, small size, and low weight of spent fuel assemblies qualified as damaged fuel or fuel debris, the DFC and its contents are bounded by the structural, thermal, and shielding analyses performed for the intact BWR design basis fuel. Separate criticality analysis of the bounding fuel assembly for the damaged fuel and fuel debris has been performed in Chapter 6.

2.1.4 Structural Parameters for Design Basis SNF

The main physical parameters of a SNF assembly applicable to the structural evaluation are the fuel assembly length, envelope (cross sectional dimensions), and weight. These parameters, which define the mechanical and structural design, are listed in Tables 2.1.6, 2.1.7. and 2.1.11. The centers of gravity reported in Section 3.2 are based on the maximum fuel assembly weight. Upper and lower fuel spacers (as appropriate) maintain the axial position of the fuel assembly within the MPC basket and, therefore, the location of the center of gravity. The upper and lower fuel spacers are designed to withstand normal, off-normal, and accident conditions of storage. An axial clearance of approximately 2 inches is provided to account for the irradiation and thermal growth of the fuel assemblies. The *suggested* upper and lower fuel spacer lengths are listed in Tables 2.1.9 and 2.1.10. In order to qualify for storage in the HI-STAR 100 MPC, the SNF must satisfy the physical parameters listed in Tables 2.1.6, 2.1.7, or 2.1.11.

2.1.5 Thermal Parameters for Design Basis SNF

The principal thermal design parameter for the stored fuel is the peak fuel cladding temperature, which is a function of the maximum heat generation rate per assembly, the allowable fuel cladding

2.1.6 Radiological Parameters for Design Basis SNF

The principal radiological design criteria for the HI-STAR 100 System are the 10CFR72.104 site boundary dose rate limits and maintaining operational dose rates as low as reasonably achievable (ALARA). The radiation dose is directly affected by the gamma and neutron source terms of the SNF assembly.

The gamma and neutron sources are separate and are affected differently by enrichment, burnup, and cooling time. It is recognized that, at a given burnup, the radiological source terms increase monotonically as the initial enrichment is reduced. The shielding design basis fuel assembly, therefore, is evaluated at the maximum burnup, minimum cooling time, and a conservative enrichment corresponding to the burnup. The shielding design basis fuel assembly thus bounds all other fuel assemblies.

The design basis dose rates can be met by a variety of burnup levels and cooling times. Tables 2.1.7 and 2.1.11 provide the burnup and cooling time values which meet the radiological source term requirements for BWR damaged fuel/fuel debris and intact stainless steel clad fuel, respectively. Figure 2.1.6 provides illustrative burnup and cooling time values which meet the radiological source term requirements for intact zircaloy clad fuel in each MPC type.

Table 2.1.8 and Figures 2.1.3 and 2.1.4 provide the axial distribution for the radiological source terms for PWR and BWR fuel assemblies based on the axial burnup distribution. The axial burnup distributions are representative of fuel assemblies with the design basis burnup levels considered. These distributions are used for analyses only, and do not provide a criteria for fuel assembly acceptability for storage in the HI-STAR 100 System.

Thoria rods placed in Dresden Unit 1 Thoria Rod Canisters meeting the requirements of Table 2.1.12 and Dresden Unit 1 fuel assemblies with one Antimony-Beryllium neutron source have been qualified for storage. Up to one Dresden Unit 1 Thoria Rod Canister plus any combination of damaged fuel assemblies in damaged fuel containers and intact fuel, up to a total of 68 may be stored.

Burnable Poison Rod Assemblies (BPRAs) and Thimble Plug Devices (TPDs) in PWR fuel have been qualified for storage in the MPC-24.

2.1.7 Criticality Parameters for Design Basis SNF

As discussed earlier, the MPC-68 features a basket without flux traps. In the MPC-68 basket, there is one panel of neutron absorber between two adjacent fuel assemblies. The MPC-24 employs a construction wherein two neighboring fuel assemblies are separated by two panels of neutron absorber with a water gap between them (flux trap construction).

The MPC-24 Boral ^{10}B areal density is specified at a minimum loading of 0.0267 g/cm^2. The MPC-68 Boral ^{10}B areal density is specified at a minimum loading of 0.0372 g/cm^2. The MPC-68F Boral ^{10}B areal density is specified at a minimum loading of 0.01 g/cm^2.

For all MPCs, the ^{10}B areal density used for analysis is conservatively established at 75% of the minimum ^{10}B areal density to demonstrate that the reactivity under the most adverse accumulation of tolerances and biases is less than 0.95. This satisfies NUREG-1536 [2.1.5] which requires a 25% *reduction in ^{10}B areal density credit. A large body of sampling data accumulated by Holtec from thousands of manufactured Boral panels indicates the average ^{10}B areal densities to be approximately 15% greater than the specified minimum.*

2.1.8 Summary of SNF Design Criteria

An intact zircaloy clad fuel assembly is acceptable for storage in a HI-STAR 100 System if it fulfills the following criteria:

a. It satisfies the physical characteristics listed in Tables 2.1.3 or 2.1.4, and 2.1.6.

b. Its initial enrichment is less than that indicated by Table 2.1.6 for the MPC it is intended to be stored in.

c. The period from discharge is greater than or equal to the minimum cooling time listed in Table 2.1.6, and the decay heat is equal to or less than the value stated in Figure 2.1.8 for a given cooling time.

d. The average burnup of the fuel assembly is equal to or less than the burnup specified in Figure 2.1.6 for a given cooling time.

A damaged fuel assembly shall meet the characteristics specified in Table 2.1.7 for storage in the MPC-68. Fuel debris shall meet the characteristics specified in Table 2.1.7 for storage in the MPC-68F.

Stainless steel clad fuel assemblies shall meet the characteristics specified in Table 2.1.11 for storage in the MPC-24 or MPC-68.

MOX BWR fuel assemblies shall meet the requirements of Tables 2.1.6 and 2.1.7 for intact and damaged fuel/fuel debris, respectively.

~~No~~ *Only* control components *specifically authorized by the Technical Specifications for* ~~in~~ PWR fuel are to be included with the fuel assembly. *Burnable Poison Rod Assemblies (BPRAs) and Thimble Plug Devices (TPDs) are authorized for storage in the MPC-24. Fuel assemblies with BPRAs shall* *satisfy the more restrictive burnup and cooling time requirements in Figure 2.1.6. BPRAs and TPDs shall meet the burnup and cooling time requirements specified in the Technical Specification.*

Thoria rods placed in Dresden Unit 1 Thoria Rod Canisters meeting the requirements of Table 2.1.12 are authorized for storage. Up to one Dresden Unit 1 Thoria Rod Canister plus any combination of damaged fuel assemblies in damaged fuel containers and intact fuel, up to a total of 68 may be stored.

Dresden Unit 1 fuel assemblies with one Antimony-Beryllium neutron source are authorized for loading in the MPC-68 or MPC-68F.

Table 2.1.2

BWR FUEL ASSEMBLIES EVALUATED TO DETERMINE DESIGN BASIS SNF

Assembly Class	Array Type			
GE BWR/2-3	All 7x7	All 8x8	All 9x9	All 10x10
GE BWR/4-6	All 7x7	All 8x8 ~~(except 8x8 WE (QUAD+))~~	All 9x9	All 10x10
Humboldt Bay	All 6x6	All 7x7 (Zircaloy Clad)		
Dresden-1	All 6x6	All 8x8		
LaCrosse (Stainless Steel Clad)	All			

Table 2.1.3
PWR FUEL ASSEMBLY CHARACTERISTICS

Fuel Assembly Array and Class	**14x14 A**	**14x14 B**	**14x14 C**	**14x14 D**	**15x15 A**
Clad Material	Zr	Zr	Zr	SS	Zr
Design Initial U (kg/assy.)	≤ ~~402~~ *407*	≤ ~~402~~ *407*	≤ ~~410~~ *425*	≤ 400	≤ ~~420~~ *464*
Initial Enrichment (wt % ^{235}U)	≤ 4.6	≤ 4.6	≤ 4.6	≤ 4.0	≤ 4.1
No. of Fuel Rods	179	179	176	180	204
Clad O.D. (in.)	≥ 0.400	≥ 0.417	≥ 0.440	≥ 0.422	≥ 0.418
Clad I.D. (in.)	≤ 0.3514	≤ 0.3734	≤ ~~0.3840~~ *0.3880*	≤ 0.3890	≤ 0.3660
Pellet Dia. (in.)	≤ 0.3444	≤ 0.3659	≤ ~~0.3770~~ *0.3805*	≤ 0.3835	≤ 0.3580
Fuel Rod Pitch (in.)	0.556	0.556	0.580	0.556	0.550
Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 144	≤ 150
No. of Guide Tubes	17	17	5	16	21
Guide Tube Thickness (in.)	≥ 0.017	≥ 0.017	≥ ~~0.040~~ *0.0380*	≥ 0.0145	≥ 0.0165

Notes:
1. All dimensions are design nominal values. Maximum and minimum values are specified to bound variations within a given assembly class.
2. Zr designates cladding material made of Zirconium or Zirconium alloys.
3. Description of the fuel assembly class designation is provided in Chapter 6.

Table 2.1.3 (continued)
PWR FUEL ASSEMBLY CHARACTERISTICS

Fuel Assembly Array and Class	**15x15 G**	***15x15 H***	**16x16 A**	**17x17A**	**17x17 B**	**17x17 C**
Clad Material	SS	*Zr*	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.)	≤ 420	*≤ 475*	≤ ~~430~~ *443*	≤ ~~450~~ *467*	≤ ~~464~~ *467*	≤ ~~460~~ *474*
Initial Enrichment (wt % ^{235}U)	≤ 4.0	*≤ 3.8*	≤ 4.6	≤ 4.0	≤ 4.0	≤ 4.0
No. of Fuel Rods	204	*208*	236	264	264	264
Clad O.D. (in.)	≥ 0.422	*≥ 0.414*	≥ 0.382	≥ 0.360	≥ 0.372	≥ 0.377
Clad I.D. (in.)	≤ 0.3890	*≤ 0.3700*	≤ 0.3320	≤ 0.3150	≤ 0.3310	≤ 0.3330
Pellet Dia. (in.)	≤ 0.3825	*≤ 0.3622*	≤ 0.3255	≤ 0.3088	≤ 0.3232	≤ 0.3252
Fuel Rod Pitch (in.)	0.563	*0.568*	0.506	0.496	0.496	0.502
Active Fuel Length (in.)	≤ 144	*≤ 150*	≤ 150	≤ 150	≤ 150	≤ 150
No. of Guide Tubes	21	*17*	5	25	25	25
Guide Tube Thickness (in.)	≥ 0.0145	*≥ 0.0140*	≥ 0.0400	≥ 0.016	≥ 0.014	≥ 0.020

Notes:
1. All dimensions are design nominal values. Maximum and minimum values are specified to bound variations within a given assembly class.
2. Zr designates cladding material made of Zirconium or Zirconium alloys.
3. Description of the fuel assembly class designation is provided in Chapter 6.

Table 2.1.4
BWR FUEL ASSEMBLY CHARACTERISTICS

Fuel Assembly Array and Class	**6x6 A**	**6x6 B**	**6x6 C**	**7x7 A**	**7x7 B**	**8x8 A**
Clad Material	Zr	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.)	≤ ~~108~~ *110*	≤ ~~108~~ *110*	≤ ~~100~~ *110*	≤ 100	≤ 195	≤ 120
No. of Fuel Rods	36	36 (up to 9 MOX rods)	36	49	49	64
Clad O.D. (in.)	≥ 0.5550	≥ 0.5625	≥ 0.5630	≥ 0.4860	≥ 0.5630	≥ 0.4120
Clad I.D. (in.)	≤ ~~0.4945~~ *0.5105*	≤ 0.4945	≤ 0.4990	≤ ~~0.4200~~ *.4204*	≤ 0.4990	≤ 0.3620
Pellet Dia. (in.)	≤ ~~0.4940~~ *0.4980*	≤ 0.4820	≤ 0.4880	≤ 0.4110	≤ ~~0.4880~~ *0.4910*	≤ 0.3580
Fuel Rod Pitch (in.)	≤ ~~0.694~~ *0.710*	≤ ~~0.694~~ *0.710*	0.740	0.631	0.738	0.523
Active Fuel Length (in.)	≤ ~~110~~ *120*	≤ ~~110~~ *120*	≤ 77.5	≤ ~~79~~ *80*	≤ 150	≤ ~~110~~ *120*
No. of Water Rods	*1 or* 0	*1 or* 0	0	0	0	*1 or* 0
Water Rod Thickness (in.)	~~N/A~~ *>0*	~~N/A~~ *>0*	N/A	N/A	N/A	N/A
Channel Thickness (in.)	≤ 0.060	≤ 0.060	≤ 0.060	≤ 0.060	≤ 0.120	≤ 0.100

Notes:
1. All dimensions are design nominal values. Maximum and minimum values are specified to bound variations within a given assembly class.
2. Zr designates cladding material made of Zirconium or Zirconium alloys.
3. Description of the fuel assembly class designation is provided in Chapter 6.

Table 2.1.4 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS

Fuel Assembly Array and Class	**8x8 B**	**8x8 C**	**8x8 D**	**8x8 E**	**9x9 A (Note 3)**	**9x9 B**
Clad Material	Zr	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.)	≤ 185	≤ 185	≤ 185	≤ ~~180~~ *185*	≤ ~~173~~ *177*	≤ ~~173~~ *177*
No. of Fuel Rods	~~63~~ *63 or 64*	62	~~60~~ *60 or 61*	59	74/66	72
Clad O.D. (in.)	≥ 0.4840	≥ 0.4830	≥ 0.4830	≥ 0.4930	≥ 0.4400	≥ 0.4330
Clad I.D. (in.)	≤ ~~0.4250~~ *0.4295*	≤ 0.4250	≤ ~~0.4190~~ *0.4230*	≤ 0.4250	≤ 0.3840	≤ 0.3810
Pellet Dia. (in.)	≤ ~~0.4160~~ *0.4195*	≤ 0.4160	≤ ~~0.4110~~ *0.4140*	≤ 0.4160	≤ 0.3760	≤ 0.3740
Fuel Rod Pitch (in.)	~~0.636 - 0.641~~ *≤ 0.642*	~~0.636 - 0.641~~ *≤ 0.641*	≤ 0.640	≤ 0.640	≤ 0.566	~~≤ 0.569~~ *≤ 0.572*
Design Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Water Rods	1	2	1 - 4	5	2	1
Water Rod Thickness (in.)	≥ 0.034	≥ 0.00	≥ 0.00	≥ 0.034	≥ 0.00	≥ 0.00
Channel Thickness (in.)	≤ 0.120	≤ 0.120	≤ 0.120	≤ 0.100	≤ 0.120	≤ 0.120

Notes:
1. All dimensions are design nominal values. Maximum values are specified to bound variations within a given array type.
2. Zr designates cladding material made of Zirconium or Zirconium alloys.
3. This assembly class contains 66 full length rods and 8 partial length rods.
4. Description of the fuel assembly class designation is provided in Chapter 6.

Table 2.1.4 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS

Fuel Assembly Array and Class	**9x9 C**	**9x9 D**	**9x9 E**	**9x9 F**	**10x10 A (Note 3)**
Clad Material	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.)	≤ ~~173~~ *177*	≤ ~~170~~ *177*	≤ ~~170~~ *177*	≤ ~~170~~ *177*	≤ ~~182~~ *186*
No. of Fuel Rods	80	79	76	76	92/78
Clad O.D. (in.)	≥ 0.4230	≥ 0.4240	≥ 0.4170	≥ 0.4430	≥ 0.4040
Clad I.D. (in.)	≤ 0.3640	≤ 0.3640	≤ ~~0.3590~~ *0.3640*	≤ ~~0.3810~~ *0.3860*	≤ 0.3520
Pellet Dia. (in.)	≤ 0.3565	≤ 0.3565	≤ ~~0.3525~~ *0.3530*	≤ 0.3745	≤ 0.3455
Fuel Rod Pitch (in.)	0.572	0.572	0.572	0.572	0.510
Design Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Water Rods	1	2	5	5	2
Water Rod Thickness (in.)	0.020	≥ ~~0.0305~~ *0.0300*	≥ ~~0.0305~~ *0.0120*	≥ ~~0.0305~~ *0.0120*	≥ 0.030
Channel Thickness (in.)	≤ 0.100	≤ 0.100	≤ ~~0.100~~ *0.120*	≤ ~~0.100~~ *0.120*	≤ 0.120

Notes:
1. All dimensions are design nominal values. Maximum values are specified to bound variations within a given array type.
2. Zr designates cladding material made of Zirconium or Zirconium alloys.
3. This assembly class contains 78 full length rods and 14 partial length rods.
4. Description of the fuel assembly class designation is provided in Chapter 6.

Table 2.1.4 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS

Fuel Assembly Array and Class	10x10 B (Note 3)	10x10 C	10x10 D	10x10 E	*8x8F*
Clad Material	Zr	Zr	SS	SS	*Zr*
Design Initial U (kg/assy.)	≤ ~~182~~ *186*	≤ ~~180~~ *186*	≤ 125	≤ 125	≤ *185*
No. of Fuel Rods	91/83	96	100	96	*64*
Clad O.D. (in.)	≥ 0.3957	≥ ~~0.3790~~ *0.3780*	≥ 0.3960	≥ 0.3940	≥*0.4576*
Clad I.D. (in.)	≤ 0.3480	≤ 0.3294	≤ 0.3560	≤ 0.3500	≤ *0.3996*
Pellet Dia. (in.)	≤ 0.3420	≤ 0.3224	≤ 0.3500	≤ 0.3430	≤ *0.3913*
Fuel Rod Pitch (in.)	0.510	0.488	0.565	0.557	≤ *0.609*
Design Active Fuel Length (in.)	≤ 150	≤ 150	≤ 83	≤ 83	≤ *150*
No. of Water Rods	1 (Note 4)	5 (Note 5)	0	4	*N/A (Note 7)*
Water Rod Thickness (in.)	≥ 0.00	≥ ~~0.034~~ *0.031*	N/A	≥ 0.022	≥ *0.0315*
Channel Thickness (in.)	≤ 0.120	≤ 0.055	≤ 0.080	≤ 0.080	≤ *0.055*

Notes:

1. All dimensions are design nominal values. Maximum values are specified to bound variations within a given array type.
2. Zr designates cladding material made of Zirconium or Zirconium alloys.
3. This assembly class contains 83 full length rods and 8 partial length rods.
4. Square, replacing nine fuel rods.
5. One center diamond and four rectangular.
6. Description of the fuel assembly class designation is provided in Chapter 6.
7. *This assembly is known as "QUAD+". It has four rectangular water cross segments dividing the assembly into four quadrants.*

Table 2.1.6

CHARACTERISTICS FOR DESIGN BASIS INTACT ZIRCALOY CLAD FUEL ASSEMBLIES

	MPC-68	MPC-24
PHYSICAL PARAMETERS:		
Max. assembly width† (in.)	5.85	8.54
Max. assembly length† (in.)	176.2	176.8
Max. assembly weight†† (lb.)	700	1680
Max. active fuel length† (in.)	150	150
Fuel rod clad material	zircaloy	zircaloy
RADIOLOGICAL AND THERMAL CHARACTERISTICS:		
	MPC-68	**MPC-24**
Max. initial enrichment (wt% ^{235}U)	4.2 2.7 (Assembly Classes 6x6A, 6x6B†††, 6x6C, 7x7A, 8x8A)	See Table 2.1.3
Max. heat generation (W)	Figure 2.1.8 115 (Assembly Classes 6x6A, 6x6B, 6x6C, 7x7A, 8x8A) *183.5 (Assembly Class 8x8F)*	Figure 2.1.8
Max. average burnup (MWD/MTU)	See Figure 2.1.6 30,000 (Assembly Classes 6x6A, 6x6B, 6x6C, 7x7A, 8x8A) *27,500 (Assembly Class 8x8F)*	See Figure 2.1.6
Min. cooling time (years)	See Figure 2.1.6 18 (Assembly Classes 6x6A, 6x6B, 6x6C, 7x7A, 8x8A) *10 (Assembly Class 8x8F)*	See Figure 2.1.6

† Unirradiated nominal design dimensions are shown.

†† Fuel assembly weight including hardware based on DOE MPC DPS [2.1.6].

††† See Table 2.1.7 for MOX enrichment specifications.

Table 2.1.9

SUGGESTED PWR UPPER AND LOWER FUEL SPACER LENGTHS

Fuel Assembly Type	**Assembly Length w/o C.C.**† **(in.)**	**Location of Active Fuel from Bottom (in.)**	**Max. Active Fuel Length (in.)**	**Upper Fuel Spacer Length (in.)**	**Lower Fuel Spacer Length (in.)**
CE 14x14	157	4.1	137	9.5	10.0
CE 16x16	176.8	4.7	150	0	0
BW 15x15	165.7	8.4	141.8	6.7	4.1
W 17x17 OFA	159.8	3.7	144	8.2	8.5
W 17x17 Std	159.8	3.7	144	8.2	8.5
W 17x17 V5H	160.1	3.7	144	7.9	8.5
W 15x15	159.8	3.7	144	8.2	8.5
W 14x14 Std	159.8	3.7	145.2	9.2	7.5
W 14x14 OFA	159.8	3.7	144	8.2	8.5
Ft. Calhoun	146	6.6	128	10.25	20.25
St. Lucie 2	158.2	5.2	136.7	10.25	8.05
B&W 15x15 SS	137.1	3.873	120.5	19.25	19.25
W 15x15 SS	137.1	3.7	122	19.25	19.25
W 14x14 SS	137.1	3.7	120	19.25	19.25

† C.C. is an abbreviation for Control Components. *Fuel assemblies with control components may required shorter fuel spacers. Each user shall specify the fuel spacer lengths based on their fuel length and any control components and allowing an approximate 2 inch gap.*

Table 2.1.10

SUGGESTED BWR UPPER AND LOWER FUEL SPACER LENGTHS

Fuel for Reactor Type	Assembly Length (in.)	Location of Active Fuel from Bottom (in.)	Max. Active Fuel Length (in.)	Upper Fuel Spacer Length (in.)	Lower Fuel Spacer Length (in.)
GE/2-3	171.2	7.3	150	4.8	0
GE/4-6	176.2	7.3	150	0	0
Dresden 1	134.4	11.2	110	18.0	23.6
Humboldt Bay	95.0	8.0	79.0	40.5	40.5
Dresden 1 Damaged Fuel or Fuel Debris	144.5†	11.2	110.0	17.0	14.5
Humboldt Bay Damaged Fuel or Fuel Debris	105.5†	8.0	79.0	35.25	35.25
LaCrosse	102.5	10.5	83.0	37.0	37.5

Note: *Each user shall specify the fuel spacer lengths based on their fuel length and allowing an approximate 2 inch gap.*

† Fuel assembly length includes the damaged fuel container.

Table 2.1.12

DESIGN CHARACTERISTICS FOR THORIA RODS IN D1 THORIA ROD CANISTERS

PARAMETER	***MPC-68 or MPC-68F***
Cladding Type	*Zircaloy (Zr)*
Composition	*98.2 wt.% ThO_2, 1.8 wt.% UO_2 with an enrichment of 93.5 wt. % ^{235}U*
Number of Rods Per Thoria Canister	*≤18*
Decay Heat Per Thoria Canister	*≤115 watts*
Post-Irradiation Fuel Cooling Time and Average Burnup Per Thoria Canister	*Cooling time ≥18 years and average burnup ≤16,000 MWD/MTIHM*
Initial Heavy Metal Weight	*≤27 kg/canister*
Fuel Cladding O.D.	*≥0.412 inches*
Fuel Cladding I.D.	*≤0.362 inches*
Fuel Pellet O.D.	*≤0.358 inches*
Active Fuel Length	*≤111 inches*
Canister Weight	*≤550 lbs., including Thoria Rods*

ILLUSTRATIVE BURNUP AND COOLING TIME FOR DECAY HEAT AND RADIATION SOURCE TERMS

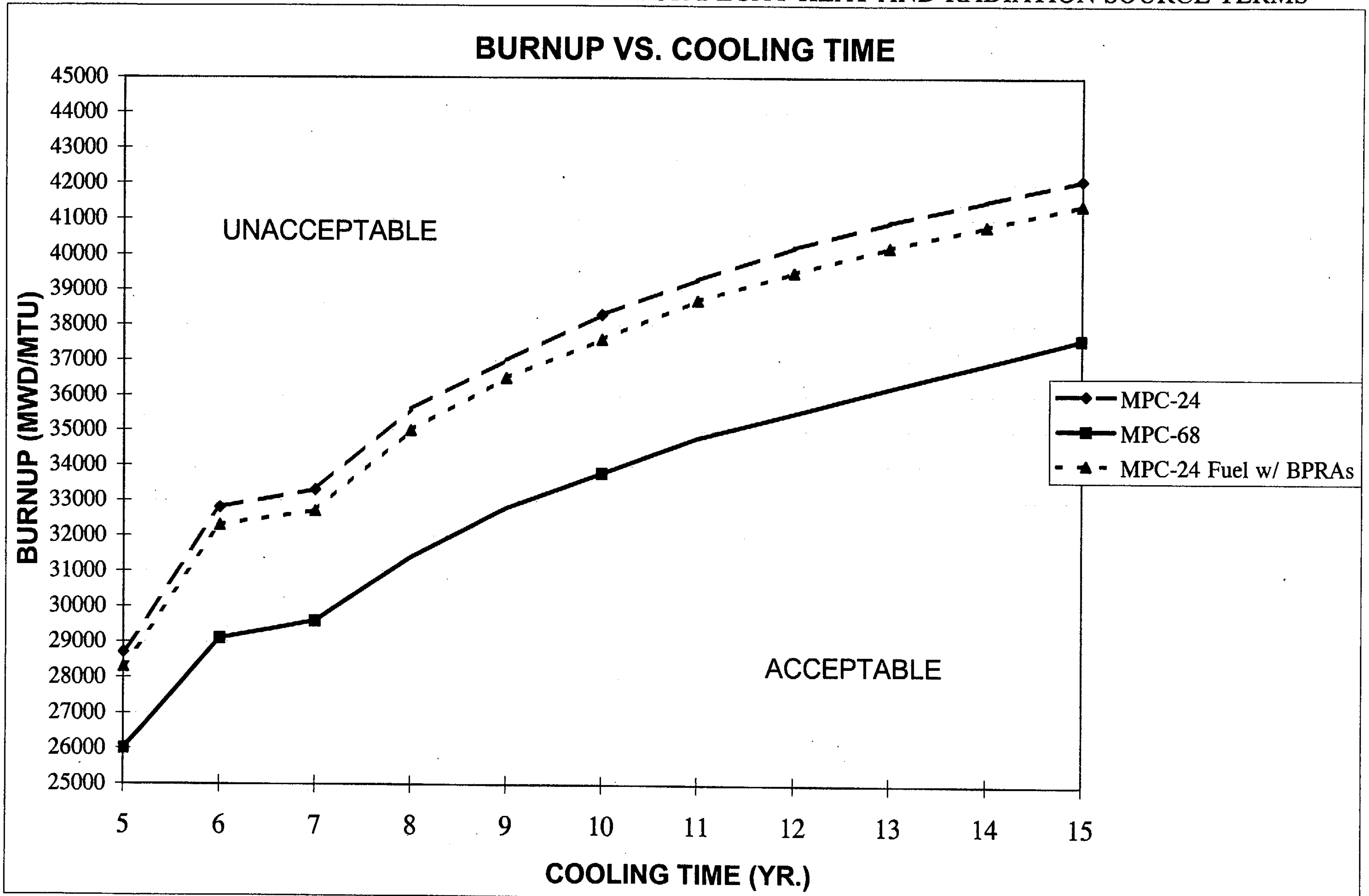


FIGURE 2.1.6; ILLUSTRATIVE BURNUP AND COOLING TIME FOR DECAY HEAT AND RADIATION SOURCE TERMS

The helium retention boundary is defined by the overpack baseplate, inner shell, top flange, vent and drain port plugs, and bolted closure plate containing two concentric seals. All welds that form a part of the helium retention boundary are examined by radiography. The overpack welds and seals are helium leakage tested during fabrication to verify their integrity. Helium leakage tests of all overpack closure seals are performed following each loading sequence.

2.2.3 Environmental Phenomena and Accident Condition Design Criteria

Environmental phenomena and accident condition design criteria are defined in the following subsections.

The minimum acceptance criteria for the evaluation of the accident condition design criteria are that the MPC confinement boundary maintains radioactive material confinement, the MPC fuel basket structure maintains the fuel contents subcritical, and the stored SNF can be retrieved by normal means.

A discussion of the effects of each environmental phenomena and accident condition is provided in Section 11.2. The consequences of each accident or environmental phenomena are evaluated against the requirements of 10CFR72.106 and 10CFR20. Section 11.2 also provides the corrective action for each event. The location of the detailed analysis for each event is referenced in Section 11.2.

2.2.3.1 Handling Accident

The HI-STAR 100 System must withstand loads due to a handling accident. Even though the *loaded* HI-STAR 100 System will be handled in accordance with approved, written procedures and will use lifting equipment which complies with ANSI N14.6, certain drop events are considered herein to demonstrate the defense-in-depth features of the HI-STAR design.

The loaded overpack will be handled so that the bottom of the cask is at a height less than the calculated vertical handling limit above the floor. The horizontal handling limit is specified to limit the height the loaded overpack can be lifted while in the horizontal position. For conservatism, the postulated drop events assume that the loaded HI-STAR 100 System falls freely from the vertical or horizontal handling limit height before impacting a thick reinforced concrete pad. Table 2.2.17 provides the acceptable carry heights for the loaded HI-STAR 100 System.

The magnitude of loadings induced into the HI-STAR 100 System due to drop events is heavily influenced by the compliance characteristics of the impacted surface. The concrete pad for storing the HI-STAR 100 System shall comply with the requirements of Table 2.2.9 to ensure that impactive and impulsive loads under accident events such as cask drop and non-mechanistic tip-over are less than those calculated by the dynamic models used in the structural qualifications.

Table 2.2.3: DESIGN TEMPERATURES

HI-STAR 100 Component	Normal Condition Design Temp. (Long-Term Events) (°F)		Off-Normal and Accident Condition Design Temp. Limits (Short-Term Events) (°F)
MPC shell	450		775
MPC basket	725		950
MPC Boral	800		950
MPC lid	550		775
MPC closure ring	400		775
MPC baseplate	400		775
MPC heat conduction elements	725		950
Overpack inner shell	400		500
Overpack bottom plate	350		700
Overpack closure plate	400		700
Overpack top flange	400		700
Overpack closure plate seals	400		1200
Overpack closure plate bolts	350		1000
Overpack port plug seals (vent and drain)	400		1600
Overpack port cover seals (vent and drain)	400		932
Neutron shielding	300		300
Overpack Neutron Shield Enclosure Shell	*300*		*1350*
Remainder of overpack	350		1000
Zircaloy fuel cladding (five-year cooled)	720 (PWR)	749 (BWR)	1058
Zircaloy fuel cladding (six-year cooled)	698 (PWR)	720 (BWR)	1058
Zircaloy fuel cladding (seven-year cooled)	657 (PWR)	676 (BWR)	1058
Zircaloy fuel cladding (ten-year cooled)	647 (PWR)	665 (BWR)	1058
Zircaloy fuel cladding (fifteen-year cooled)	633 (PWR)	653 (BWR)	1058

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STAR 100 SYSTEM

MPC [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
~~Helium Retention~~ *Confinement*	Shell	A	ASME Section III; Subsection NB	Alloy X [5]	See Appendix 1.A	NA	NA
~~Helium Retention~~ *Confinement*	Baseplate	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
~~Helium Retention~~ *Confinement*	Lid	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
~~Helium Retention~~ *Confinement*	Closure Ring	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
~~Helium Retention~~ *Confinement*	Port Cover Plates	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
Criticality Control	Basket Cell Plates	A	ASME Section III; Subsection NG	Alloy X	See Appendix 1.A	NA	NA
Criticality Control	Boral	A	Non-code	NA	NA	NA	Aluminum/SS
Shielding	Drain and Vent Shield Block	C	Non-code	Alloy X	See Appendix 1.A	NA	NA
Shielding	Plugs for Drilled Holes	NITS	Non-code	Alloy X	See Appendix 1.A	NA	NA
Heat Transfer	Heat Conduction Elements	B	Non-code	Aluminum; Alloy 1100	NA	Sandblast Specified Surfaces	Aluminum/SS

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A,B and C denote important to safety classifications as described in Chapter 13. NITS stands for Not Important To Safety.
5) For details on Alloy X material, see Appendix 1.A.

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STAR 100 SYSTEM

OVERPACK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
~~Confinement~~ *Helium Retention*	Inner Shell	A	ASME Section III; Subsection NB	SA203-E	Table 3.3.4	Paint inside surface with Thermaline 450	NA
~~Confinement~~ *Helium Retention*	Bottom Plate	A	ASME Section III; Subsection NB	SA350-LF3	Table 3.3.4	Paint inside surface with Thermaline 450	NA
~~Confinement~~ *Helium Retention*	Top Flange	A	ASME Section III; Subsection NB	SA350-LF3	Table 3.3.4	Paint inside surface with Thermaline 450. Paint outside surface with Carboline 890.	NA
~~Confinement~~ *Helium Retention*	Closure Plate	A	ASME Section III; Subsection NB	SA350-LF3	Table 3.3.4	Paint inside surface with Thermaline 450. Paint outside surface with Carboline 890.	NA
~~Confinement~~ *Helium Retention*	Closure Plate Bolts	A	ASME Section III; Subsection NB	SB637-N07718	Table 3.3.5	NA	NA
~~Confinement~~ *Helium Retention*	Port Plug	A	Non-code	SA193-B8	Not required	NA	NA
~~Confinement~~ *Helium Retention*	Port Plug Seal	A	Non-code	Alloy X750	Not required	NA	NA
~~Confinement~~ *Helium Retention*	Closure Plate Seal	A	Non-code	Alloy X750	Not required	NA	NA

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A,B and C denote important to safety classifications as described in Chapter 13. NITS stands for Not Important To Safety.

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STAR 100 SYSTEM

OVERPACK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
~~Confinement~~ *Helium Retention*	Port Cover Seal	B	Non-code	Alloy X750	Not required	NA	NA
Shielding	Intermediate Shells	B	ASME Section III; Subsection NF	SA516-70	Table3.3.2	Exposed areas of fifth intermediate shell to be painted with Carboline 890.	NA
Shielding	Neutron Shield	B	Non-code	Holtite-A	Not required	NA	NA
Shielding	Plugs for Drilled Holes	NITS	Non-code	SA193-B7	Not required	NA	NA
Shielding	Removeable Shear Ring	B	ASME Section III; Subsection NF	SA203-E	Table 3.3.4	Paint external surface with Carboline 890.	NA
Shielding	Pocket Trunnion Plug Plate	C	Non-code	SA240-304	Not required	NA	NA
Heat Transfer	Radial Channels	B	ASME Section III; Subsection NF	SA515-70	Table 3.3.3	Paint outside surface with Carboline 890.	NA
Structural Integrity	Pocket Trunnion	B	ASME Section III; Subsection NF	SA705-630	Table 3.3.5	NA	NA
Structural Integrity	Lifting Trunnion	A	ANSI N14.6	SB637-N07718	Table 3.3.5	NA	NA
~~Structural Integrity~~	~~Backing Strip~~	~~B~~	~~Non-code~~	~~A569~~	~~Not required~~	~~NA~~	~~NA~~
~~Structural Integrity~~	~~Rupture Disk Coupling~~	~~NITS~~	~~Non-code~~	~~C/S~~	~~Not required~~	~~NA~~	~~NA~~
Structural Integrity	Rupture Disk	C	Non-code	~~Brass~~ *Commercial*	Not required	NA	Brass-C/S

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A,B and C denote important to safety classifications as described in Chapter 13. NITS stands for Not Important To Safety.

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STAR 100 SYSTEM

OVERPACK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
~~Structural Integrity~~	~~Rupture Disk Pipe~~	~~C~~	~~Non-code~~	~~SA-106~~	~~Not required~~	~~NA~~	~~NA~~
Structural Integrity	Rupture Disk Plate	C	Non-code	A569	Not required	NA	NA
Structural Integrity	Removeable Shear Ring Bolt	C	Non-code	SA193-B7	Not required	NA	NA
Structural Integrity	Thermal Expansion Foam	NITS	Non-code	Silicone Foam	Not required	NA	NA
Structural Integrity	Closure Bolt Washer	~~C~~ *NITS*	Non-code	SA240-304	Not required	NA	NA
Structural Integrity	Enclosure Shell Panels	B	ASME Section III; Subsection NF	SA515-70	Table 3.3.3	Paint outside surface with Carboline 890.	NA
Structural Integrity	Enclosure Shell Return	B	ASME Section III; Subsection NF	SA515-70	Table 3.3.3	Paint outside surface with Carboline 890.	NA
Structural Integrity	Port Cover	B	ASME Section III; Subsection NF	SA203E	Table 3.3.4	Paint outside surface with Carboline 890.	NA
Structural Integrity	Port Cover Bolt	C	Non-code	SA193-B7	Not required	NA	NA
Operations	Trunnion Locking Pad and End Cap Bolt	C	Non-code	SA193-B7	Not required	NA	NA
Operations	Lifting Trunnion End Cap	C	Non-code	SA516-70	Table 3.3.2	Paint exposed surfaces with Carboline 890.	NA

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A,B and C denote important to safety classifications as described in Chapter 13. NITS stands for Not Important To Safety.

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STAR 100 SYSTEM

OVERPACK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Operations	Lifting Trunnion Locking Pad	C	Non-code	SA516-70	Table 3.3.2	Paint exposed surfaces with Carboline 890.	NA
~~Operations~~	~~Alignment Pin~~	~~NITS~~	~~Non-code~~	~~SA193-B7~~	~~Not required~~	~~NA~~	~~NA~~
Operations	Nameplate	NITS	Non-code	SA240-304	Not required	NA	NA

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A,B and C denote important to safety classifications as described in Chapter 13. NITS stands for Not Important To Safety.

Table 2.2.15

LIST OF ASME CODE EXCEPTIONS FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
MPC	NB-1100	Statement of requirements for Code stamping of components.	MPC enclosure vessel is designed and will be fabricated in accordance with ASME Code, Section III, Subsection NB to the maximum practical extent, but Code stamping is not required.
MPC	NB-2000	Requires materials to be supplied by ASME-approved material supplier.	Materials will be supplied by Holtec approved suppliers with Certified Material Test Reports (CMTRs) in accordance with NB-2000 requirements.
MPC Lid and Closure Ring Welds	NB-4243	Full penetration welds required for Category C Joints (flat head to main shell per NB-3352.3)	MPC lid and closure ring are not full penetration welds. They are welded independently to provide a redundant seal. Additionally, a weld efficiency factor of 0.45 has been applied to the analyses of these welds.
MPC Lid to Shell Weld	*NB-5230*	*Radiographic (RT) or ultrasonic (UT) examination required*	*Only UT or multi-layer liquid penetrant (PT) examination is permitted. If PT alone is used, at a minimum, it will include the root and final weld layers and each approximately 3/8 inch of weld depth.*

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
MPC Closure Ring, Vent and Drain Cover Plate Welds	NB-5230	Radiographic (RT) or ultrasonic (UT) examination required.	Root *(if more than one weld pass is required)* and final liquid penetrant examination to be performed in accordance with NB-5245. The MPC vent and drain cover plate welds are leak tested. The closure ring provides independent redundant closure for vent and drain cover plates.

Table 2.2.17

ALLOWABLE CARRY HEIGHTS

Cask Orientation	Height (Inches)
Vertical	21
Horizontal	72

<u>Note:</u> *The carry height is measured from the lowest surface of the overpack to the potential impact surface.*

Table 2.3.1

RADIOLOGICAL SITE BOUNDARY REQUIREMENTS

BOUNDARY OF CONTROLLED AREA (m) (minimum)	100
NORMAL AND OFF-NORMAL CONDITIONS: Whole Body (mrem/yr) Thyroid (mrem/yr) Any Other Organ (mrem/yr)	 25 75 25
DESIGN BASIS ACCIDENT: *Whole Body-Total Effective Dose (rem)* *Deep Dose Equivalent and Any Organ or Tissue(rem)* *Lens of Eye (rem)* *Skin or Extremity (rem)*	 *5* *50* *15* *50*

Table 3.0.1 MATRIX OF NUREG-1536 COMPLIANCE ITEMS – STRUCTURAL EVALUATION † (Continued)

PARAGRAPH IN NUREG-1536	NUREG-1536 COMPLIANCE ITEM	LOCATION IN TSAR CHAPTER 3	LOCATION OUTSIDE OF TSAR CHAPTER 3
"	Specific Analyses	3.4.4.2; 3.4.4.3.1; 3.4.4.4.1; 3.B; 3.M; 3.N; 3.R; 3.U; 3.W; 3.AA; 3.AD; 3.AI;Table 3.4.3, Table 3.4.9; Table 3.4.11	
"	Dynamic Amplifiers	3.X	
"	Stability	3.4.4.3.1.3; Figures 3.4.27-32	
V.1.d.i.(4).(c)	Confinement Closure Lid Bolts		
"	Pre-Torque	NA	
"	Analyses	NA	
"	Engagement Length	NA	
"	Miscellaneous Bolting		
"	Pre-Torque	3.F; 3.K	Table 8.1.3
"	Analyses	3.4.4.3.2.3; 3.F; 3.K; 3.Z; Tables 3.4.17, 3.4.18; 3.AE; 3.AF	
"	Engagement Length	3.K	

Table 3.2.3

LIFT WEIGHT ABOVE POOL

Item	Calculated Weight (lb.)
Total weight of overpack	153,710
Total weight of an MPC (Upper Bound) + fuel	89,057[1]
Overpack closure plate	-7,984
Water in MPC and overpack	16,384
Lift yoke	3,600
Inflatable annulus seal	50
TOTAL	254,816[2]

1 Includes MPC closure ring.

2 Trunnion rating and crane limits at certain sites may require temporary water removal from the HI-STAR 100 System during removal from the pool (See Chapter 8).

Table 3.2.4
COMPONENT WEIGHTS AND DIMENSIONS FOR ANALYTIC CALCULATIONS[1]

Component	Weight (lbs)
MPC baseplate	3,000
MPC closure lid	10,400
MPC shell	5,900
MPC basket supports and fuel spacers	3,700
Fuel basket	13,000
Fuel	54,000
Total MPC package	90,000
Overpack bottom plate	10,000
Overpack closure plate	8,000
Overpack shell	137,000
Total overpack	155,000
Total HI-STAR 100 lift weight	250,000
Item	**Dimension (inch)**
Overpack Outer Diameter	96
Overpack Length	203.125
MPC Outer Diameter	68.375
MPC Length	190.5
Overpack Inner Diameter	68.75

1 Analytic calculations may use the weights and dimensions in Table 3.2.4 or actual weights and dimensions for conservatism in calculation of safety factors. Finite element analyses use other bounding weights or weights calculated based on input weight densities.

3.AC MPC Enclosure Vessel Lifting
3.AD Thermal Expansion During Fire Accident
3.AE Stress Analysis of Overpack Closure Bolts Under Cold Conditions of Storage
3.AF Stress Analysis of Overpack Closure Bolts for the Storage Fire Accident
3.AG Stress Analysis of the HI-STAR 100 Enclosure Shell Under 30 psi Internal Pressure
3.AH MPC-Lift Lugs
3.AI Analysis of Transnuclear Damaged Fuel Canister and Thoria Rod Canister

The margin of safety, $MS_9 := \frac{S_{acr}}{SI_{ring}} - 1$ $MS_9 = 0.405$

Since the actual support condition provides some clamped support, this result is very conservative.

The total load capacity of the closure ring weld is determined by calculating the total area of the two weld lines at radii R_i and R_o, multiplying by the allowable weld stress, and conservatively applying the specified weld efficiency.

The closure ring weld thickness, $t_{crw} := 0.125 \cdot in$ (this allows for fit-up)

The quality factor for a single groove or a single fillet weld that is examined by root and final PT is $n := 0.45$

The load capacity of the ring welds, $LC_{crw} := n \cdot 2 \cdot \pi \cdot \left(R_i + \frac{R_o}{\sqrt{2}}\right) \cdot t_{crw} \cdot Sa$

$LC_{crw} = 3.164 \times 10^5\, lbf$

The margin of safety of these welds for the applied loading condition (internal pressure only) is determined as:

$$MS_{10} := \frac{LC_{crw}}{\pi \cdot P_{int} \cdot \left(R_o^2 - R_i^2\right)} - 1 \qquad MS_{10} = 1.24$$

3.E.9 Conclusions

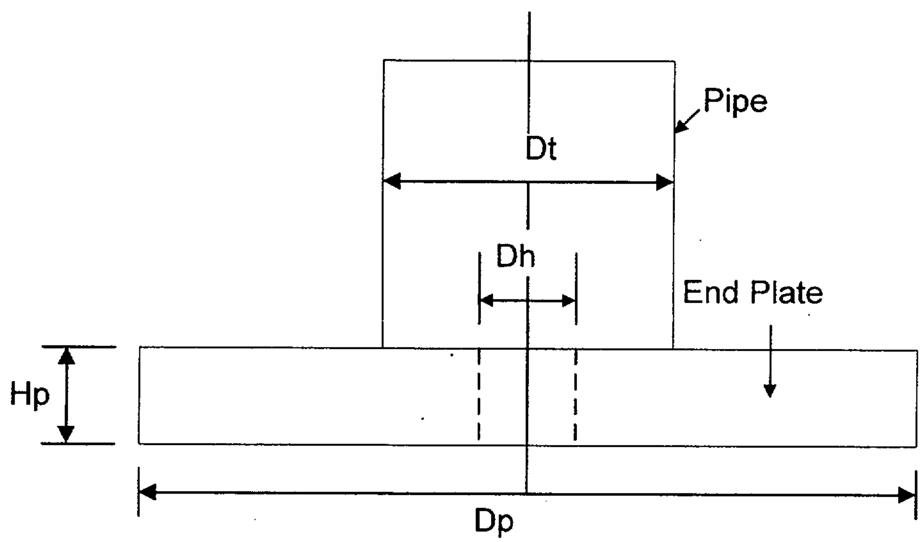
The results of the evaluations presented in this appendix demonstrate the adequacy of the MPC closure plate, closure ring and associated weldments to maintain their structural integrity during applied bounding load cases considered. Positive safety margins exist for all components examined for all load cases considered.

The bending stress evaluation of the closure ring conservatively assumes a simple support condition at the peripheral welds. Therefore, any seal welds in the closure ring configuration need be sized based on positive margins on shear stress.

The seal weld size (0.125") adequately supports the expacted shear load. Note that a closure ring peripheral weld thickness as small as 0.056" provides a small positive margin of safety.

3.J.4 Analysis of Upper Spacer End Plate for PWR Spacers

Some PWR fuel types are not supportable by the current upper spacer design having a simple pipe extension. To insure that all PWR fuel types are captured, an end plate having sufficient diameter is welded to the end of the pipe to extend the contact area. This section of the appendix addresses the stress analysis of the end plate to insure that it performs as desired under a handling accident that results in a direct impact of the fuel assembly onto the end plate. The configuration is shown below:



The dimensions are:(note that outer adius is taken equal to inside radius of limiting fuel assembly contact circle

$Hp := 0.75 \cdot in$ $\qquad$ $Dp := 4.1 \cdot in$ $\qquad$ $Dt := 3.5 \cdot in$ $\qquad$ $Dh := 1 \cdot in$

Under the postulated handling accident, the total applied load is (design basis deceleration of 60 g's):

$P := 60 \cdot 1680 \cdot lbf$ $\qquad$ $P = 1.008 \times 10^{5}\, lbf$

This load may be applied as a line load around the outer periphery

$$q_o := \frac{P}{\pi \cdot Dp} \qquad q_o = 7.826 \times 10^{3} \frac{lbf}{in}$$

or it may be applied as a line load at a diameter of 1.8" (from a survey of fuel assembly types)

$$q_i := \frac{P}{\pi \cdot 1.8 \cdot in} \qquad q_i = 1.783 \times 10^{4} \frac{lbf}{in}$$

In either case, the shear load at the pipe connection is approximately

$$q_p := \frac{P}{\pi \cdot Dt} \qquad q_p = 9.167 \times 10^3 \frac{lbf}{in}$$

At the design temperature, the ultimate strength is, (conservatively neglect any increase in ultimate strength due to strain rate effects

$$S_u := 62350 \cdot psi$$

The spacer pipe has been designed to NG, Level D requirements for axial strength and to the appropriate ASME Code requirements for gross stability. The function of the end plate is to insure that the fuel assembly impacts the spacer; the only requirement is that under an accident condition, no permanent deformation of this end plate occurs to the extent that the positioning limits of the fuel assembly is compromised. This is insured if we demonstrate that the ultimate shear capacity of the added end plate and the ultimate moment capacity of the end plate is not exceeded during the impact. Satisfaction of these stress limits will insure that no large axial movement of the assembly can occur because of the impact.

The ultimate shear capacity of the section is taken as 0.577Su, and the ultimate moment capacity is calculated assuming perfectly plastic behavior at the ultimate stress. Therefore, at any section of the plate the shear capacity is:

$$q_{cap} := .577 \cdot S_u \cdot Hp \qquad q_{cap} = 2.698 \times 10^4 \frac{lbf}{in}$$

Comparison of this limit with the peripheral shear loads computed previously demonstrates that the end plate will not experience a gross shear failure at any section. The minimum safety factor "SF" is

$$\frac{q_{cap}}{q_i} = 1.514$$

The ultimate moment capacity is (assume rectangular distribution throuh the thickness):

$$M_u := S_u \cdot \frac{Hp^2}{4} \qquad M_u = 8.768 \times 10^3 in \cdot \frac{lbf}{in}$$

The weight of the added end plate is:

$$Weight := 0.29 \cdot \frac{lbf}{in^3} \cdot \frac{\pi}{4} \cdot Hp \cdot \left(Dp^2 - Dh^2\right) \qquad Weight = 2.701\, lbf$$

The following calculations are performed to establish the maximum bending moment in the end plate based on the two extreme locations of impact load. The electronic version of Roark's Handbook (6th Edition) that is a Mathcad add-on, is used for this computation. Mathcad 2000 is used for this section of Appendix 3.J.

Table 24 Formulas for shear, moment and deflection of flat circular plates of constant thickness

Cases 1a - 1d Annular Plate With Uniform Annular Line Load w at Radius r_0; Outer Edge Simply Supported

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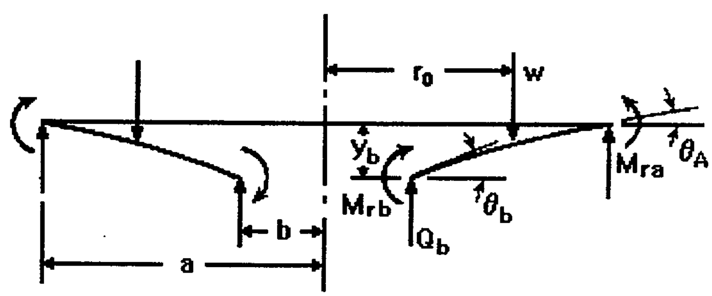
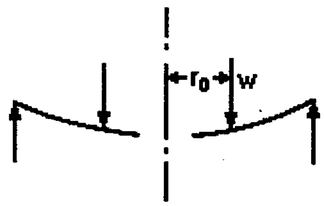
This file corresponds to Cases 1a - 1d in *Roark's Formulas for Stress and Strain.*

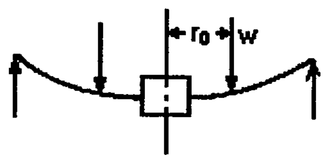
Annular plate with a uniform annular line load w at a radius r_o



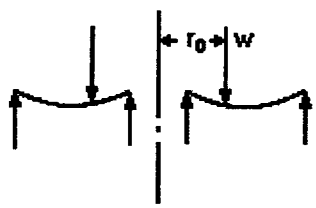
Outer edge simply supported, inner edge free



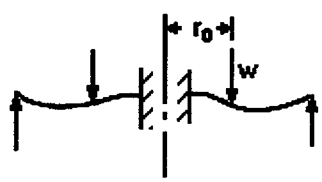
Outer edge simply supported, inner edge guided



Outer edge simply supported, inner edge simply supported



Outer edge simply supported, inner edge fixed



CASE 1A applies to the impact load at the outer periphery. The pipe diameter is the applied load location

Enter dimensions, properties and loading

Plate dimensions:

thickness: $t \equiv 0.75 \cdot in$

outer radius: $a \equiv 2.05 \cdot in$

inner radius: $b \equiv 0.5 \cdot in$

Applied unit load: $w \equiv 9167 \cdot \frac{lbf}{in}$

Modulus of elasticity: $E \equiv 24.625 \cdot 10^{6} \cdot \frac{lbf}{in^{2}}$

Poisson's ratio: $\nu \equiv 0.3$

Radial location of applied load: $r_0 \equiv .5 \cdot 3.5 \cdot in$

Constants

Shear modulus: $G \equiv \frac{E}{2 \cdot (1 + \nu)}$

D is a plate constant used in determining boundary values; it is also used in the general equations for deflection, slope, moment and shear. K_{sb} and K_{sro} are tangential shear constants used in determining the deflection due to shear:

$$D \equiv \frac{E \cdot t^{3}}{12 \cdot \left(1 - \nu^{2}\right)} \qquad D = 9.513 \times 10^{5} \, lbf \cdot in$$

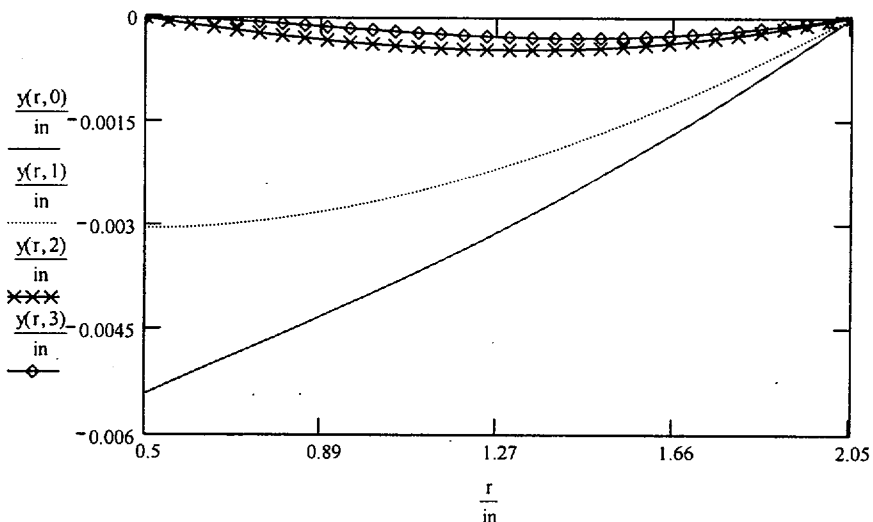
$$K_{sro} \equiv -1.2 \cdot \frac{r_o}{a} \cdot \ln\left(\frac{a}{r_o}\right) \qquad K_{sb} \equiv K_{sro}$$

General formulas and graphs for deflection, slope, moment, shear and stress as a function of r

Define r, the range of the radius and i, the vector index:

$r \equiv b, 1.1 \cdot b .. a$ $\qquad\qquad$ $i \equiv 0 .. 3$

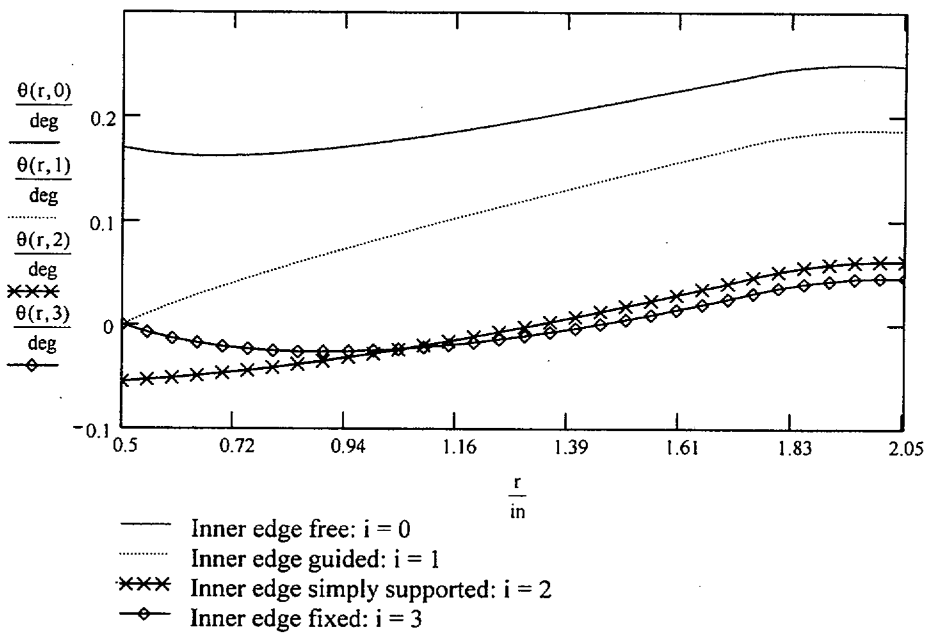
Deflection $\quad y(r,i) := y_{b_i} + \theta_{b_i} \cdot r \cdot F_1(r) + M_{rb_i} \cdot \frac{r^2}{D} \cdot F_2(r) + Q_{b_i} \cdot \frac{r^3}{D} \cdot F_3(r) - w \cdot \frac{r^3}{D} \cdot G_3(r)$



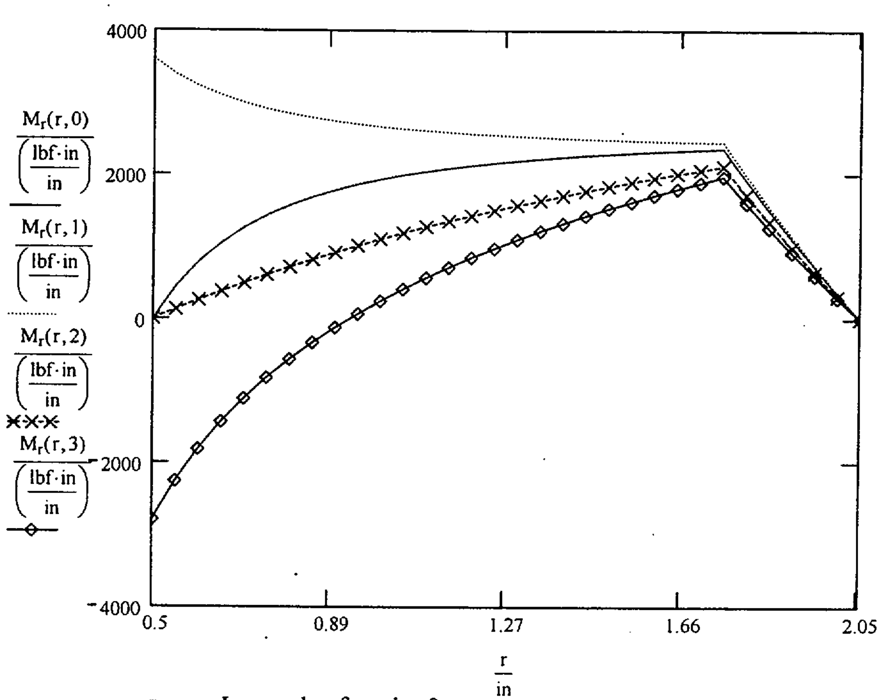
Inner edge free: i = 0
Inner edge guided: i = 1
Inner edge simply supported: i = 2
Inner edge fixed: i = 3

Slope

$$\theta(r,i) := \theta_{b_i} \cdot F_4(r) + M_{rb_i} \cdot \frac{r}{D} \cdot F_5(r) + Q_{b_i} \cdot \frac{r^2}{D} \cdot F_6(r) - w \cdot \frac{r^2}{D} \cdot G_6(r)$$



Radial moment $M_r(r,i) := \theta_{b_i} \cdot \frac{D}{r} \cdot F_7(r) + M_{rb_i} \cdot F_8(r) + Q_{b_i} \cdot r \cdot F_9(r) - w \cdot r \cdot G_9(r)$



Inner edge free: i = 0
Inner edge guided: i = 1
Inner edge simply supported: i = 2
Inner edge fixed: i = 3

The following values are listed in order of inner edge:

- **free (i = 0)**
- **guided (i = 1)**
- **simply supported (i = 2)**
- **fixed (i = 3)**

Moment at points b and a (inner and outer radius):

$$\frac{M_{rb}}{\left(\frac{lbf \cdot in}{in}\right)} = \begin{pmatrix} 0 \\ 3.595 \times 10^{3} \\ 0 \\ -2.798 \times 10^{3} \end{pmatrix} \qquad \frac{M_{ra}}{\left(\frac{lbf \cdot in}{in}\right)} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Maximum radial moment (magnitude):

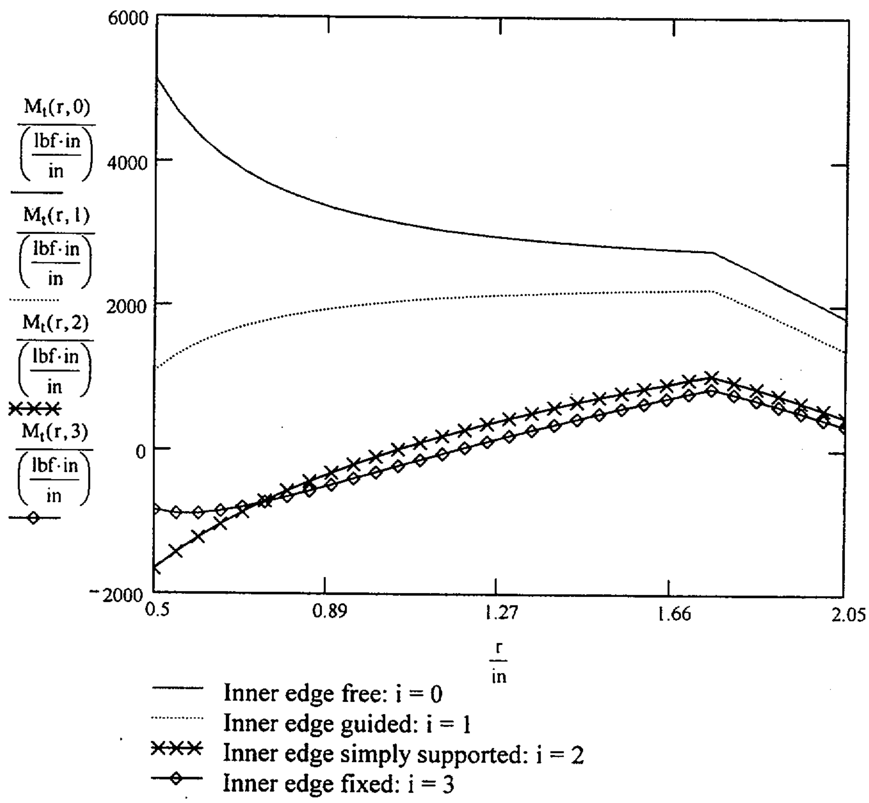
$$Mr_{(r-b)\cdot\frac{100}{in},i} := M_r(r,i) \qquad A_{mr_i} := \max\left(Mr^{\langle i\rangle}\right) \qquad B_{mr_i} := \min\left(Mr^{\langle i\rangle}\right)$$

$$Mr_{max_i} := \left(A_{mr_i} > -B_{mr_i}\right)\cdot A_{mr_i} + \left(A_{mr_i} \le -B_{mr_i}\right)\cdot B_{mr_i}$$

$$\frac{Mr_{max}}{\left(\frac{lbf \cdot in}{in}\right)} = \begin{pmatrix} 2.355 \times 10^{3} \\ 3.595 \times 10^{3} \\ 2.115 \times 10^{3} \\ -2.798 \times 10^{3} \end{pmatrix}$$

Transverse moment

$$M_t(r,i) := \frac{\theta(r,i)\cdot D\cdot\left(1-\nu^2\right)}{r} + \nu\cdot M_r(r,i)$$



The following values are listed in order of inner edge:

- **free (i = 0)**
- **guided (i = 1)**
- **simply supported (i = 2)**
- **fixed (i = 3)**

Transverse moment at points b and a (inner and outer radius) due to bending:

$$\frac{M_t(b,i)}{\left(\frac{lbf \cdot in}{in}\right)} = \qquad \frac{M_t(a,i)}{\left(\frac{lbf \cdot in}{in}\right)} =$$

$M_t(b,i)$	$M_t(a,i)$
$5.128 \cdot 10^3$	$1.828 \cdot 10^3$
$1.078 \cdot 10^3$	$1.373 \cdot 10^3$
$-1.661 \cdot 10^3$	452.798
-839.265	334.706

Maximum tangential moment (magnitude):

$$Mt_{(r-b)\cdot\frac{100}{in},i} := M_t(r,i) \qquad A_{mt_i} := \max\left(Mt^{\langle i \rangle}\right) \qquad B_{mt_i} := \min\left(Mt^{\langle i \rangle}\right)$$

$$Mt_{max_i} := \left(A_{mt_i} > -B_{mt_i}\right)\cdot A_{mt_i} + \left(A_{mt_i} \le -B_{mt_i}\right)\cdot B_{mt_i}$$

$$\frac{Mt_{max}}{\frac{lbf \cdot in}{in}} = \begin{pmatrix} 5.128 \times 10^3 \\ 2.234 \times 10^3 \\ -1.661 \times 10^3 \\ -884.013 \end{pmatrix} \qquad SF := \frac{M_u}{5128 \cdot lbf} \qquad SF = 1.71$$

The remainder of the document displays the general plate functions and constants used in the equations above.

$$C_1 \equiv \frac{1+\nu}{2}\cdot\frac{b}{a}\cdot\ln\left(\frac{a}{b}\right) + \frac{1-\nu}{4}\cdot\left(\frac{a}{b} - \frac{b}{a}\right)$$

$$C_2 \equiv \frac{1}{4}\cdot\left[1 - \left(\frac{b}{a}\right)^2\cdot\left(1 + 2\cdot\ln\left(\frac{a}{b}\right)\right)\right]$$

$$C_3 \equiv \frac{b}{4\cdot a}\cdot\left[\left[\left(\frac{b}{a}\right)^2 + 1\right]\cdot\ln\left(\frac{a}{b}\right) + \left(\frac{b}{a}\right)^2 - 1\right]$$

$$C_4 \equiv \frac{1}{2}\cdot\left[(1+\nu)\cdot\frac{b}{a} + (1-\nu)\cdot\frac{a}{b}\right]$$

$$C_5 \equiv \frac{1}{2}\cdot\left[1 - \left(\frac{b}{a}\right)^2\right]$$

$$C_6 \equiv \frac{b}{4\cdot a}\cdot\left[\left(\frac{b}{a}\right)^2 - 1 + 2\cdot\ln\left(\frac{a}{b}\right)\right]$$

$$C_7 \equiv \frac{1}{2}\cdot\left(1 - \nu^2\right)\cdot\left(\frac{a}{b} - \frac{b}{a}\right)$$

$$C_8 \equiv \frac{1}{2}\cdot\left[1 + \nu + (1-\nu)\cdot\left(\frac{b}{a}\right)^2\right]$$

$$C_9 \equiv \frac{b}{a}\cdot\left[\frac{1+\nu}{2}\cdot\ln\left(\frac{a}{b}\right) + \left(\frac{1-\nu}{4}\right)\cdot\left[1 - \left(\frac{b}{a}\right)^2\right]\right]$$

$$L_3 \equiv \frac{r_o}{4\cdot a}\cdot\left[\left[\left(\frac{r_o}{a}\right)^2 + 1\right]\cdot\ln\left(\frac{a}{r_o}\right) + \left(\frac{r_o}{a}\right)^2 - 1\right]$$

$$L_6 \equiv \frac{r_o}{4\cdot a}\cdot\left[\left(\frac{r_o}{a}\right)^2 - 1 + 2\cdot\ln\left(\frac{a}{r_o}\right)\right]$$

$$L_9 \equiv \frac{r_o}{a}\cdot\left[\frac{1+\nu}{2}\cdot\ln\left(\frac{a}{r_o}\right) + \frac{1-\nu}{4}\cdot\left[1 - \left(\frac{r_o}{a}\right)^2\right]\right]$$

Boundary values due to bending:

At the inner edge of the plate:

$$Q_b \equiv \begin{bmatrix} 0\cdot\dfrac{lbf}{in} \\ 0\cdot\dfrac{lbf}{in} \\ w\cdot\left(\dfrac{C_1\cdot L_9 - C_7\cdot L_3}{C_1\cdot C_9 - C_3\cdot C_7}\right) \\ w\cdot\left(\dfrac{C_2\cdot L_9 - C_8\cdot L_3}{C_2\cdot C_9 - C_3\cdot C_8}\right) \end{bmatrix} \qquad M_{rb} \equiv \begin{bmatrix} 0\cdot\dfrac{lbf\cdot in}{in} \\ \dfrac{w\cdot a}{C_8}\cdot L_9 \\ 0\cdot\dfrac{lbf\cdot in}{in} \\ -w\cdot a\cdot\left(\dfrac{C_3\cdot L_9 - C_9\cdot L_3}{C_2\cdot C_9 - C_3\cdot C_8}\right) \end{bmatrix}$$

$$y_b \equiv \begin{bmatrix} \dfrac{-w\cdot a^3}{D}\cdot\left(\dfrac{C_1\cdot L_9}{C_7} - L_3\right) \\ \dfrac{-w\cdot a^3}{D}\cdot\left(\dfrac{C_2\cdot L_9}{C_8} - L_3\right) \\ 0\cdot in \\ 0\cdot in \end{bmatrix} \qquad \theta_b \equiv \begin{bmatrix} \dfrac{w\cdot a^2}{D\cdot C_7}\cdot L_9 \\ 0\cdot deg \\ \dfrac{-w\cdot a^2}{D}\cdot\left(\dfrac{C_3\cdot L_9 - C_9\cdot L_3}{C_1\cdot C_9 - C_3\cdot C_7}\right) \\ 0\cdot deg \end{bmatrix}$$

At the outer edge of the plate:

$$y_a \equiv \begin{pmatrix} 0 \cdot in \\ 0 \cdot in \\ 0 \cdot in \\ 0 \cdot in \end{pmatrix}$$

$$\theta_a \equiv \begin{bmatrix} \frac{w \cdot a^2}{D} \cdot \left(\frac{C_4 \cdot L_9}{C_7} - L_6 \right) \\ \frac{w \cdot a^2}{D} \cdot \left(\frac{C_5 \cdot L_9}{C_8} - L_6 \right) \\ \theta_{b_2} \cdot C_4 + Q_{b_2} \cdot \frac{a^2}{D} \cdot C_6 - \frac{w \cdot a^2}{D} \cdot L_6 \\ M_{rb_3} \cdot \frac{a}{D} \cdot C_5 + Q_{b_3} \cdot \frac{a^2}{D} \cdot C_6 - \frac{w \cdot a^2}{D} \cdot L_6 \end{bmatrix} \quad Q_a \equiv \begin{pmatrix} -w \cdot \frac{r_o}{a} \\ -w \cdot \frac{r_o}{a} \\ Q_{b_2} \cdot \frac{b}{a} - \frac{w \cdot r_o}{a} \\ Q_{b_3} \cdot \frac{b}{a} - \frac{w \cdot r_o}{a} \end{pmatrix} \quad M_{ra} \equiv \begin{pmatrix} 0 \cdot \frac{lbf \cdot in}{in} \\ 0 \cdot \frac{lbf \cdot in}{in} \\ 0 \cdot \frac{lbf \cdot in}{in} \\ 0 \cdot \frac{lbf \cdot in}{in} \end{pmatrix}$$

Due to tangential shear stresses:

$$y_{sb} \equiv \begin{pmatrix} \frac{K_{sb} \cdot w \cdot a}{t \cdot G} \\ \frac{K_{sb} \cdot w \cdot a}{t \cdot G} \\ 0 \cdot in \\ 0 \cdot in \end{pmatrix} \quad y_{sro} \equiv \begin{pmatrix} \frac{K_{sro} \cdot w \cdot r_o}{t \cdot G} \\ \frac{K_{sro} \cdot w \cdot r_o}{t \cdot G} \\ 0 \cdot in \\ 0 \cdot in \end{pmatrix}$$

$$F_1(r) \equiv \frac{1+\nu}{2}\cdot\frac{b}{r}\cdot\ln\left(\frac{r}{b}\right) + \frac{1-\nu}{4}\cdot\left(\frac{r}{b} - \frac{b}{r}\right)$$

$$F_2(r) \equiv \frac{1}{4}\cdot\left[1 - \left(\frac{b}{r}\right)^2\cdot\left(1 + 2\cdot\ln\left(\frac{r}{b}\right)\right)\right]$$

$$F_3(r) \equiv \frac{b}{4\cdot r}\cdot\left[\left[\left(\frac{b}{r}\right)^2 + 1\right]\cdot\ln\left(\frac{r}{b}\right) + \left(\frac{b}{r}\right)^2 - 1\right]$$

$$F_4(r) \equiv \frac{1}{2}\cdot\left[(1+\nu)\cdot\frac{b}{r} + (1-\nu)\cdot\frac{r}{b}\right]$$

$$F_5(r) \equiv \frac{1}{2}\cdot\left[1 - \left(\frac{b}{r}\right)^2\right]$$

$$F_6(r) \equiv \frac{b}{4\cdot r}\cdot\left[\left(\frac{b}{r}\right)^2 - 1 + 2\cdot\ln\left(\frac{r}{b}\right)\right]$$

$$F_7(r) \equiv \frac{1}{2}\cdot\left(1-\nu^2\right)\cdot\left(\frac{r}{b} - \frac{b}{r}\right)$$

$$F_8(r) \equiv \frac{1}{2}\cdot\left[1 + \nu + (1-\nu)\cdot\left(\frac{b}{r}\right)^2\right]$$

$$F_9(r) \equiv \frac{b}{r}\cdot\left[\frac{1+\nu}{2}\cdot\ln\left(\frac{r}{b}\right) + \frac{1-\nu}{4}\cdot\left[1 - \left(\frac{b}{r}\right)^2\right]\right]$$

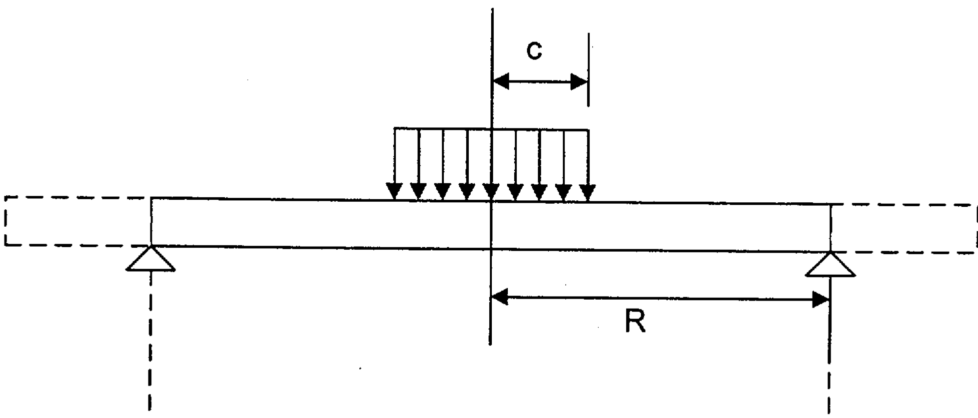
$$G_3(r) \equiv \frac{r_o}{4\cdot r}\cdot\left[\left[\left(\frac{r_o}{r}\right)^2 + 1\right]\cdot\ln\left(\frac{r}{r_o}\right) + \left(\frac{r_o}{r}\right)^2 - 1\right]\cdot(r > r_o)$$

$$G_6(r) \equiv \frac{r_o}{4\cdot r}\cdot\left[\left(\frac{r_o}{r}\right)^2 - 1 + 2\cdot\ln\left(\frac{r}{r_o}\right)\right]\cdot(r > r_o)$$

$$G_9(r) \equiv \frac{r_o}{r}\cdot\left[\frac{1+\nu}{2}\cdot\ln\left(\frac{r}{r_o}\right) + \frac{1-\nu}{4}\cdot\left[1 - \left(\frac{r_o}{r}\right)^2\right]\right]\cdot(r > r_o)$$

The actual safety factor against a complete collapse of the ring like plate is much larger since unlimited large rotations will only occur when a substantial region of the plate has the circumferential moment reach capacity (this can be shown by a limit analysis solution of the plate equations).

The second impact scenario has the loading applied over a region inside the outer diameter of the pipe. To qualify this load case, we consider the plate as simply supported at the pipe diameter and conservatively neglect the overhanging portion of the pipe. Further, we assume the loading is conservatively applied as a uniform pressure over an area equal to the minimum impact diameter of 1.8". For simplicity, we neglect the inner hole in this calculation. Therefore, the limit analysis model for the second impact scenario is shown below:



Calculate effective load area at middle surface assuming a 45 degree spread of load patch

$Hp = 0.75\ in$

$R := 0.5\cdot[(3.5 - 2\cdot 0.226)\cdot in]$

$P = 1.008\times 10^{5}\ lbf$

$c := 0.5\cdot(1.8\cdot in + Hp)$

Use inside radius of pipe for this calc.

$M_u = 8.768\times 10^{3}\ lbf\cdot\frac{in}{in}$

Using a solution in the text "Introduction to Plasticity"by W. Prager, Addison Wesley, 1959, p. 61, the limit load is

$$P_{lim} := 6\cdot\pi\cdot\frac{M_u}{\left(3 - 2\cdot\frac{c}{R}\right)}$$

Therefore, the safety factor for this case is

$$\frac{P_{lim}}{P} = 1.236$$

Therefore it is concluded that an end plate of diameter and thickness equal to

$Dp = 4.1\ in$ $Hp = 0.75\ in$

will perform the intended load transfer and limit the movement of the fuel assembly.

(d) Calculation of Weld Shear Stress

We consider the vertical weld between enclosure shell flat panels and the radial sectors and the circumferential weld between the enclosure shell and the enclosure shell return as representative welds for analysis. Table NF-3324.5(a)-1 in Subsection NF of the Code, requires that the allowable stress for the weld be equal to the allowable stress in the base metal. For the allowable weld stress in shear, we apply the limit given in NF-3252.2 for pure shear, namely, 60% of the tensile limit.

Model the weld as a 3/16" groove weld for calculation purposes.

$$t_{weld} := \frac{3}{16} \cdot in$$

The shear stress due to the internal pressure in the vertical flat panel weld is

$$\tau_{weld} := \frac{q \cdot .5 \cdot b_s}{t_{weld}} \qquad \tau_{weld} = 630\,psi$$

Since the allowable base metal stress for primary bending has been input earlier, we divide this value by 1.5 to obtain an allowable primary membrane stress.

$$SF := \frac{.6 \cdot \left(\frac{S_a}{1.5}\right)}{\tau_{weld}} \qquad SF = 16.698$$

For the weld around the annular ring, we note that since the unsupported strip width is less than the value used above, the weld shear stress will be even lower. Thus, the flat panel weld controls the design.

3.AG.4 Conclusion

For a 30 psi internal pressure, all safety factors are well in excess of 1.0 demonstrating that the 30 psig internal pressure is safely supported by the enclosure shell and the enclosure shell return.

Although the effect of dead weight of the neutron absorber material has not been included as an additional loading in the analysis of the enclosure shell return, it is clear from the large safety factors that structural integrity will not be compromised.

There is no credible mechanism for the pressure to exceed 30 psi under normal operating conditions in the enclosure shell sectors.

APPENDIX 3.AI - ANALYSIS OF TRANSNUCLEAR DAMAGED FUEL CANISTER AND THORIA ROD CANISTER

3.AI.1 Introduction

Some of the items at the Dresden Station that have been considered for storage in the HI-STAR 100 System are damaged fuel stored in Transnuclear damaged fuel canisters and Thoria rods that are also stored in a special canister designed by Transnuclear. Both of these canisters have been designed and have been used by ComEd to transport the damaged fuel and the Thoria rods. Despite the previous usage of these canisters, it is prudent and appropriate to provide an independent structural analysis of the major load path of these canisters prior to accepting them for inclusion as permitted items in the HI-STAR 100 MPC's. This appendix contains the necessary structural analysis of the Transnuclear damaged fuel canister and Thoria rod canister. The objective of the analysis is to demonstrate that the canisters are structurally adequate to support the loads that develop during normal lifting operations and during postulated accident conditions.

The upper closure assembly is designed to meet the requirements of NUREG-0612 [2]. The remaining components of the canisters are governed by ASME Code Section III, Subsection NG [3]. These are the same criteria used in Appendix 3.B to analyze the Holtec damaged fuel container for Dresden damaged fuel.

3.AI.2 Composition

This appendix was created using the Mathcad (version 8.02) software package. Mathcad uses the symbol ':=' as an assignment operator, and the equals symbol '=' retrieves values for constants or variables.

3.AI.3 References

1. Crane Manufacture's of America Association, Specifications for Electric Overhead Traveling Cranes #70.

2. NUREG-0612, Control of Heavy Loads at Nuclear Power Plants

3. ASME Boiler and Pressure Vessel Code, Section III, July 1995

3.AI.4 Assumptions

1. Buckling is not a concern during an accident since during a drop the canister will be confined by the fuel basket.

2. The strength of the weld is assumed to decrease the same as the base metal as the temperature increases.

3.AI.5 Method

Two are considered: 1) normal lifting and handling of canister, and 2) accident drop event.

3.AI.6 Acceptance Criteria

1) Normal Handling -

a) Canister governed by ASME NG allowables:

b)Welds governed by NG and NF allowables;
quality factors taken from NG
stress limit = 0.3 Su

c) Lifting governed by NUREG-0612 allowables.

2) Drop Accident -

a) canister governed by ASME NG allowables:
shear = 0.42 Su (conservative)

b)Welds governed by NG and NF allowables;
quality factors taken from NG
stress limit = 0.42 Su

3.AI.7 Input Stress Data

The canisters is handled while still in the spent fuel pool. Therefore, its design temperature for lifting considerations is the temperature of the fuel pool water (150°F). The design temperature for accident conditions is 725°F. All dimensions are taken from the Transnuclear design drawings listed at the end of this appendix. The basic input parameters used to perform the calculations are:

Design stress intensity of SA240-304 (150°F) $S_{m1} := 20000 \cdot psi$

Design stress intensity of SA240-304 (775°F) $S_{m2} := 15800 \cdot psi$

Yield stress of SA240-304 (150°F) $S_{y1} := 27500 \cdot psi$

Yield stress of SA240-304 (775°F) $S_{y2} := 17500 \cdot psi$

Ultimate strength of SA240-304 (150°F) $S_{u1} := 73000 \cdot psi$

Ultimate strength of SA240-304 (775°F) $S_{u2} := 63300 \cdot psi$

Ultimate strength of weld material (150°F) $Su_w := 70000 \cdot psi$

Ultimate strength of weld material (775°F) $Su_{wacc} := Su_w - (S_{u1} - S_{u2})$

Weight of a BWR fuel assembly (D-1) $W_{fuel} := 400 \cdot lbf$

Weight of 18 Thoria Rods (Calculated by Holtec) $W_{thoria} := 90 \cdot lbf$

Bounding Weight of the damaged fuel canister (Estimated by Holtec) $W_{container} := 150 \cdot lbf$

Bounding Weight of the Thoria Rod Canister (Estimated) $W_{rodcan} := 300 \cdot lbf$

Quality factor for full penetration weld (visual inspection) $n := 0.5$

Dynamic load factor for lifting $DLF := 1.15$

The remaining input data is provided as needed in the calculation section

3.AI.8 Calculations for Transnuclear Damaged Fuel Canister

3.AI.8.1 Lifting Operation (Normal Condition)

The critical load case under normal conditions is the lifting operation. The key areas of concern for ASME NG analysis are the canister sleeve, the sleeve to lid frame weld, and the lid frame. All calculations performed for the lifting operation assume a dynamic load factor of 1.15 [1].

3.AI.8.1.1 Canister Sleeve

During a lift, the canister sleeve is loaded axially, and the stress state is pure tensile membrane. For the subsequent stress calculation, it is assumed that the full weight of the damaged fuel canister and the fuel assembly are supported by the sleeve. The magnitude of the load is

$$F := DLF \cdot (W_{container} + W_{fuel}) \qquad F = 632\, lbf$$

From TN drawing 9317.1-120-4, the canister sleeve geometry is

$id_{sleeve} := 4.81 \cdot in$ $\qquad t_{sleeve} := 0.11 \cdot in$

The cross sectional area of the sleeve is

$$A_{sleeve} := (id_{sleeve} + 2 \cdot t_{sleeve})^2 - id_{sleeve}^2 \qquad A_{sleeve} = 2.16\, in^2$$

Therefore, the tensile stress in the sleeve is $\sigma := \frac{F}{A_{sleeve}}$ $\sigma = 292\,\text{psi}$

The allowable stress intensity for the primary membrane category is S_m per Subsection NG of the ASME Code. The corresponding safety margin is

$$SM := \frac{S_{ml}}{\sigma} - 1 \qquad SM = 67.5$$

3.AI.8.1.2 Sleeve Welds

The top of the canister must support the amplified weight. This load is carried directly by the fillet weld that connects the lid frame to the canister sleeve. The magnitude of the load is conservatively taken a the entire amplified weight of canister plus fuel.

$$F = 632\,\text{lbf}$$

The weld thickness is $t_{base} := 0.09 \cdot in$

The area of the weld, with proper consideration of quality factors, is

$$A_{weld} := n \cdot 4 \cdot \left(id_{sleeve} + 2 \cdot t_{sleeve}\right) \cdot .7071 \cdot t_{base} \qquad A_{weld} = 0.64\,\text{in}^2$$

Therefore, the shear stress in the weld is $\tau := \frac{F}{A_{weld}}$ $\tau = 988\,\text{psi}$

From the ASME Code the allowable weld shear stress, under normal conditions (Level A), is 30% of the ultimate strength of the base metal. The corresponding safety margin is

$$SM := \frac{0.3 \cdot S_{ul}}{\tau} - 1 \qquad SM = 21.2$$

3.AI.8.1.3 Lid Frame Assembly

The Lid Frame assembly is classified as a NUREG-0612 lifting device. As such the allowable stress for design is the lesser of one-sixth of the yield stress and one-tenth of the ultimate strength.

$$\sigma_l := \frac{S_{yl}}{6} \qquad \sigma_2 := \frac{S_{ul}}{10}$$

$$\sigma_l = 4583\,\text{psi} \qquad \sigma_2 = 7300\,\text{psi}$$

For SA240-304 material the yield stress governs. $\sigma_{allowable} := \sigma_{1}$

The total lifted load is $F := DLF\cdot(W_{container} + W_{fuel})$ $F = 632\ lbf$

The frame thickness is obtained from Transnuclear drawing 9317.1-120-11

$t_{frame} := 0.395\cdot in$

The inside span is the same as the canister sleeve $id_{sleeve} = 4.81\ in$

The area available for direct load is

$A_{frame} := (id_{sleeve} + 2\cdot t_{frame})^2 - id_{sleeve}^2$ $A_{frame} = 8.224\ in^2$

The direct stress in the frame is $\sigma := \dfrac{F}{A_{frame}}$ $\sigma = 77\ psi$

The safety margin is $SM := \dfrac{\sigma_{allowable}}{\sigma} - 1$ $SM = 58.59$

The bearing stress at the four lift locations is computed from the same drawing

$A_{bearing} := 4\cdot t_{frame}\cdot(2\cdot 0.38\cdot in)$ $A_{bearing} = 1.201\ in^2$

$\sigma_{bearing} := \dfrac{F}{A_{bearing}}$ $\sigma_{bearing} = 526.732\ psi$ $SM := \dfrac{\sigma_{allowable}}{\sigma_{bearing}} - 1$ $SM = 7.7$

3.AI.8.2 60g End Drop (Accident Condition)

The critical member of the damaged fuel canister during the drop scenario is the bottom assembly (see Transnuclear drawing 9317.1-120-5). It is subjected to direct compression due to the amplified weight of the fuel assembly and the canister. The bottom assembly is a 3.5" Schedule 40S pipe. The load due to the 60g end drop is

$F := 60\cdot(W_{fuel} + W_{container})$ $F = 33000\ lbf$

The properties of the pipe are obtained from the Ryerson Stock Catalog as

$od := 4\cdot in$ $id := 3.548\cdot in$ $t_{pipe} := \dfrac{(od - id)}{2}$ $t_{pipe} = 0.226\ in$

The pipe area is

$$A_{pipe} := \frac{\pi}{4}\cdot\left(od^2 - id^2\right) \qquad A_{pipe} = 2.68\,in^2$$

The stress in the member is

$$\sigma := \frac{F}{A_{pipe}} \qquad \sigma = 12316\,psi$$

The allowable primary membrane stress from Subsection NG of the ASME Code, for accident conditions (Level D), is

$$\sigma_{allowable} := 2.4\cdot S_{m2} \qquad \sigma_{allowable} = 37920\,psi$$

The safety margin is

$$SM := \frac{\sigma_{allowable}}{\sigma} - 1 \qquad SM = 2.1$$

To check the stability of the pipe, we conservatively compute the Euler Buckling load for a simply supported beam.

The Young's Modulus is

$$E := 27600000\cdot psi$$

Compute the moment of inertia as

$$I := \frac{\pi}{64}\cdot\left(od^4 - id^4\right) \qquad I = 4.788\,in^4$$

$$L := 22\cdot in \qquad P_{crit} := \pi^2\cdot\frac{E\cdot I}{L^2} \qquad P_{crit} = 2.695\times 10^6\,lbf$$

The safety margin is

$$SM := \frac{P_{crit}}{F} - 1 \qquad SM = 80.654$$

3.AI.8.3 Conclusion for TN Damaged Fuel Canister

The damaged fuel canister and the upper closure assembly are structurally adequate to withstand the specified normal and accident condition loads. All calculated safety margins are greater than zero.

3.AI.9 Calculations for Transnuclear Thoria Rod Canister

3.AI.9.1 Lifting Operation (Normal Condition)

The critical load case under normal conditions is the lifting operation. The key areas of concern for ASME NG analysis are the canister sleeve, the sleeve to lid frame weld, and the lid frame. All calculations performed for the lifting operation assume a dynamic load factor of 1.15.

3.AI.9.1.1 Canister Sleeve

During a lift, the canister sleeve is loaded axially, and the stress state is pure tensile membrane. For the subsequent stress calculation, it is assumed that the full weight of the Thoria rod canister and the Thoria rods are supported by the sleeve. The magnitude of the load is

$$F := DLF \cdot (W_{rodcan} + W_{thoria}) \qquad F = 449\ lbf$$

From TN drawing 9317.1-182-1, the canister sleeve geometry is

$id_{sleeve} := 4.81 \cdot in$ $\qquad t_{sleeve} := 0.11 \cdot in$

The cross sectional area of the sleeve is

$$A_{sleeve} := (id_{sleeve} + 2 \cdot t_{sleeve})^2 - id_{sleeve}^2 \qquad A_{sleeve} = 2.16\ in^2$$

Therefore, the tensile stress in the sleeve is $\sigma := \frac{F}{A_{sleeve}}$ $\qquad \sigma = 207\ psi$

The allowable stress intensity for the primary membrane category is S_m per Subsection NG of the ASME Code. The corresponding safety margin is

$$SM := \frac{S_{ml}}{\sigma} - 1 \qquad SM = 95.5$$

3.AI.9.1.2 Sleeve Welds

The top of the canister must support the amplified weight. This load is carried directly by the fillet weld that connects the lid frame to the canister sleeve. The magnitude of the load is conservatively taken a the entire amplified weight of canister plus Thoria rod.

$$F = 449\ lbf$$

The weld thickness is $t_{base} := 0.09 \cdot in$ (assumed equal to the same weld for the damaged fuel canister

The area of the weld, with proper consideration of quality factors, is

$$A_{weld} := n \cdot 4 \cdot (id_{sleeve} + 2 \cdot t_{sleeve}) \cdot .7071 \cdot t_{base} \qquad A_{weld} = 0.64\ in^2$$

Therefore, the shear stress in the weld is $\tau := \frac{F}{A_{weld}}$ $\qquad \tau = 701\ psi$

From the ASME Code the allowable weld shear stress, under normal conditions (Level A), is 30% of the ultimate strength of the base metal. The corresponding safety margin is

$$SM := \frac{0.3 \cdot S_{ul}}{\tau} - 1 \qquad SM = 30.3$$

3.AI.9.1.3 Lid Frame Assembly

The Lid Frame assembly is classified as a NUREG-0612 lifting device. As such the allowable stress for design is the lesser of one-sixth of the yield stress and one-tenth of the ultimate strength.

$$\sigma_1 := \frac{S_{yl}}{6} \qquad \sigma_2 := \frac{S_{ul}}{10}$$

$$\sigma_1 = 4583\,\text{psi} \qquad \sigma_2 = 7300\,\text{psi}$$

For SA240-304 material the yield stress governs. $\sigma_{allowable} := \sigma_1$

The total lifted load is $F := DLF\cdot(W_{rodcan} + W_{thoria})$ $F = 449\,\text{lbf}$

The frame thickness is obtained from Transnuclear drawing 9317.1-182-8. This drawing was not available, but the TN drawing 9317.1-182-4 that included a view of the lid assembly suggests that it is identical in its structural aspects to the lid frame in the damaged fuel canister.

$$t_{frame} := 0.395\cdot in$$

The inside span is the same as the canister sleeve $id_{sleeve} = 4.81\,\text{in}$

The area available for direct load is

$$A_{frame} := (id_{sleeve} + 2\cdot t_{frame})^2 - id_{sleeve}^2 \qquad A_{frame} = 8.224\,\text{in}^2$$

The direct stress in the frame is

$$\sigma := \frac{F}{A_{frame}} \qquad \sigma = 55\,\text{psi}$$

The safety margin is

$$SM := \frac{\sigma_{allowable}}{\sigma} - 1 \qquad SM = 83.04$$

The bearing stress at the four lift locations is computed from the same drawing

$$A_{bearing} := 4\cdot t_{frame}\cdot(2\cdot 0.38\cdot in) \qquad A_{bearing} = 1.201\,\text{in}^2$$

$$\sigma_{bearing} := \frac{F}{A_{bearing}} \qquad \sigma_{bearing} = 373.501\,\text{psi} \qquad SM := \frac{\sigma_{allowable}}{\sigma_{bearing}} - 1 \qquad SM = 11.27$$

3.AI.9.2 60g End Drop (Accident Condition)

The critical member of the damaged fuel canister during the drop scenario is the bottom assembly. Transnuclear drawing 9317.1-120-5). It is subjected to direct compression due to the amplified weight of the Thoria rods and the canister.

$F := 60 \cdot (W_{thoria} + W_{rodcan})$ $F = 23400\,lbf$

The properties of the pipe are obtained from the Ryerson Stock Catalog as

$od := 4 \cdot in$ $id := 3.548 \cdot in$ $t_{pipe} := \frac{(od - id)}{2}$ $t_{pipe} = 0.226\,in$

The pipe area is $A_{pipe} := \frac{\pi}{4} \cdot (od^2 - id^2)$ $A_{pipe} = 2.68\,in^2$

The stress in the member is $\sigma := \frac{F}{A_{pipe}}$ $\sigma = 8733\,psi$

The allowable primary membrane stress from Subsection NG of the ASME Code, for accident conditions (Level D), is

$\sigma_{allowable} := 2.4 \cdot S_{m2}$ $\sigma_{allowable} = 37920\,psi$

The safety margin is $SM := \frac{\sigma_{allowable}}{\sigma} - 1$ $SM = 3.3$

To check the stability of the pipe, we compute the Euler Buckling load for a simply supported beam.

The Young's Modulus is $E := 27600000 \cdot psi$

Compute the moment of inertia as $I := \frac{\pi}{64} \cdot (od^4 - id^4)$ $I = 4.788\,in^4$

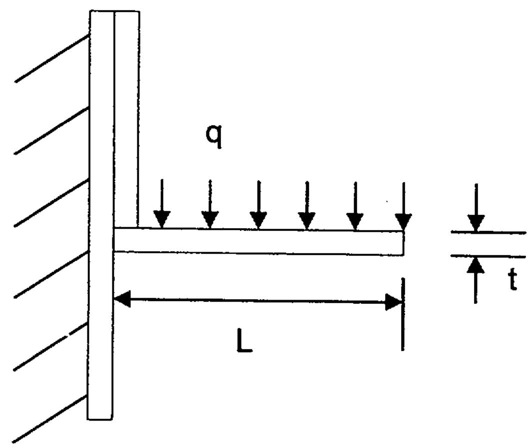
$L := 22 \cdot in$

$P_{crit} := \pi^2 \cdot \frac{E \cdot I}{L^2}$ $P_{crit} = 2.695 \times 10^6\,lbf$

The safety margin is $SM := \frac{P_{crit}}{F} - 1$ $SM = 114.153$

3.AI.9.4 60g Side Drop (Accident Condition)

The Thoria Rod Separator Assembly is shown in TN drawings 9317.1-182-1 and 9317.1-182-3. under the design basis side drop or tipover accident, we examine the consequences to one of the rod support strips acting as a cantilever strip acted upon by self-weight and the weight of one Thoria rod.



Weight of 1 rod per unit length

$length := 113.16 \cdot in$

$w_{rod} := 90 \cdot \frac{lbf}{18} \cdot \frac{1}{length}$ $w_{rod} = 0.044 \frac{lbf}{in}$

Weight of support per unit length (per drawing 9317.1-182-3

$L := 1.06 \cdot in$ $t := 0.11 \cdot in$

$w_{sup} := .29 \cdot \frac{lbf}{in^3} \cdot L \cdot t$ $w_{sup} = 0.034 \frac{lbf}{in}$

Amplified load (assumed as a uniform distribution)

$q := 60 \cdot (w_{rod} + w_{sup})$ $q = 4.68 \frac{lbf}{in}$

$Moment := \frac{q \cdot L^2}{2}$ $Moment = 2.629 \, in \cdot lbf$

Bending stress at the root of the cantilever beam is

$\sigma := 6 \cdot \frac{Moment}{1 \cdot in \cdot t^2}$ $\sigma = 1.304 \times 10^3 \, psi$

Shear stress at the root of the cantilever $\tau := q \cdot \frac{L}{t \cdot 1 \cdot in}$ $\tau = 45.098 \, psi$

Large margins of safety are indicated by these stress results.

3.AI.9.5 Conclusion for TN Thoria Rod Canister

The Thoria rod canister is structurally adequate to withstand the specified normal and accident condition loads. All calculated safety margins are greater than zero.

3.AI.10 General Conclusion

The analysis of the TN damaged fuel canister and the TN Thoria rod canister have demonstrated that all structural safety margins are large. We have confirmed that the TN canisters have positive safety margins for the HI-STAR 100 govening design basis loads. Therefore, the loaded TN canisters from ComEd Dresden Unit#1 can safely be carried in the HI-STAR 100 System.

3.AI.11 List of Transnuclear Drawing Numbers

9317.1-120 - 2,3,4,5,6,7,8,9,10,11,13,14,15,17,18,19,20,21,22,23

9317.1-182- 1,2,3,4,5,6

Table 4.3.2

SUMMARY OF PWR ASSEMBLY RODS INITIAL GAS FILL DATA

Assembly Type	Rods Per Assembly	Free Rod Volume (in.^{3})	Fill Pressure (psig) at 70°F	Fill Gas Volume at STP† (Liters) Per Rod	Fill Gas Volume at STP† (Liters) Per Assembly
W-14x14 Std.	179	1.72	0-460	0.845	151.2
W-15x15 Std.	204	1.25	0-475	0.633	129.1
W-17x17 Std.	264	1.05-1.25	275-500	0.666	175.8
B&W-15x15 Mark B	208	1.308	415	0.582	121.1
B&W-17x17 Mark C	264	0.819	435	0.381	100.6
CE-14x14 Std.	164	1.693	300-450	0.814	133.5
CE-16x16 Std.	220	1.411	300-450	0.678	149.2
B&W-15x15 Mark B-11	*208*	*1.260*	*415*	*0.524*	*109.0*
CE-14x14 (MP2)	*176*	*1.728*	*300-450*	*0.777*	*136.8*

† STP stands for standard temperature (°C) and pressure (1 atmosphere).

Table 4.3.3

BOUNDING VALUES OF FUEL CLADDING STRESS FOR PWR SNF

	W-14X14 Std	**W-15x15 Std**	**W-17x17 Std**	**B&W-15x15 Mark B**	**B&W-17x17 Mark C**	**CE-14x14 Std**	**CE-16x16 Sys 80**	***B&W-15x15 Mark B-11***	***CE-14x14 (MP2)***
Fresh Fuel Rods O.D. (inch)	0.4220	0.422	0.374	0.430	0.379	0.440	0.382	*0.414*	*0.440*
End of Life Oxidation Thickness (inch)†	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	*0.0027*	*0.0027*
End of Life Rods O.D. (inch)	0.4166	0.4166	0.3686	0.4246	0.3736	0.4346	0.3766	*0.4086*	*0.4346*
Rods I.D. (inch)	0.3734	0.373	0.329	0.377	0.331	0.384	0.332	*0.370*	*0.388*
Average tube Diameter (inch)	0.3950	0.3948	0.3488	0.4008	0.3523	0.4093	0.3493	*0.3893*	*0.4113*
Wall Thickness (inch)	0.0216	0.0218	0.0198	0.0238	0.0213	0.0253	0.0223	*0.0193*	*0.0233*
Hot Volume Pressure at 300°C (MPa)††	9.77	10.67	10.08	9.62	10.87	10.01	9.61	*9.40*	*9.23*
Cladding Stress (MPa)	89.3	96.7	88.8	81.0	90.0	81.0	75.2	*94.8*	*81.4*

† PNL-4835 [4.3.4] reported maximum cladding thickness loss due to in-reactor oxidation.

†† This average rod gas temperature conservatively bounds the plenum gas temperature.

Table 4.3.5
SUMMARY OF BWR ASSEMBLY RODS INITIAL GAS FILL DATA

Assembly Type	Rods/ Assembly	Free Rod Volume (in^3)	Fill Pressure (psig) at 70°F	Fill Gas Volume at STP	
				(liters) Per Rod	(liters) Per Assembly
GE-7x7 (1966)	49	2.073	0-44.1[†]	0.126	6.17
GE-7x7 (1968)	49	2.073	0-44.1	0.126	6.17
GE-7x7R	49	1.991	0-44.1	0.121	5.93
GE-8x8	60	1.504	0-44.1	0.0915	5.49
GE-8x8R	60	1.433	0-147[††]	0.240	14.4
EXXON-9x9	79	1.323	58.8-88.2[†††]	0.141	11.1
6x6 GE Dresden-1	36	2.304	58.8-88.2	0.245	8.82
6x6 Dresden-1 MOX	36	2.286	58.8-88.2	0.243	8.75
6x6 GE Humboldt Bay	36	2.346	58.8-88.2	0.250	9.0
7x7 GE Humboldt Bay	49	*1.666* ~~1.662~~	58.8-88.2	0.177	8.67
8x8 GE Dresden-1	64	1.235	58.8-88.2	0.131	8.38
8x8 SPC	63	1.615	58.8-88.2	0.172	10.8
9x9 SPC-2 wtr. Rods	79	1.248	58.8-88.2	0.133	10.5
9x9 SPC-1 wtr. Rod	80	1.248	58.8-88.2	0.133	10.6
9x9 GE11/GE13	74	1.389	58.8-88.2	0.150	11.1
9x9 Atrium 9B SPC	72	1.366	58.8-88.2	0.145	10.4
10x10 SVEA-96	96	1.022	58.8-88.2	0.109	10.5
10x10 GE12	92	1.167	58.8-88.2	0.124	11.4
6x6 Dresden Thin Clad	*36*	*2.455*	*58.8-88.2*	*0.261*	*9.4*
7x7 Oyster Creek	*49*	*2.346*	*58.8-88.2*	*0.234*	*11.5*
8x8 Oyster Creek	*64*	*1.739*	*58.8-88.2*	*0.173*	*11.1*
8x8 Quad[+] Westinghouse	*64*	*1.201*	*58.8-88.2*	*0.120*	*7.68*
8x8 TVA Browns Ferry	*61*	*1.686*	*58.8-88.2*	*0.168*	*10.2*
9x9 SPC-5	*76*	*1.249*	*58.8-88.2*	*0.124*	*9.4*

Table 4.3.6

† Conservatively bounding for GE-7x7 (1966), GE-7x7 (1968), GE-7x7R and GE-8x8 (ORNL/TM-9591/V1-R1).

†† Conservatively bounding initial fill pressure. ORNL/TM-9591/V1-R1 reports GE-8x8R prepressurized to 3 atm.

††† BWR fuel rods internal pressurization between 4 to 6 atm (PNL-4835).

Table 4.3.6

BOUNDING VALUES OF FUEL CLADDING STRESS FOR BWR SNF

Fuel Type	Fresh Fuel Rod O.D. (inch)	End of Life Oxidation Thickness (inch)	End of Life Rods O.D. (inch)	Rods I.D. (inch)	Average Tube Diameter (inch)	Wall Thickness (inch)	Hot Volume Pressure at 300°C (MPa)	Cladding Stress (MPa)
GE-7x7 (1966)	0.563	0.0047	0.5536	0.499	0.5263	0.0273	4.61	44.4
GE-7x7 (1968)	0.570	0.0047	0.5606	0.499	0.5298	0.0308	4.61	39.6
GE-7x7R	0.563	0.0047	0.5536	0.489	0.5213	0.0323	4.76	38.4
GE-8x8	0.493	0.0047	0.4836	0.425	0.4543	0.0293	5.08	39.4
GE-8x8R	0.483	0.0047	0.4736	0.419	0.4463	0.0273	6.68	54.7
EXXON-9x9	0.42	0.0047	0.4106	0.36	0.3853	0.0253	5.08	38.7
6x6 GE Dresden-1	0.5645	0.0047	0.5551	0.4945	0.5248	0.0303	6.1	52.8
6x6 Dresden-1 MOX	0.5625	0.0047	0.5531	0.4925	0.5228	0.0303	6.1	52.8
6x6 GE Humboldt Bay	0.563	0.0047	0.5536	0.499	0.5263	0.0273	5.98	57.6†
7x7 GE Humboldt Bay	0.486	0.0047	0.4766	*0.4204* ~~0.42~~	*0.4485* ~~0.4483~~	*0.0281* ~~0.0283~~	*6.13* ~~6.15~~	*48.9* ~~48.7~~
8x8 GE Dresden-1	0.412	0.0047	0.4026	0.362	0.3813	0.0203	6.29	59.1†
8x8 SPC	0.484	0.0047	0.4746	0.414	0.4443	0.0303	5.19	38.0
9x9 SPC-2 wtr. Rods	0.424	0.0047	0.4146	0.364	0.3893	0.0253	5.32	40.9
9x9 SPC-1 wtr. Rod	0.423	0.0047	0.4136	0.364	0.3888	0.0248	5.25	41.1
9x9 GE11/GE 13	0.44	0.0047	0.4306	0.384	0.4073	0.0233	5.17	45.2
9x9 Atrium 9B SPC	0.433	0.0047	0.4236	0.3808	0.4022	0.0214	5.32	50.0

† These two fuel types are separately analyzed for peak fuel cladding temperature limits.

Table 4.3.6 (continued) BOUNDING VALUES OF FUEL CLADDING STRESS FOR BWR SNF								
Fuel Type	Fresh Fuel Rod O.D. (inch)	End of Life Oxidation Thickness (inch)	End of Life Rods O.D. (inch)	Rods I.D. (inch)	Average Tube Diameter (inch)	Wall Thickness (inch)	Hot Volume Pressure at 300°C (MPa)	Cladding Stress (MPa)
10x10 SVEA-96	0.379	0.0047	0.3696	0.3294	0.3495	0.0201	4.38	38.1
10x10 GE12	0.404	0.0047	0.3946	0.352	0.3733	0.0213	4.99	43.7
6x6 Dresden Thin Clad	*0.5625*	*0.0047*	*0.5531*	*0.5105*	*0.5318*	*0.0213*	*5.77*	*72.5†*
7x7 Oyster Creek	*0.5700*	*0.0047*	*0.5606*	*0.499*	*0.5298*	*0.0308*	*4.68*	*40.2*
8x8 Oyster Creek	*0.5015*	*0.0047*	*0.4921*	*0.4295*	*0.4608*	*0.0313*	*4.78*	*35.2*
8x8 Quad+ Westinghouse	0.4576	0.0047	0.4482	0.3996	0.4239	0.0243	6.33	55.2†
8x8 TVA Browns Ferry	*0.483*	*0.0047*	*0.4736*	*0.423*	*0.4483*	*0.0253*	*5.05*	*44.7*
9x9 SPC-5	*0.417*	*0.0047*	*0.4076*	*0.364*	*0.3858*	*0.0218*	*5.38*	*47.6*

† These fuel types are separately analyzed for peak fuel cladding temperature limits.

Table 4.3.7

INITIAL PEAK ZIRCALOY* CLADDING TEMPERATURE LIMITS FOR STORAGE

Fuel Age (years)	Temperature Limits for PWR SNF (C°) [°F]	Temperature Limits for *Design Basis* BWR SNF (except 8x8 GE Dresden-1, 6x6 Dresden 1, 6x6 GE Humboldt Bay, and *Quad$^+$)* (C°) [°F]	Temperature Limits for 8x8 GE Dresden-1, 6x6 Dresden-1, 6x6 GE Humboldt Bay, and 8x8 Quad$^+$ SNF†† (C°) [°F]
5	382.3 [720]	398.2 [749]	*391.2 [736]* ~~396.0 [745]~~
6	370.2 [698]	382.3 [720]	*376.2 [709]* ~~380.7 [717]~~
7	347.0 [657]	357.9 [676]	*352.2 [666]* ~~356.2 [673]~~
10	341.6 [647]	351.4 [665]	*346.6 [656]* ~~349.9 [662]~~
15	334.1 [633]	344.9 [653]	*339.5 [643]* ~~343.4 [650]~~

* The listed limits are conservatively applied to stainless steel clad fuel assemblies, which actually have substantially higher limits.

†† The 8x8 GE Dresden-1, 6x6 Dresden-1, *Quad$^+$* and 6x6 Humboldt Bay fuel types are low heat emitting assemblies. The Technical Specifications limit the heat load for these assemblies to 115 watts per assembly (approximately 58% lower than the design basis maximum heat load for BWR fuel (Table 4.4.19) *(183.5 watts/assembly for Quad$^+$).* Consequently, these assembly types are not deemed to be limiting.

4.4.1.1.2 Fuel Region Effective Thermal Conductivity Calculation

Thermal properties of a large number of PWR and BWR fuel assembly configurations manufactured by the major fuel suppliers (i.e., Westinghouse, CE, B&W, and GE) have been evaluated for inclusion in the HI-STAR 100 System thermal analysis. It is noted that PWR fuel assemblies are equipped with removable non-fuel hardware, in particular, control rods which are inserted in guide tube locations for in-core usage. In dry cask storage, PWR fuel is optionally stored with the control rods. The control rods, when inserted in the fuel assemblies, displace gas in the guide tubes replacing it with solid materials (neutron absorbers and metals) which conduct heat much more readily. As a result, dissipation of heat in the fuel assemblies is enhanced by the presence of these control rods. For conservatism, credit for presence of control rods in fuel assemblies is neglected. Bounding PWR and BWR fuel assembly configurations are determined using the simplified procedure described below. This is followed by the determination of temperature-dependent properties of the bounding PWR and BWR fuel assembly configurations to be used for cask thermal analysis using a finite volume (FLUENT) approach.

To determine which of the numerous PWR assembly types listed in Table 4.4.5 should be used in the thermal model for the MPC-24 fuel basket, we must establish which assembly has the maximum thermal resistance. The same determination must be made for the MPC-68, out of the menu of SNF types listed in Table 4.4.6. For this purpose, we utilize a simplified procedure which we describe below.

Each fuel assembly consists of a large array of fuel rods typically arranged on a square layout. Every fuel rod in this array is generating heat due to radioactive decay in the enclosed fuel pellets. There is a finite temperature difference required to transport heat from the innermost fuel rods to the storage cell walls. Heat transport within the fuel assembly is based on principles of conduction heat transfer combined with the highly conservative analytical model proposed by Wooton and Epstein [4.4.1]. The Wooton-Epstein model considers radiative heat exchange between individual fuel rod surfaces as a means to bound the hottest fuel rod cladding temperature.

Transport of heat energy within any cross section of a fuel assembly is due to a combination of radiative energy exchange and conduction through the helium gas which fills the interstices between the fuel rods in the array. With the assumption of uniform heat generation within any given horizontal cross section of a fuel assembly, the combined radiation and conductive heat transport effects result in the following heat flow equation:

$$Q = \sigma \, C_o \, F_\varepsilon \, A \, [T_C^4 - T_B^4] + 13.5740 \, L \, K_{cs} \, [T_C - T_B]$$

where:

$$F_\varepsilon = \textit{Emissivity Factor}$$

$$= \frac{1}{\left(\frac{1}{\varepsilon_C} + \frac{1}{\varepsilon_B} - 1\right)}$$

$\varepsilon_C, \varepsilon_B$ = emissivities of fuel cladding, fuel basket (see Table 4.2.4)

$$C_o = \textit{Assembly Geometry Factor}$$

$$= \frac{4N}{(N+1)^2} \textit{ (when N is odd)}$$

$$= \frac{4}{N+2} \textit{ (when N is even)}$$

N = Number of rows or columns of rods arranged in a square array

A = fuel assembly "box" heat transfer area
= 4 × width × length

L = fuel assembly length

K_{cs} = fuel assembly constituent materials volume fraction weighted mixture conductivity

T_C = hottest fuel cladding temperature (°R)

T_B = box temperature (°R)

Q = net radial heat transport from the assembly interior

σ = Stefan-Boltzmann Constant (0.1714×10^{-8} Btu/ft^2-hr-°R^4)

In the above heat flow equation, the first term is the Wooten-Epstein radiative heat flow contribution while the second term is the conduction heat transport contribution based on the classical solution to the temperature distribution problem inside a square shaped block with uniform heat generation [4.4.5]. The 13.574 factor in the conduction term of the equation is the shape factor for two-dimensional heat transfer in a square section. Planar fuel assembly heat transport by conduction occurs through a series of resistances formed by the interstitial helium fill gas, fuel cladding and enclosed fuel. An effective planar mixture conductivity is determined by a volume fraction weighted sum of the individual constituent material resistances. For BWR assemblies, this formulation is applied to the region inside the fuel channel. A second conduction and radiation model is applied between the channel and the fuel basket gap. These two models are combined, in series, to yield a total effective conductivity.

The effective conductivity of the fuel for several representative PWR and commonly used BWR assemblies is presented in Tables 4.4.5 and 4.4.6. At higher temperatures (approximately 450°F and above), the zircaloy clad fuel assemblies with the lowest effective thermal conductivities are the W-17×17 OFA (PWR) and the GE11-9×9 (BWR). A discussion of fuel assembly conductivities for some of the newer 10×10 array *and plant specific* BWR fuel designs is presented near the end of this subsection. As noted in Table 4.4.6, the Dresden 1 (intact and damaged) fuel assemblies are excluded from consideration. The design basis decay heat load for Dresden-1 intact and damaged fuel (Table 2.1.7) is approximately 58% lower than the MPC-68 design basis maximum heat load (Table 4.4.19). Examining Table 4.4.6, the effective conductivity of the damaged Dresden-1 fuel assembly in a damaged fuel container is approximately 40% lower than the bounding (GE-11 9×9) fuel assembly. Consequently, the fuel cladding temperatures in the HI-STAR 100 System with Dresden-1 intact of damaged fuel assemblies will be bounded by design basis fuel cladding temperatures. *This is demonstrated in Subsection 4.4.1.1.16.* Based on this simplified analysis, the W-17×17 OFA PWR and GE11-9×9 BWR fuel assemblies are determined to be the bounding configurations for analysis of zircaloy clad fuel at design basis maximum heat loads. As discussed in Section 4.3.1, stainless clad fuel assemblies with significantly lower decay heat emission characteristics are not deemed to be bounding.

Having established the governing (most resistive) PWR and BWR SNF types, we use a finite volume code to determine the effective conductivities in a conservative manner. Detailed conduction-radiation finite volume models of the bounding PWR and BWR fuel assemblies are developed in the FLUENT code as shown in Figures 4.4.8 and 4.4.9, respectively. The PWR model was originally developed on the ANSYS code which enables individual rod-to-rod and rod-to-basket wall view factor calculations to be performed by the AUX12 procedure for the special case of black body radiation (surfaces emissivity = 1). Limitations of radiation modeling techniques implemented in ANSYS do not permit taking advantage of quarter symmetry of the fuel assembly geometry. Unacceptably long CPU time and large workspace requirements necessary for performing gray body radiation calculations for a complete fuel assembly geometry on ANSYS prompted the development of an alternate simplified model on the FLUENT code. The FLUENT model is benchmarked with the ANSYS model results for a Westinghouse 17×17 fuel assembly geometry for the case of black body radiation (emissivities = 1). The FLUENT model is found to yield conservative results in comparison to the ANSYS model for the "black" surface case. The FLUENT model benchmarked in this manner is used to solve the gray body radiation problem to provide the necessary results for determining the effective thermal conductivity of the governing PWR fuel assembly. The same modeling approach using FLUENT is then applied to the governing BWR fuel assembly, and the effective conductivity of GE11-9×9 fuel determined.

The combined fuel rods-helium matrix is replaced by an equivalent homogeneous material which fills the basket opening by the following two-step procedure. In the first step, the FLUENT-based fuel assembly model is solved by applying equal heat generation per unit length to the individual fuel rods and a uniform boundary temperature along the basket cell opening inside periphery. The temperature difference between the peak cladding and boundary temperatures is used to determine an effective conductivity as described in the next step. For this purpose, we consider a two-dimensional cross section of a square shaped block of size equal to 2L and a uniform volumetric heat source (q_g) cooled at the periphery with a uniform boundary temperature. Under the assumption of constant material thermal conductivity (K), the temperature difference (ΔT) from the center of the cross section to the periphery is analytically given by [4.4.5]:

$$\Delta T = 0.29468 \frac{q_g L^2}{K}$$

This analytical formula is applied to determine the effective material conductivity from a known quantity of heat generation applied in the FLUENT model (smeared as a uniform heat source, q_g) basket opening size and ΔT calculated in the first step.

As discussed earlier, the effective fuel space conductivity is a function of the temperature coordinate. The above two step analysis is carried out for a number of reference temperatures. In this manner, the effective conductivity as a function of temperature is established.

In Table 4.4.23, 10×10 array type BWR fuel assembly conductivity results from a simplified analysis are presented to determine the most resistive fuel assembly in this class. From the data in Table 4.4.23, the Atrium-10 fuel type is determined to be the most resistive in this class of fuel assemblies. A detailed finite element model of this assembly type was developed to rigorously quantify the heat dissipation characteristics. The results of this study are presented in Table 4.4.24 and compared to the BWR bounding fuel assembly conductivity depicted in Figure 4.4.14. The results of this study demonstrate that the bounding fuel assembly conductivity is conservative with respect to the 10x10 class of BWR fuel assemblies.

Table 4.4.25 summarizes plant specific fuel types effective conductivities. From these analytical results, the SPC-5 is determined to be the most resistive fuel assembly in this group of fuel types. A rigorous finite element model of SPC-5 fuel assembly was developed to confirm that its in-plane heat dissipation characteristics are bounded from below by the Design Basis BWR fuel conductivities used in the HI-STAR thermal analysis.

Temperature-dependent effective conductivities of PWR and BWR design basis fuel assemblies (most resistive SNF types) are shown in Figure 4.4.14. The finite volume *computational* results are also compared to results reported from independent technical sources. From this comparison, it is readily apparent that FLUENT-based fuel assembly conductivities are conservative. The

$$R_I = \frac{T_h - T_{h'}}{Q_I} = \frac{h}{K_{He}\ L\ \sqrt{\alpha}} \left(1 - \frac{1}{e^{\frac{P}{\sqrt{\alpha}}} + e^{-\frac{P}{\sqrt{\alpha}}}}\right)^{-1}$$ (Equation f)

The Region II resistance expression can be developed from the following net heat transfer equation in the vertical leg of the conduction element as shown below:

$$Q_{II} = \frac{K_{Al}\ L\ t}{W} (T_h' - T_c')$$ (Equation g)

$$R_{II} = \frac{T_h' - T_c'}{Q_{II}} = \frac{W}{K_{Al}\ L\ t}$$ (Equation h)

Similarly, a Region III resistance expression can be analytically determined as shown below:

$$R_{III} = \frac{(T_c' - T_c)}{Q_{III}} = \frac{h}{K_{He}\ L\ \sqrt{\alpha}} \left(1 - \frac{1}{e^{\frac{P}{\sqrt{\alpha}}} + e^{-\frac{P}{\sqrt{\alpha}}}}\right)^{-1}$$ (Equation i)

This completes the analysis for the total thermal resistance attributable to the heat conduction elements, equal to the sum of the three individual resistances. The total heat conduction element resistance is smeared across the basket-to-MPC shell region as an effective uniform annular gap conductivity (see Figure 4.4.2). We note that heat transport along the conduction elements is an independent conduction path in parallel with conduction and radiation mechanisms in the large helium gaps. Helium conduction and radiation in the MPC basket-to-MPC shell peripheral gaps is accounted for separately in the ANSYS models for the MPCs, described earlier. Therefore, the total MPC basket-to-MPC shell peripheral gaps conductivity will be the sum of the heat conduction elements effective conductivity and the helium gap conduction-radiation effective conductivity.

4.4.1.1.11 FLUENT Model for HI-STAR 100 Temperature Field Computation

In the preceding subsection, a series of analytical and numerical models to define the thermal characteristics of the various elements of the HI-STAR 100 System are presented. The thermal modeling begins with the replacement of the SNF cross section and surrounding fuel cell space with a solid region with an equivalent conductivity. Since radiation is an important constituent of the heat transfer process in the SNF/storage cell space, and the rate of radiation heat transfer is a strong function of the surface temperatures, it is necessary to treat the equivalent region conductivity as a function of temperature. Because of the relatively large range of temperatures in a loaded HI-STAR 100 System under the design basis heat loads, the effects of variation in the thermal conductivity of materials with temperature throughout the system model are included. The presence of significant radiation effects in the storage cell spaces adds to the imperative to treat the equivalent storage cell lamina conductivity as temperature-dependent.

FLUENT finite volume simulations have been performed to establish the equivalent thermal conductivity as a function of temperature for the limiting (thermally most resistive) BWR and PWR spent fuel types. Utilizing the limiting SNF (established through a simplified analytical process for comparing conductivities) ensures that the numerical idealization for the fuel space effective conductivity is conservative for all non-limiting fuel types.

Having replaced the fuel spaces by solid square blocks with temperature-dependent conductivity essentially renders the basket into a non-homogeneous three-dimensional solid where the non-homogeneity is introduced by the honeycomb basket structure. The basket panels themselves are a composite of Alloy X cell wall, Boral neutron absorber, and Alloy X sheathing metal. A conservative approach to replace this composite section with an equivalent "solid wall" was described earlier.

In the next step, a planar section of the MPC is considered. The MPC contains a non-symmetric basket lamina wherein the equivalent fuel spaces are separated by the "equivalent" solid metal walls. The space between the basket and the MPC, called the peripheral gap, is filled with helium gas and aluminum heat conduction elements (shown in MPC drawings 1395 and 1401 in Section 1.5). The equivalent thermal conductivity of the MPC section is computed using a finite element procedure on ANSYS. To the "helium conduction-radiation" based peripheral gap conductivity, the effective conductivity of the aluminum conduction elements is added to obtain a combined peripheral gap effective conductivity. At this stage in the thermal analysis, the SNF/basket/MPC assemblage has been replaced with a two-zone (Figure 4.4.2) cylindrical solid whose thermal conductivity is a strong function of temperature.

The idealization for the overpack is considerably more straightforward. The overpack is radially symmetric except for the neutron absorber (Holtite-A) region (Figure 4.4.7). The procedure to replace the multiple shell layers, Holtite-A and radial connectors with an equivalent solid utilizes classical heat conduction analogies, as discussed in Sections 4.4.1.1.6 and 4.4.1.1.9.

In the final step of the analysis, the equivalent two-zone MPC cylinder, equivalent overpack shell, top and bottom plates, and ISFSI pad are assembled into a comprehensive finite volume model. A cross section of this axisymmetric model implemented on FLUENT is shown in Figure 4.4.15. A summary of the essential features of this model is presented in the following:

- The overpack shell is represented by 840 axisymmetric elements.

- The overpack bottom plate and bolted closure plate are modeled by 312 axisymmetric elements.

- The two-zone MPC "solid" (including the baseplate, lid and shell) is represented by 1188 axisymmetric elements.

- The ISFSI pad is conservatively modeled as a thermal resistance from a 36" thick concrete cylinder whose bottom surface is at 60°F. The portion of the concrete outside the footprint of the cask is conservatively omitted from the model.

- The space between the MPC and the overpack interior inner surface contains helium.

- Heat input due to insolation is applied to the top surface and the cylindrical surface of the overpack.

- The heat generation in the MPC is assumed to be uniform in each horizontal plane, but to vary in the axial direction to correspond to the axial power distribution listed in Table 2.1.8.

- The most disadvantageously placed cask *in a HI-STAR cask array* (i.e., the one subjected to maximum radiative blockage (see Subsection 4.4.1.1.7), is modeled.

The emissivity applied to the external surfaces of the HI-STAR model accounts for radiation-blockage of the outer enclosure surface and no blockage for the overpack closure plate top surface.

The finite element model constructed in this manner will produce an axisymmetric temperature distribution. The peak temperature will occur at the centerline and is expected to occur at the axial location of peak heat generation. As we will see later, the results from the finite volume solution bear out these observations.

4.4.1.1.12 MPC Temperature Distribution Under Vacuum Conditions

The initial loading of SNF in the MPC requires that the water within the MPC be drained and replaced with helium. This operation on the HI-STAR MPCs will be carried out using a conventional vacuum drying approach. In this method, removal of the last traces of residual moisture from the MPC cavity is accomplished by evacuating the MPC for a short time after draining the MPC.

Prior to the start of the MPC draining operation, both the overpack annulus and the MPC are full of water. The presence of water in the MPC ensures that the fuel cladding temperatures are lower than design basis limits by large margins. As the heat generating active fuel length is

As set forth in the HI-STAR 100 operating procedures, in the unlikely event where the maximum allowable time provided in Table 4.4.21 is found to be insufficient to complete all wet transfer operations, a forced water circulation shall be initiated and maintained to remove the decay heat from the MPC cavity. In this case, relatively cooler water will enter via the MPC lid drain port connection and heated water will exit from the vent port. The minimum water flow rate required to maintain the MPC cavity water temperature below boiling with an adequate subcooling margin is determined as follows:

$$M_W = \frac{Q}{C_{pw}\,(T_{max} - T_{in})}$$

where:

M_W = minimum water flow rate (lb/hr)

C_{pw} = water heat capacity (Btu/lb-°F)

T_{max} = maximum MPC cavity water mass temperature

T_{in} = temperature of water supply to MPC

With the MPC cavity water temperature limited to 150°F, MPC inlet water maximum temperature equal to 125°F and at the design basis maximum heat load, the water flow rate is determined to be 2,594 lb/hr (5.3 gpm).

4.4.1.1.15 Cask Cooldown and Reflood Analysis During Fuel Unloading Operation

NUREG-1536 requires an evaluation of cask cooldown and reflood procedures to support fuel unloading from a dry condition. Past industry experience generally supports cooldown of cask internals and fuel from hot storage conditions by direct water quenching. However, the extremely rapid cooldown rates that are typical during water injection, to which the hot cask internals and fuel cladding are subjected to, may result in uncontrolled thermal stresses and failure in the structural members. Moreover, water injection results in large amounts of steam generation and unpredictable transient two-phase flow conditions inside the MPC cavity, which may result in over-pressurization of the confinement boundary and a potentially unacceptable reduction in the safety margins to prevent criticality. To avoid potential safety concerns related to rapid cask cooldown by direct water quenching, the HI-STAR MPCs are designed to be cooled in a gradual manner, thereby eliminating thermal shock loads on the cask internals and fuel cladding.

In the unlikely event that a HI-STAR system is required to be unloaded, it will be transported back to the fuel handling building. Prior to reflooding the MPC cavity with water, a forced flow helium recirculation system with adequate flow capacity shall be operated to remove the decay heat and initiate a slow cask cooldown lasting for several days. The operating procedures in Chapter 8 (Section 8.3) provide a detailed description of the steps involved in the cask unloading. In this section, an analytical evaluation is presented to provide the basis for helium flow rates and time of forced cooling to meet the objective of eliminating thermal shock when the MPC cavity is eventually flooded with water.

Under a closed loop forced helium circulation condition, the helium gas is cooled via an external chiller, down to 100°F, and then introduced inside the MPC cavity from the drain line near the bottom baseplate. The helium gas enters the MPC basket from the bottom oversized flow holes and moves upwards through the hot fuel assemblies, removing heat and cooling the MPC internals. The heated helium gas exits from the basket top and collects in the top plenum, from where it is expelled through the MPC lid vent connection to the helium recirculation and cooling system. The MPC contents bulk average temperature reduction as a function of time is principally dependent upon the rate of helium circulation. The temperature transient is governed by the following heat balance equation

$$C_h \frac{dT}{dt} = Q_D - m\, C_p\, (T - T_i) - Q_c$$

Initial Condition: $T = T_o$ at $t = 0$

where:

T = MPC bulk average temperature (°F)

T_o = initial MPC bulk average temperature in the HI-STAR system (equal to 439°F)

t = time after start of forced circulation (*°F hrs*)

Q_D = decay heat load (Btu/hr) (equal to Design Basis maximum 19.0 kW (i.e., 64,847 Btu/hr))

m = helium circulation rate (lb/hr)

C_p = helium heat capacity (Btu/lb-°F) (equal to 1.24 Btu/lb-°F)

Q_c = heat rejection from cask exposed surfaces to ambient (Btu/hr) (conservatively neglected)

C_h = thermal capacity of the loaded MPC (Btu/°F)

(For a bounding upper bound 100,000 lb loaded MPC weight, and heat capacity of Alloy X equal to 0.12 Btu/lb-°F, the heat capacity is equal to 12,000 Btu/°F.)

T_i = MPC helium inlet temperature (°F)

The differential equation is analytically solved, yielding the following expression for time-dependent MPC bulk temperature.

$$T(t) = (T_i + \frac{Q_D}{m\ C_p})(1 - e^{-\frac{m\ C_p}{C_h}t}) + T_o\ e^{-\frac{m\ C_p}{C_h}t}$$

This equation is used to determine the minimum helium mass flow rate which would cool the MPC cavity down from initially hot conditions to less than 200°F in 72 hours. The required helium mass flow rate is 546 lb/hr (i.e., 817 SCFM).

Once the helium gas circulation has cooled the MPC internals to less than 200°F, water can be injected to the MPC without risk of boiling and the associated thermal stress concerns. Because of the relatively long cooldown period, the thermal stress contribution to the total cladding stress would be negligible, and the total stress would therefore be bounded by the normal (dry) condition. The elimination of boiling eliminates any concern of over-pressurization due to steam production.

4.4.1.1.16 HI-STAR Temperature Field With Low Emitting Fuel

The HI-STAR 100 thermal evaluations for BWR fuel are divided in two groups of fuel assemblies proposed for storage in MPC-68. These groups are classified as Low Heat Emitting (LHE) fuel assemblies and Design Basis (DB) fuel assemblies. The LHE group of fuel assemblies are characterized by low burnup, long cooling time, and short active fuel lengths. Consequently, their heat loads are dwarfed by the DB group of fuel assemblies. The Dresden-1 (6x6 and 8x8), Quad$^+$, and Humboldt Bay (7x7 and 6x6) fuel characteristics warrant their classification as LHE fuel. These characteristics, including burnup and cooling time limits imposed on this class of fuel, are presented in Table 2.1.6. This fuel (except Quad$^+$) is permitted to be loaded when encased in Damaged Fuel Containers (DFCs). As a result of interruption of radiation heat exchange between the fuel assembly and the fuel basket by the DFC boundary, this loading configuration is bounding for thermal evaluation. In Subsection 4.4.1.1.2, two canister designs for encasing LHE fuel are evaluated – a previously approved Holtec Design (Holtec Drawing-1783) and an existing canister in which some of the Dresden-1 fuel is currently stored (Transnuclear D-1 Canister). The most resistive fuel assembly determined by analytical evaluation is considered for thermal evaluation (see Table 4.4.6). The MPC-68 basket effective conductivity, loaded with the most resistive fuel assembly from the LHE group of fuel (encased in a canister) is provided in Table 4.4.7. To this basket, LHE decay heat load is applied and a HI-STAR 100 System temperature field obtained. The low heat load burden limits the initial peak cladding temperature to 595°F which is substantially below the temperature limit for long-cooled fuel (~643°F).

A thoria rod canister designed to hold a maximum of 20 fuel rods arrayed in a 5x4 configuration is currently stored at the Dresden-1 spent fuel pool. The fuel rods contain a mixture of enriched UO_2 and Thorium Oxide in the fuel pellets. The fuel rods were originally constituted as part of an 8x8 fuel assembly and used in the second and third cycle of Dresden-1 operation. The maximum fuel burnup of these rods is quite low (~14,400 MWD/MTU). The thoria rod canister internal design is a honeycomb structure formed from 12 gage stainless steel plates. The rods are loaded in individual square cells and are isolated from each other by the cell walls. The few number of rods (18 per assembly) and very low burnup of fuel stored in these Dresden-1 canisters render them as miniscule sources of decay heat. The canister all-metal internal honeycomb construction serves as an additional means of heat dissipation in the fuel cell space. In accordance with preferential fuel loading requirements imposed in the Technical Specifications, low burnup fuel shall be loaded toward the basket periphery (i.e., away from the hot central core of the fuel basket). All these considerations provide ample assurance that these fuel rods will be stored in a benign thermal environment and therefore remain protected during long-term storage.

4.4.1.2 Test Model

A detailed analytical model for thermal design of the HI-STAR 100 System was developed using the FLUENT CFD code and the industry standard ANSYS modeling package, as discussed in Subsection 4.4.1.1. As discussed throughout this chapter and specifically in Section 4.4.6, the analysis incorporates significant conservatisms so as to predict the fuel cladding temperature with considerable margins. Furthermore, compliance with specified limits of operation is demonstrated with adequate margins. In view of these considerations, the HI-STAR 100 System thermal design complies with the thermal criteria set forth in the design basis (Sections 2.1 and 2.2) for long-term storage under normal conditions. Additional experimental verification of the thermal design is therefore not required.

4.4.2 Maximum Temperatures

4.4.2.1 Maximum Temperatures Under Normal Storage Conditions

The two MPC basket designs developed for the HI-STAR 100 System have been analyzed to determine the temperature distribution under long-term normal storage conditions. The MPC baskets are considered to be loaded at design basis maximum heat loads with PWR or BWR fuel assemblies, as appropriate. The systems are considered to be arranged in an ISFSI array and subjected to design basis normal ambient conditions with insolation.

Applying the radiative blocking factor applicable for the worst case cask location, converged temperature contours are shown in Figures 4.4.17 and 4.4.18 for the MPC-24, and MPC-68 basket designs. The temperatures in these two figures are in degrees Kelvin. The calculated temperatures presented in this chapter are based on an array of analyses that incorporate many conservatisms. As such, the calculated temperatures are upper bound values which would exceed actual temperatures.

- The maximum fuel cladding temperature is well within the PNL [4.3.1] and the LLNL [4.3.6] recommended temperature limits.

- The maximum temperature of the basket structural material is within the stipulated Design Temperature.

- The maximum temperature of the Boral neutron absorber is below the material supplier's recommended limit.

- The maximum temperatures of the MPC pressure boundary materials are well below their respective ASME Code limits.

- The maximum temperatures of the overpack pressure boundary material are well below their respective ASME Code limits.

- The neutron shielding material (Holtite-A) will not experience temperatures in excess of its qualified limit.

- The local temperatures of the mechanical seals are well below their respective long-term limits (Table 4.3.1).

Noting that the allowable maximum initial peak cladding temperature is significantly lower for older fuel, parametric peak fuel cladding temperature versus total decay heat load tables for each of the two basket designs were developed. This lower than design basis heat load performance data is presented in Tables 4.4.18 and 4.4.19. The decay heat limit curve in Figure 2.1.8 is developed based on these tables and the allowable fuel cladding temperature limits listed in Table 2.2.3.

The above observations lead us to conclude that the temperature field in the HI-STAR 100 System with a fully loaded MPC containing design-basis heat emitting SNF complies with all regulatory and industry temperature limits. In other words, the thermal environment in the HI-STAR 100 System will be conducive to long-term safe storage of spent nuclear fuel.

4.4.2.2 Maximum MPC Basket Temperature Under Vacuum Conditions

A plot of typical steady-state temperature contours under vacuum conditions is shown in Figure 4.4.19. The peak fuel clad temperature during short-term vacuum drying operations is limited to less than 950°F for both baskets at design basis maximum heat loads by a significant margin. This limit is lower than the recommended fuel cladding temperature (see Table 4.3.1) limits for short-term conditions by a large margin.

4.4.3 Minimum Temperatures

In Table 2.2.2 of this report, the minimum ambient temperature condition required to be considered for HI-STAR 100 System design is specified to be -40°F. If, conservatively, a zero decay heat load (with no solar input) is applied to the stored fuel assemblies then every component of the system at steady state would be at this minimum ambient temperature. All HI-STAR 100 System materials of construction would satisfactorily perform their intended function in the storage mode at this minimum postulated temperature condition. Structural evaluations in Chapter 3 show the acceptable performance of the overpack and MPC steel material at low temperature. Criticality and shielding functions of the HI-STAR 100 System materials (Chapters 5 and 6) are unaffected by exposure to this minimum temperature.

4.4.4 Maximum Internal Pressure

The MPC is initially filled with helium after fuel loading and drying prior to installing the MPC closure ring. During normal storage, the gas temperature within the MPC rises to its maximum operating basis temperature as determined based on the thermal analysis methodology described earlier. The gas pressure inside the MPC will also increase with rising temperature. The pressure rise is determined using the ideal gas law which states that the absolute pressure of a fixed volume of confined gas is proportional to its absolute temperature. In Tables 4.4.13 and 4.4.14, a summary of calculations for determining the net free volume in the MPC-24 and MPC-68 are presented.

The maximum gas pressure in the MPC is considered for a postulated accidental release of fission product gases caused by fuel rods rupture. For these fuel rod rupture conditions, the amounts of each of the release gas constituents in the MPC cavity are summed and the resulting total pressures determined from the Ideal Gas Law. Based on fission gases release fractions (per NUREG-1536 criteria [4.1.3]), minimum net free volume and maximum initial fill gas pressure, bounding maximum gas pressures with 1% (normal), 10% (off-normal), and 100% (accident condition) rod rupture are given in Table 4.4.15. The MPC maximum gas pressures listed in Table 4.4.15 are all below the MPC design internal pressure listed in Table 2.2.1.

The inclusion of PWR non-fuel hardware (BPRA control elements and thimble plugs) to the MPC-24 influences the internal pressure in two ways. The presence of non-fuel hardware enhances heat dissipation, thus lowering fuel temperatures and the gas filling the space between fuel rods. The gas volume displaced by the mass of non-fuel hardware lowers the cavity free volume. These two effects, namely, temperature lowering and free volume reduction, have opposing influence in the MPC cavity pressure. The first effect lowers gas pressure while the second effect raises it. In the HI-STAR thermal analysis, the computed temperature field (with non-fuel hardware excluded) provides a conservatively bounding MPC-24 temperature field. The MPC cavity free space is computed based on volume displacement by the heaviest fuel (bounding weight) with non-fuel hardware included).

During in-core irradiation of BPRAs, the B-10 isotope in the neutron absorbing material is transformed to helium atoms. Two different forms of the neutron absorbing material are used in BPRAs: Borasilicate glass and B_4C in a refractory solid matrix ($A\ell_2O_3$). Borosilicate glass (primarily a constiuent of Westinghouse BPRAs) is used in the shape of hollow pyrex glass tubes *sealed within steel rods and supported on the inside by a thin walled steel liner. To accommodate helium diffusion from the glass rod into the rod internal space, a relatively high void volume (~40%) is engineered in this type of rod design. The rod internal pressure is thus designed to remain below reactor operating conditions (2,300 psia and approximately 600°F coolant temperature). The B_4C- $A\ell_2O_3$ neutron absorber material is principally used in B&W and CE fuel BPRA designs. The relatively low temperature of the poison material in BPRA rods (relative to fuel pellets) favor the entrapment of helium atoms in the solid matrix.*

Several BPRA designs are used in PWR fuel which differ in the number, diameter, and length of poison rods. The older Westinghouse fuel (W-14x14 and AW-15x15) has used 6,12, 16, and 20 rods per assembly BPRAs and the later (W-17x17) fuel uses up to 24 rods per BPRA. The BPRA rods in the older fuel are much larger than the later fuel and, therefore, the B-10 isotope inventory in the 20-rod BPRAs bound the newer W-17x17 fuel. Based on bounding BPRA rods internal pressure, a large hypothetical quantity of helium (7.2 g-moles/BPRA) is assumed to be available for release into the MPC cavity from each fuel assembly in the MPC-24. To accommodate this quantity of helium gas at the NUREG-1536 stipulated rods rupture assumptions, the initial helium backfill in the MPC-24 is reduced such that the final confinement boundary pressures are approximately unchanged from inclusion of non-fuel hardware. The MPC cavity pressures are summarized in Table 4.4.15*

4.4.5 Maximum Thermal Stresses

Thermal expansion induced mechanical stresses due to the non-uniform temperature distribution are reported in Chapter 3. Table 4.4.16 provides a summary of HI-STAR 100 System component temperature inputs for structural evaluation.

Table 4.4.22 provides a summary of confinement boundary temperatures during normal storage conditions. Structural evaluation in Section 3.4.4 references these temperature results to demonstrate confinement boundary integrity.

4.4.6 Evaluation of System Performance for Normal Conditions of Storage

The HI-STAR 100 System thermal analysis is based on a detailed and complete heat transfer model which properly accounts for radiation, conduction and natural convection modes of heat transfer in various portions of the MPC and overpack. The thermal model incorporates many conservative features that are listed below:

1. The most severe levels of environmental factors - bounding long-term annual ambient temperature with insolation - were coincidentally imposed on the HI-STAR 100 cask. A bounding solar absorbtivity of 1.0 was applied to all surfaces exposed to insolation.

2. No credit was considered for the thermosiphon heat transfer which is intrinsic to the HI-STAR fuel baskets.

* 3,875 liters of helium gas at STP from 100% BPRA rods rupture.

Table 4.4.5

SUMMARY OF PWR FUEL ASSEMBLY EFFECTIVE THERMAL CONDUCTIVITIES

	Fuel	@ 200°F (Btu/ft-hr-°F)	@ 450°F (Btu/ft-hr-°F)	@ 700°F (Btu/ft-hr-°F)
1	W - 17×17 OFA	0.182	0.277	**0.402**
2	W - 17×17 Std	0.189	0.286	0.413
3	W - 17×17 Vantage	0.182	0.277	0.402
4	W - 15×15 Std	0.191	0.294	0.430
5	W - 14×14 Std	0.182	0.284	0.424
6	W - 14×14 OFA	**0.175**	**0.275**	0.413
7	B&W - 17×17	0.191	0.289	0.416
8	B&W - 15×15	0.195	0.298	0.436
9	CE - 16×16	0.183	0.281	0.411
10	CE - 14×14	0.189	0.293	0.435
11	HN† -15×15 SS	0.180	0.265	0.370
12	W-14×14 SS	0.170	0.254	0.361
13	*B&W – 15x15*	*0.187*	*0.289*	*0.424*
14	*CE-14x14 (MP2)*	*0.188*	*0.293*	*0.434*

Note: Boldface values denote the lowest thermal conductivity in each column.

† Haddam Neck B&W or Westinghouse stainless steel clad fuel assemblies.

Table 4.4.6
SUMMARY OF BWR FUEL ASSEMBLY EFFECTIVE
THERMAL CONDUCTIVITIES

	Fuel	**@ 200°F (Btu/ft-hr-°F)**	**@ 450°F (Btu/ft-hr-°F)**	**@ 700°F (Btu/ft-hr-°F)**
1	Dresden 1 - 8×8†	0.119	0.201	0.319
2	Dresden 1 - 6×6†	0.126	0.215	0.345
3	GE - 7×7	0.171	0.286	0.449
4	GE - 7×7R	0.171	0.286	0.449
5	GE - 8×8	0.168	0.278	0.433
6	GE - 8×8R	**0.166**	0.275	0.430
7	GE10 - 8×8	0.168	0.280	0.437
8	GE11 - 9×9	0.167	**0.273**	**0.422**
9	AC†† -10×10 SS	0.152	0.222	0.309
10	Exxon-10×10 SS	0.151	0.221	0.308
11	*Humboldt Bay-7x7†*	*0.127*	*0.215*	*0.343*
12	*Dresden-1 Thin †Clad-6x6*	*0.124*	*0.212*	*0.343*
13	Damaged Dresden-1 8×8† (in a damaged fuel container)	0.107	0.169	0.254
14	*Damaged† Dresden-1 8x8 (in TN D-1 canister)*	*0.107*	*0.168*	*0.252*
15	*8x8 QUAD+ Westinghouse†*	*0.164*	*0.276*	*0.435*

Note: Boldface values denote the lowest thermal conductivity in each column.

† Fuel cladding temperatures for low heat emitting ~~Dresden~~ (intact and damaged) fuel types in the HI-STAR 100 System will be bounded by design basis fuel cladding temperatures. Therefore, these fuel assembly types are excluded from the list of *design basis* fuel assemblies (zircaloy clad) evaluated to determine the most resistive SNF type.

†† Allis-Chalmers stainless steel clad fuel assemblies.

Table 4.4.7

MPC BASKET EFFECTIVE THERMAL CONDUCTIVITY RESULTS FROM ANSYS MODELS

Basket	**@200°F [Btu/ft-hr-°F]**	**@450°F [Btu/ft-hr-°F]**	**@700°F [Btu/ft-hr-°F]**
MPC-24 (Zircaloy Clad Fuel)	1.108	1.495	1.954
MPC-68 (Zircaloy Clad Fuel)	0.959	1.188	1.432
MPC-24 (Stainless Steel Clad Fuel)	0.995	1.321	1.700 (a)
MPC-68 (Stainless Steel Clad Fuel)	0.931	1.125	1.311 (b)
MPC-68 (Dresden-1 8x8 in canister)	*0.861*	*1.055*	*1.242*

(a) Conductivity is 13% less than corresponding zircaloy fueled basket.
(b) Conductivity is 9% less than corresponding zircaloy fueled basket.

Table 4.4.15

SUMMARY OF MPC CONFINEMENT BOUNDARY PRESSURES[†] FOR NORMAL LONG-TERM STORAGE

Condition	Pressure (psig)
MPC-24:*	
Initial backfill (at 70°F)	*22.2* ~~28.3~~
Normal condition	*43.8* ~~58.3~~
With 1% rods rupture	*44.3* ~~58.7~~
With 10% rods rupture	*49.1* ~~62.1~~
With 100% rods rupture	*97.3* ~~95.9~~
MPC-68:	
Initial backfill (at 70°F)	28.5
Normal condition	57.5
With 1% rods rupture	57.8
With 10% rods rupture	60.2
With 100% rods rupture	84.5

[†] Pressure analysis is based on NUREG-1536 criteria (i.e., 100% of rods fill gas and 30% of radioactive gases are available for release from a ruptured rod).
* PWR fuel storage includes hypothetical BPRA rods rupture in the pressure calculations.

Table 4.4.25

*PLANT SPECIFIC BWR FUEL TYPES EFFECTIVE THERMAL CONDUCTIVITY**

Fuel	@200° F [Btu/ft-hr-°F]	@ 450° F [Btu/ft-hr-°F]	@ 700° F [Btu/ft-hr-°F]
Oyster Creek (7x7)	0.165	0.273	0.427
Oyster Creek (8x8)	0.162	0.266	0.413
TVA Browns Ferry (8x8)	0.160	0.264	0.411
SPC-5 (9x9)	0.149	0.245	0.380

* *The conductivities reported in this table are obtained by a simplified analytical method described in Subsection 4.4.1.2.*

CHAPTER 5: SHIELDING EVALUATION

5.0 INTRODUCTION

The shielding analysis of the HI-STAR 100 System is presented in this chapter. The HI-STAR 100 System is designed to accommodate different MPCs within one standard HI-STAR overpack. The MPCs are designated as MPC-24 (24 PWR fuel assemblies) and MPC-68 (68 BWR fuel assemblies).

In addition to storing intact PWR and BWR fuel assemblies, the HI-STAR 100 System is designed to store damaged BWR fuel assemblies and BWR fuel debris. Damaged fuel assemblies and fuel debris are defined in Section 2.1.3 and Appendix B to the Certificate of Compliance. Both damaged BWR fuel assemblies and BWR fuel debris are required to be loaded into Damaged Fuel Containers (DFCs) prior to being loaded into the MPC. DFCs containing fuel debris must be stored in the MPC-68F. DFCs containing damaged fuel assemblies may be stored in either the MPC-68 or the MPC-68F. Only the fuel assemblies in the Dresden 1 and Humboldt Bay fuel assembly classes identified in Table 2.1.2 are authorized as contents for storage in the HI-STAR 100 system as either damaged fuel or fuel debris.

The MPC-68 and MPC-68F are also capable of storing Dresden Unit 1 antimony-beryllium neutron sources and the single Thoria rod canister which contains 18 thoria rods that were irradiated in two separate fuel assemblies.

PWR fuel assemblies may contain burnable poison rod assemblies (BPRAs) or thimble plug devices (TPDs) or similarly named devices. These devices are an integral yet removable part of PWR fuel assemblies and therefore the HI-STAR 100 System has been designed to store PWR fuel assemblies with or without BPRAs or TPDs. Since BPRAs and TPDs occupy the same space within a fuel assembly, a single PWR fuel assembly will not contain both devices.

The sections that follow will demonstrate that the design of the HI-STAR 100 dry cask storage system fulfills the following acceptance criteria outlined in the Standard Review Plan, NUREG-1536[5.2.1]:

Acceptance Criteria

1. The minimum distance from each spent fuel handling and storage facility to the controlled area boundary must be at least 100 meters. The "controlled area" is defined in 10CFR72.3 as the area immediately surrounding an ISFSI or monitored retrievable storage (MRS) facility, for which the licensee exercises authority regarding its use and within which ISFSI operations are performed.

2. The cask vendor must show that, during both normal operations and anticipated occurrences, the radiation shielding features of the proposed dry cask storage system are sufficient to meet the radiation dose requirements in Sections 72.104(a). Specifically, the vendor must demonstrate this capability for a typical array of casks in the most bounding site configuration. For example, the most bounding configuration might be located at the minimum distance (100 meters) to the controlled area boundary, without any shielding from other structures or topography.

3. Dose rates from the cask must be consistent with a well-established "as low as reasonably achievable" (ALARA) program for activities in and around the storage site.

4. After a design-basis accident, an individual at the boundary or outside the controlled area shall not receive a dose greater than *the limits specified in 10 CFR 72.106*~~5 Rem to the whole body or any organ~~.

5. The proposed shielding features must ensure that the dry cask storage system meets the regulatory requirements for occupational and radiation dose limits for individual members of the public, as prescribed in 10 CFR Part 20, Subparts C and D.

This chapter contains the following information which demonstrates full compliance with the Standard Review Plan, NUREG-1536:

- A description of the shielding features of the HI-STAR 100 System.
- A description of the bounding source terms.
- A general description of the shielding analysis methodology.
- A description of the analysis assumptions and results for the HI-STAR 100 System.
- Analyses are presented for each MPC showing that the radiation dose rates follow As-Low-As-Reasonably-Achievable (ALARA) practices.
- The HI-STAR 100 System has been analyzed to show that the 10CFR72.104 and 10CFR72.106 controlled area boundary radiation dose limits are met during normal, off-normal, and accident conditions of storage for non-effluent radiation from illustrative ISFSI configurations at a minimum distance of 100 meters.
- Analyses are also presented which demonstrate that the storage of damaged fuel and fuel debris in the HI-STAR 100 System is bounded by the BWR intact fuel analysis during normal, off-normal, and accident conditions.

Chapter 10, Radiation Protection, contains the following information:

- A discussion of the estimated occupational exposures for the HI-STAR 100 System.
- A summary of the estimated radiation exposure to the public.

5.1 DISCUSSION AND RESULTS

The principal sources of radiation in the HI-STAR 100 System are:

- Gamma radiation originating from the following sources

  1. Decay of radioactive fission products
  2. Secondary photons from neutron capture in fissile and non-fissile nuclides
  3. Hardware activation products generated during core operations

- Neutron radiation originating from the following sources

  1. Spontaneous fission
  2. α,n reactions in fuel materials
  3. Secondary neutrons produced by fission from subcritical multiplication
  4. γ,n reactions (this source is negligible)
  5. *Dresden Unit 1 antimony-beryllium neutron sources*

Shielding from gamma radiation is provided by the steel structure of the MPC and overpack. In order for the neutron shielding to be effective, the neutrons must be thermalized and then absorbed in a material of high neutron cross section. In the HI-STAR 100 design, a neutron shielding material, Holtite-A, is used to thermalize the neutrons. Boron carbide, dispersed in the neutron shield, utilizes the high neutron absorption cross section of ^{10}B to absorb the thermalized neutrons.

The shielding analyses were performed with MCNP-4A [5.1.1] from Los Alamos National Laboratory. The source terms for the design basis fuels were calculated with the SAS2H and ORIGEN-S modules from the SCALE 4.3 system [5.1.2, 5.1.3]. A detailed description of the MCNP models and the source term calculations is presented in Sections 5.3 and 5.2, respectively.

The design basis intact zircaloy clad fuel assemblies used for calculating the dose rates presented in this chapter are B&W 15x15 and the GE 7x7, for PWR and BWR fuel types, respectively. The design basis intact 6x6, damaged, and mixed oxide (MOX) fuel assemblies are the GE 6x6. Table 2.1.6 specifies the acceptable intact zircaloy clad fuel characteristics for storage. Table 2.1.7 specifies the acceptable damaged and MOX zircaloy clad fuel characteristics for storage.

The design basis intact stainless steel clad fuels are the WE 15x15 and the A/C 10x10, for PWR and BWR fuel types, respectively. Table 2.1.11 specifies the acceptable fuel characteristics of stainless steel clad fuel for storage.

The MPC-24 and MPC-68 are qualified for storage of SNF with different combinations of maximum burnup levels and minimum cooling times. Figure 2.1.6 specifies the acceptable maximum burnup levels and minimum cooling times for storage of zircaloy clad fuel in the MPC-24 and the MPC-68 (Appendix B to the Certificate of Compliance presents this data in tabular form). Table 2.1.11 specifies the acceptable maximum burnup levels and minimum cooling times for storage of stainless steel clad fuel. The values in Figure 2.1.6 and Table 2.1.11 were chosen based on an analysis of the maximum decay heat load that could be accommodated within each MPC. The shielding analyses presented in this chapter used the burnup and cooling time combinations listed below which are either equal to or conservatively bound the acceptable burnup levels and cooling times shown in Figure 2.1.6 and Table 2.1.11.

Maximum Burnup and Minimum Cooling Times Analyzed	
Zircaloy Clad Fuel	
MPC-24	**MPC-68**
40,000 MWD/MTU 5 year cooling	35,000 MWD/MTU 5 year cooling
47,500 MWD/MTU 8 year cooling	45,000 MWD/MTU 9 year cooling
N/A	30,000 MWD/MTU 18 year cooling (6x6 intact, damaged and MOX fuel)
Stainless Steel Clad Fuel	
MPC-24	**MPC-68**
30,000 MWD/MTU 9 year cooling	22,500 MWD/MTU 10 year cooling
40,000 MWD/MTU 15 year cooling	N/A

Appendix B to the Certificate of Compliance requires that, in the MPC-24, for a minimum cooling time of 5-years, the maximum burnup is 28,700 MWD/MTU, and for 15-year cooling the maximum burnup is 42,100 MWD/MTU *for PWR fuel assemblies without Burnable Poison Rod Assemblies (BPRAs). PWR fuel assemblies containing BPRAs are limited to 28,300 MWD/MTU for 5 year cooling and 41,400 MWD/MTU for 15 year cooling.* Since the burnup and cooling times analyzed in this chapter for the MPC-24 were 40,000 MWD/MTU and 5-year cooling and 47,500 MWD/MTU and 8-year cooling, the shielding analysis presented is conservatively bounding for the MPC-24.

Appendix B to the Certificate of Compliance requires that, in the MPC-68, for a minimum cooling time of 5-years, the maximum burnup is 26,000 MWD/MTU, and for 15-year cooling the maximum burnup is 37,600 MWD/MTU. Since the burnup and cooling times analyzed in this chapter for the MPC-68 were 35,000 MWD/MTU and 5-year cooling and 45,000 MWD/MTU and 9-year cooling, the shielding analysis presented is conservatively bounding for the MPC-68.

The dose rates corresponding to the burnup and cooling time combination which resulted in the highest dose rates at the midplane of the cask during normal conditions are reported in this section. Dose rates for each of the combinations are listed in Section 5.4.

5.1.1 Normal and Off-Normal Operations

Chapter 11 discusses the potential off-normal conditions and their effect on the HI-STAR 100 System. None of the off-normal conditions have any impact on the shielding analysis. Therefore, off-normal and normal conditions are identical for the purpose of the shielding evaluation.

The 10CFR72.104 criteria for radioactive materials in effluents and direct radiation during normal operations are:

1. During normal operations and anticipated occurrences, the annual dose equivalent to any real individual who is located beyond the controlled area, must not exceed 25 mrem to the whole body, 75 mrem to the thyroid and 25 mrem to any other *critical* organ.

2. Operational restrictions must be established to meet as low as reasonably achievable objectives for radioactive materials in effluents and direct radiation.

10CFR20 Subparts C and D specify additional requirements for occupational dose limits and radiation dose limits for individual members of the public. Chapter 10 specifically addresses these regulations.

In accordance with ALARA practices, design objective dose rates are established for the HI-STAR 100 in Section 2.3.5.2 as: 125 mrem/hour on the radial surface of the overpack, and 375 mrem/hour in areas above and below the neutron shield in the radial direction.

The dose rates presented in this section are calculated at 40,000 MWD/MTU and 5-year cooling for the MPC-24, and 35,000 MWD/MTU and 5-year cooling for the MPC-68. Based on a comparison of the normal condition dose rates at the fuel mid-plane for the various burnup and cooling time combinations analyzed, these were chosen as the worst case for the MPC-24 and the MPC-68. Section 5.4 provides a detailed list of dose rates at several cask locations for all burnup and cooling times analyzed.

Figure 5.1.1 identifies the locations of the dose points referenced in the summary tables. The bottom shield shown in this figure is temporary shielding which may be used during on-site horizontal handling operations. Dose Point #7 is located directly below the overpack bottom plate or directly below the bottom shield when it is attached. Dose Points #1, #3, and #4 are not contact doses, but rather, in-air doses at the locations shown. The dose values reported at the locations shown on Figure 5.1.1 are averaged over a region that is approximately 1 foot in width.

Tables 5.1.2 and 5.1.3 provide the maximum dose rates adjacent to the overpack during normal conditions for each of the MPCs. Tables 5.1.5 and 5.1.6 provide the maximum dose rates at one meter from the overpack.

The dose to any real individual at or beyond the controlled area boundary is required to be below 25 mrem per year. The minimum distance to the controlled area boundary is 100 meters from the ISFSI. Only the MPC-24 was used in the calculation of the dose rates at the controlled area boundary. The MPC-24 was chosen because its dose rates are equivalent or greater than the dose rates from the MPC-68 as shown in Tables 5.1.2, 5.1.3, 5.1.5, and 5.1.6. Table 5.1.7 presents the annual dose to an individual from a single cask and various arrays of casks, assuming 100% occupancy (8760 hours). The minimum distance required for the corresponding dose is also listed. These values were calculated for the MPC-24 with a burnup of 40,000 MWD/MTU and a 5-year cooling time. It will be shown in Section 5.4.3 that this burnup and cooling time results in the highest offsite dose for the combinations of maximum burnup and minimum cooling time analyzed. It is noted that these data are provided for illustrative purposes only. A detailed site specific evaluation of dose at the controlled area boundary will be performed for each ISFSI in accordance with 10CFR72.212, as stated in Chapter 12, Operating Controls and Limits. The site specific evaluation will consider dose from other portions of the facility and will consider the specifics of the fuel being stored (burnup and cooling time).

Figure 5.1.2 is an annual dose versus distance graph for the cask configurations provided in Table 5.1.7. This curve, which is based on 100% occupancy, is provided for illustrative purposes only and will be re-evaluated on a site-specific basis.

Section 5.2 lists the gamma and neutron sources for the design basis intact and damaged fuels. Since the source strengths of the damaged fuel and the MOX fuel are significantly smaller in all energy groups than those corresponding to the intact design basis fuel source strengths, the damaged and MOX fuel dose rates for normal conditions are bounded by the MPC-68 analysis with design basis intact fuel. Therefore, no explicit analysis is required to demonstrate that the MPC-68 with damaged or MOX fuel will meet the normal condition regulatory requirements.

Section 5.2.6 lists the gamma and neutron sources from the Dresden Unit 1 Thoria rod canister and demonstrates that the Thoria rod canister is bounded by the design basis Dresden Unit 1 6x6 intact fuel.

Section 5.2.4 presents the Co-60 sources from the BPRAs and TPDs that are permitted for storage in the HI-STAR 100. Section 5.4.6 demonstrates that the maximum dose rates presented in this section bound the dose rates from fuel assemblies containing either BPRAs or TPDs.

Section 5.4.7 demonstrates that the Dresden Unit 1 fuel assemblies containing antimony-beryllium neutron sources are bounded by the shielding analysis presented in this section.

Section 5.2.3 presents the gamma and neutron source for the design basis intact stainless steel clad fuel. The dose rates from this fuel are provided in Section 5.4.5.

The analyses summarized in this section demonstrate that the HI-STAR 100 System is in compliance with the 10CFR72.104 limits and ALARA practices.

5.1.2 Accident Conditions

The 10CFR72.106 radiation dose limits at the controlled area boundary for design basis accidents are:

> Any individual located on or beyond the nearest boundary of the controlled area ~~shall~~ *may* not receive *from any design basis accident the more limiting of a total effective dose equivalent of 5 Rem, or the sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue (other than the lens of the eye) of 50 Rem. The lens dose equivalent shall not exceed 15 Rem and the shallow dose equivalent to skin or to any extremity shall not exceed 50 rem.* ~~a dose greater than 5 Rem to the whole body or any organ from any design basis accident.~~ The minimum distance from the spent fuel or high level radioactive waste handling and storage facilities to the nearest boundary of the controlled area shall be at least 100 meters.

The design basis accidents analyzed in Chapter 11 have one bounding consequence which affects the shielding materials. It is the damage to the neutron shield as a result of the design basis fire. Other design basis accidents result in damage to the outer enclosure shell and neutron shield; however, these accidents are localized. In a conservative fashion, the dose analysis assumes that as a result of the fire, the neutron shield is completely destroyed and replaced by a void. This is highly conservative as there will be limited sources of combustible materials stored in or around the ISFSI. Additionally, the neutron shield is assumed to be completely lost, whereas some portion of the neutron shield would be expected to remain, as the neutron shield material is fire retardant.

Throughout all design basis accident conditions the axial location of the fuel will remain fixed within the MPC because of the fuel spacers. Chapter 3 provides an analysis to show that the fuel spacers do not fail under all normal, off-normal, and accident conditions of storage. Chapter 3 also shows that the inner shell, intermediate shells, radial channels, and outer enclosure shell of the overpack remain unaltered throughout all design basis accident conditions. Localized damage of the overpack outer enclosure shell could be experienced. However, the localized deformations will have a negligible impact on the dose rate at the boundary of the controlled area.

The complete loss of the neutron shield significantly affects the dose at Dose Point #2 at the mid-height adjacent to the overpack neutron shield. Loss of the neutron shield has a small effect on the other dose points. To illustrate the impact of the design basis accident, the dose rates at Dose

Table 5.1.3

DOSE RATES ADJACENT TO OVERPACK FOR NORMAL CONDITIONS
MPC-68 WITH DESIGN BASIS ZIRCALOY CLAD FUEL AT WORST CASE
BURNUP AND COOLING TIME
35,000 MWD/MTU AND 5-YEAR COOLING

Dose Point† Location	**Fuel Gammas†† (mrem/hr)**	**^{60}Co Gammas (mrem/hr)**	**Neutrons (mrem/hr)**	**Totals (mrem/hr)**
1	10.25	297.85	65.65	373.75
2	99.95	0.03	19.40	119.39
3	0.87	117.57	29.48	147.92
4	0.40	44.36	17.04	61.81
5	0.13	0.43	24.74	25.30
6 (dry MPC)†††	5.19	204.40	59.07	~~286~~*268*.65
7 (no temp. shield)	64.46	1794.41	327.79	2186.65
7 (with temp. shield)	20.35	381.90	14.49	416.74

† Refer to Figure 5.1.1.

†† Gammas generated by neutron capture are included with fuel gammas.

††† Overpack closure plate not present.

5.2.4 Control Components

~~Control components~~ *Rod cluster control assemblies and axial power shaping rods* are not permitted for storage in the HI-STAR 100 system. *However, burnable poison rod assemblies (BPRAs) and thimble plug devices (TPDs) are permitted for storage in the HI-STAR 100 System as an integral part of a PWR fuel assembly.*

5.2.4.1 BPRAs and TPDs

Burnable poison rod assemblies (BPRA) (including wet annular burnable absorbers and similarly designed devices with different names) and thimble plug devices (TPD) (including orifice rod assemblies, guide tube plugs, and similarly designed devices with different names) are an integral, yet removable, part of a large portion of PWR fuel. The TPDs are not used in all assemblies in a reactor core but are reused from cycle to cycle. Therefore, these devices can achieve very high burnups. In contrast, BPRAs are burned with a fuel assembly in core and are not reused. In fact, many BPRAs are removed after one or two cycles before the fuel assembly is discharged. Therefore, the achieved burnup for BPRAs is not significantly different than fuel assemblies.

TPDs are made of stainless steel and contain a small amount of inconel. These devices extend down into the plenum region of the fuel assembly but do not extend into the active fuel region with the exception of the W 14x14 water displacement guide tube plugs. Since these devices are made of stainless steel, there is a significant amount of cobalt-60 produced during irradiation. This is the only significant radiation source from the activation of steel and inconel.

BPRAs are made of stainless steel in the region above the active fuel zone and may contain a small amount of inconel in this region. Within the active fuel zone the BPRAs may contain 2-24 rodlets which are burnable absorbers clad in either zircaloy or stainless steel. The stainless steel clad BPRAs create a significant radiation source (Co-60) while the zircaloy clad BPRAs create a negligible radiation source. Therefore the stainless steel clad BPRAs are bounding.

SAS2H and ORIGEN-S were used to calculate a radiation source term and decay heat level for the TPDs and BPRAs. In the ORIGEN-S calculations the cobalt-59 impurity level was conservatively assumed to be 0.8 gm/kg for stainless steel and 4.7 gm/kg for inconel. These calculations were performed by irradiating the appropriate mass of steel and inconel using the flux calculated for the design basis B&W 15x15 fuel assembly. The mass of material in the regions above the active fuel zone was scaled by the appropriate scaling factors listed in Table 5.2.10 in order to account for the reduced flux levels above the fuel assembly. The total curies of cobalt and the decay heat load were calculated for the TPDs and BPRAs as a function of burnup and cooling time. For burnups beyond 45,000 MWD/MTU, it was assumed, for the purpose of the calculation, that the burned fuel assembly was replaced with a fresh fuel assembly every 45,000 MWD/MTU. This was achieved in ORIGEN-S by resetting the flux levels and cross sections to the 0 MWD/MTU condition after every 45,000 MWD/MTU.

Since the HI-STAR 100 cask system is designed to store many varieties of PWR fuel, a bounding TPD and BPRA had to be determined for the purposes of the analysis. This was accomplished by analyzing all of the BPRAs and TPDs (Westinghouse and B&W 14x14 through 17x17) found in references [5.2.5] and [5.2.7] to determine the TPD and BPRA which produced the highest Cobalt-60 source term and decay heat for a specific burnup and cooling time. The bounding TPD was determined to be the Westinghouse 17x17 guide tube plug and the bounding BPRA was actually determined by combining the higher masses of the Westinghouse 17x17 and 15x15 BPRAs into a singly hypothetical BPRA. The masses of this TPD and BPRA are listed in Table 5.2.29. As mentioned above, reference [5.2.5] describes the Westinghouse 14x14 water displacement guide tube plug as having a steel portion which extends into the active fuel zone. This particular water displacement guide tube plug was analyzed and determined to be bounded by the design basis TPD and BPRA.

Once the bounding BPRA and TPD were determined, the allowable decay heat load and Co-60 source from the BPRA and TPD were specified: 0.77 watts and 50 curies Co-60 for each TPD, and 13.0 watts and 831 curies Co-60 for each BPRA. Table 5.2.30 shows the curies of Co-60 that were calculated for BPRAs and TPDs in each region of the fuel assembly (e.g. incore, plenum, top). The allowable decay heat load for the TPDs and BPRAs was subtracted from the allowable decay heat load per assembly to determine the allowable PWR fuel assembly burnup and cooling times listed in Table 1.1-6 of Appendix B of the Certificate of Compliance. Since the decay heat load of the TPDs is negligible the same burnup and cooling time is used for assemblies with or without TPDs. However, a different burnup and cooling time is used for assemblies that contain BPRAs to account for the allowable BPRA decay heat load of 13.0 watts. A separate allowable burnup and cooling time is used for BPRAs and TPDs. These burnup and cooling times assure that the decay heat load and Cobalt-60 activity remain below the allowable levels specified above. It should be noted that at very high burnups, greater than 200,000 MWD/MTU the TPD decay heat load for a given cooling time actually decreases as the burnup continues to increase. This is due to a decrease in the Cobalt-60 production rate as the initial Cobalt-59 impurity is being depleted. Conservatively, a constant cooling time has been specified for burnups from 180,000 to 630,000 MWD/MTU for the TPDs.

Section 5.4.6 demonstrates that the dose rates from fuel assemblies containing BPRAs or TPDs is bounded by the dose rates presented in Section 5.1.1.

5.2.5 Choice of Design Basis Assembly

The analysis presented in this chapter was performed to bound the fuel assembly classes listed in Tables 2.1.1 and 2.1.2. In order to perform a bounding analysis, a design basis fuel assembly must be chosen. Therefore, a fuel assembly from each fuel class was analyzed and a comparison of the neutrons/sec, photons/sec, and thermal power (watts) was performed. The fuel assembly which produced the highest source for a specified burnup, cooling time, and enrichment was

Since the design basis damaged fuel assembly and the design basis intact 6x6 fuel assembly are identical, the analysis presented in Section 5.4.2 for the damaged fuel assembly also demonstrates the acceptability of storing intact 6x6 fuel assemblies from the Dresden 1 and Humboldt Bay fuel assembly classes.

5.2.5.3 Decay Heat Loads

Section 2.1.5 describes the calculation of the burnup versus cooling time Technical Specification which is based on a maximum permissible decay heat per assembly. The decay heat values per assembly were calculated using the methodology described in Section 5.2. The design basis fuel assemblies, as described in Table 5.2.1, were used in the calculation of the burnup versus cooling time Technical Specification. The enrichments used in the calculation of the decay heats were consistent with Table 5.2.23. As demonstrated in Tables 5.2.26 and 5.2.27, the design basis fuel assembly produces a higher decay heat value than the other assembly types considered. This is due to the higher heavy metal mass in the design basis fuel assemblies. Conservatively, ~~the Technical Specifications~~*Appendix B of the Certificate of Compliance* limits the heavy metal mass *of the design basis fuel assembly classes* to a value less than the design basis value utilized in this chapter. This provides additional assurance that the decay heat values are bounding values.

As further demonstration that the decay heat values (calculated using the design basis fuel assemblies) are conservative, a comparison between these calculated decay heats and the decay heats reported in Reference [5.2.7] are presented in Table 5.2.28. This comparison is made for a burnup of 30,000 MWD/MTU and a cooling time of 5 years. The burnup was chosen based on the limited burnup data available in Reference [5.2.7].

The heavy metal mass of the non-design basis fuel assembly classes in Appendix B of the Certificate of Compliance are limited to the masses used in Tables 5.2.24 and 5.2.25. No margin is applied between the allowable mass and the analyzed mass of heavy metal for the non-design basis fuel assemblies. This is acceptable because additional assurance that the decay heat values for the non-design basis fuel assemblies are bounding values is obtained by using the decay heat values for the design basis fuel assemblies to determine the acceptable storage criteria for all fuel assemblies. As mentioned above, Table 5.2.28 demonstrates the level of conservatism in applying the decay heat from the design basis fuel assembly to all fuel assemblies.

5.2.6 Thoria Rod Canister

Dresden Unit 1 has a single DFC containing 18 thoria rods which have obtained a relatively low burnup, 16,000 MWD/MTU. These rods were removed from two 8x8 fuel assemblies which contained 9 rods each. The irradiation of thorium produces an isotope which is not commonly found in depleted uranium fuel. Th-232 when irradiated produces U-233. The U-233 can undergo an (n,2n) reaction which produces U-232. The U-232 decays to produce Tl-208 which produces a 2.6 MeV gamma during Beta decay. This results in a significant source in the 2.5-3.0

MeV range which is not commonly present in depleted uranium fuel. Therefore, this single DFC container was analyzed to determine if it was bounded by the current shielding analysis.

A radiation source term was calculated for the 18 thoria rods using SAS2H and ORIGEN-S for a burnup of 16,000 MWD/MTU and a cooling time of 18 years. Table 5.2.31 describes the 8x8 fuel assembly that contains the thoria rods. Table 5.2.32 and 5.2.33 show the gamma and neutron source terms, respectively, that were calculated for the 18 thoria rods in the thoria rod canister. Comparing these source terms to the design basis 6x6 source terms for Dresden Unit 1 fuel in Tables 5.2.6 and 5.2.14 clearly indicates that the design basis source terms bound the thoria rods source terms in all neutron groups and in all gamma groups except the 2.5-3.0 MeV group. As mentioned above, the thoria rods have a significant source in this energy range due to the decay of Tl-208.

Section 5.4.8 provides a further discussion of the thoria rod cansiter and its acceptablity for storage in the HI-STAR 100 System.

5.2.7 Fuel Assembly Neutron Sources

Neutron sources are used in reactors during initial startup of reactor cores. There a different types of neutron sources (e.g. californium, americium-beryllium, plutonium-beryllium, antimony-beryllium). These neutron sources are typically inserted into the water rod of a fuel assembly and are usually removable.

Dresden Unit 1 has a few antimony-beryllium neutron sources. These sources have been analyzed in Section 5.4.7 to demonstrate that they are acceptable for storage in the HI-STAR 100 System. Currently these are the only neutron source permitted for storage in the HI-STAR 100 System.

Table 5.2.29

DESCRIPTION OF DESIGN BASIS BURNABLE POISON ROD ASSEMBLY AND THIMBLE PLUG DEVICE

Region	***BPRA***	***TPD***
Upper End Fitting (kg of steel)	*2.62*	*2.3*
Upper End Fitting (kg of inconel)	*0.42*	*0.42*
Gas Plenum Spacer (kg of steel)	*0.77488*	*1.71008*
Gas Plenum Springs (kg of steel)	*0.67512*	*1.48992*
In-core (kg of steel)	*13.2*	*N/A*

Table 5.2.30

DESIGN BASIS COBALT-60 ACTIVITIES FOR BURNABLE POISON ROD ASSEMBLIES AND THIMBLE PLUG DEVICES

Region	***BPRA***	***TPD***
Upper End Fitting (curies Co-60)	*30.4*	*25.21*
Gas Plenum Spacer (curies Co-60)	*4.6*	*9.04*
Gas Plenum Springs (curies Co-60)	*8.2*	*15.75*
In-core (curies Co-60)	*787.8*	*N/A*

Table 5.2.31

DESCRIPTION OF FUEL ASSEMBLY USED TO ANNALYZE THORIA RODS IN THE THORIA ROD CANISTER

	BWR
Fuel type	*8x8*
Active fuel length (in.)	*110.5*
No. of UO_2 fuel rods	*55*
No. of UO_2/ThO_2 fuel rods	*9*
Rod pitch (in.)	*0.523*
Cladding material	*zircaloy*
Rod diameter (in.)	*0.412*
Cladding thickness (in.)	*0.025*
Pellet diameter (in.)	*0.358*
Pellet material	*98.2% ThO_2 and 1.8% UO_2 for UO_2/ThO_2 rods*
Pellet density (gm/cc)	*10.412*
Enrichment (w/o ^{235}U)	*93.5 in UO_2 for UO_2/ThO_2 rods and 1.8 for UO_2 rods*
Burnup (MWD/MTIHM)	*16,000*
Cooling Time (years)	*18*
Specific power (MW/MTIHM)	*16.5*
Weight of THO_2 and UO_2 (kg)†	*121.46*
Weight of U (kg)†	*92.29*
Weight of Th (kg)†	*14.74*

† *Derived from parameters in this table.*

Table 5.2.32

CALCULATED FUEL GAMMA SOURCE FOR THORIA ROD CANISTER CONTAINING EIGHTEEN THORIA RODS

Lower Energy	***Upper Energy***	***16,000 MWD/MTIHM 18-Year Cooling***	
(MeV)	*(MeV)*	*(MeV/s)*	*(Photons/s)*
7.0e-01	*1.0*	*5.79e+11*	*6.81e+11*
1.0	*1.5*	*3.79e+11*	*3.03e+11*
1.5	*2.0*	*4.25e+10*	*2.43e+10*
2.0	*2.5*	*4.16e+8*	*1.85e+8*
2.5	*3.0*	*2.31e+11*	*8.39e+10*
Totals		*1.23e+12*	*1.09e+12*

Table 5.2.33

CALCULATED FUEL NEUTRON SOURCE FOR THORIA ROD CANISTER CONTAINING EIGHTEEN THORIA RODS

Lower Energy (MeV)	***Upper Energy (MeV)***	***16,000 MWD/MTIHM 18-Year Cooling (Neutrons/s)***
1.0e-01	*4.0e-01*	*5.65e+2*
4.0e-01	*9.0e-01*	*3.19e+3*
9.0e-01	*1.4*	*6.79e+3*
1.4	*1.85*	*1.05e+4*
1.85	*3.0*	*3.68e+4*
3.0	*6.43*	*1.41e+4*
6.43	*20.0*	*1.60e+2*
Totals		*7.21e+4*

5.3.1.1 Fuel Configuration

As described above, the active fuel region is modeled as a homogenous zone. The end fittings and the plenum regions are also modeled as homogenous regions of steel. The masses of steel used in these regions are shown in Table 5.2.1. The axial description of the design basis fuel assemblies is provided in Table 5.3.1. Figures 5.3.7 and 5.3.8 graphically depict the location of the PWR and BWR fuel assemblies within the HI-STAR 100 System. The axial locations of the Boral, basket, pocket trunnion, and transition areas are shown in these figures.

5.3.1.2 Streaming Considerations

The streaming from the radial steel fins and pocket trunnions in the neutron shield is evaluated in Section 5.4.1. The MCNP model of the HI-STAR 100 completely describes the radial steel fins and pocket trunnions, thereby properly accounting for the streaming effect. This is discussed further in Section 5.4.1.

The design of the HI-STAR 100 System, as described in the Design Drawings in Section 1.5, has eliminated all other possible streaming paths. Therefore, the MCNP model does not represent any additional streaming paths. A brief justification of this assumption is provided for each penetration.

- The lifting trunnions will remain installed in the overpack top flange. No credit is taken for any part of the trunnion that extends outside of the overpack.

- The pocket trunnions are modeled as solid blocks of steel. The pocket trunnion will be filled with a solid steel rotation trunnion attached to the transport frame during handling and a ~~neutron~~ shield plug when located at the ISFSI pad.

- The threaded holes in the MPC lid are plugged with solid plugs during storage and, therefore, do not create a void in the MPC lid.

- The drain and vent ports in the MPC lid are designed to eliminate streaming paths. The steel lost in the MPC lid at the port location is replaced with a block of steel approximately 6 inches thick below the port opening and attached to the underside of the lid. This design feature is shown on the Design Drawings in Section 1.5. The MCNP model did not explicitly represent this arrangement but, rather, modeled the MPC lid as a solid piece.

- The penetrations in the overpack are filled with bolts that extend into the penetration when in storage operations, thereby eliminating any potential direct streaming paths. Cover plates are also designed in such a way as to maintain the thickness of the overpack

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

FIGURE 5.3.9; HI-STAR 100 OVERPACK WITH MPC-24 CROSS SECTIONAL VIEW SHOWING THE THICKNESS OF THE MPC *8444P•LD-SHELL* AND OVERPACK AS MODELED IN MCNP reported in Section 5.1. A detailed discussion of the normal, off-normal, and accident condition dose rates was provided in Sections 5.1.1 and 5.1.2.

Since MCNP is a statistical code, there is an uncertainty associated with the calculated values. In MCNP the uncertainty is expressed as the relative error which is defined as the standard deviation of the mean divided by the mean. Therefore, the standard deviation is represented as a percentage of the mean. The relative error for the total dose rates presented in this chapter were typically less than 3% and the relative error for the individual dose components was typically less than 5%.

5.4.1 Streaming Through Radial Steel Fins and Pocket Trunnions

The HI-STAR 100 overpack utilizes 0.5 inch thick radial steel fins for structural support and cooling. The attenuation of neutrons through steel is substantially less than the attenuation of neutrons through the Holtite-A. Therefore, it is possible to have neutron streaming through the fins which could result in a localized dose peak. The reverse is true for photons which would result in a localized reduction in the photon dose. Analyses were performed to determine the magnitude of the dose peaks and depressions and the impact on localized dose as compared to average total dose. This effect was evaluated at the radial surface of the cask and a distance of one meter from the cask.

In addition to the fins, the pocket trunnions are essentially blocks of steel that are approximately 12 inches wide and 12 inches high. The effect of the pocket trunnion on neutron streaming and photon transmission will be more substantial than the effect of a single fin. Therefore, analyses were performed to quantity this effect. Figure 5.1.1 illustrates the location of the pocket trunnion and its axial position relative to the active fuel. This position will be important in the discussion that follows.

The effect of streaming through the pocket trunnion and the fins was analyzed using MCNP. The model used was an infinite height radial model which consisted of the MPC and the surrounding overpack. The active fuel region of the fuel assemblies was represented in the MPC basket when the neutron source was used and the lower steel regions of the fuel elements were presented in the MPC basket when the cobalt source was used. The pocket trunnion was represented in this infinite model as being axially adjacent to the active fuel. A calculation was not performed with the photon source. Any depression of the gamma dose due to the steel will be evident when using the cobalt source and this will conservatively bound the effects due to the photon source. This is because the average energy of the photons from ^{60}Co is higher than the average energy of decay gammas.

The MPC-24 and the MPC-68 were analyzed. Figure 5.4.1 shows a quarter of the HI-STAR 100 overpack with 91 azimuthal bins drawn. There is one bin per steel fin and 8 bins in each Holtite-A region. This azimuthal binning structure was used in an infinite height two-dimensional model of the MPC and overpack. The dose was calculated in each of these bins and then compared to the average dose calculated over the surface to determine a peak-to-average ratio for the dose in that bin. The location of the pocket trunnion is shown in Figure 5.4.1. The pocket trunnion was modeled as solid steel. During storage, a ~~neutron~~ shield plug shall be placed in the pocket trunnion recess, and during handling operations a steel rotation trunnion shall be placed in the pocket trunnion recess. To conservatively evaluate the peak-to-average ratio, the pocket trunnion is assumed to be solid steel. The peak-to-average ratio was calculated for the entire pocket trunnion which would correspond to the first seven azimuthal bins.

Table 5.4.10 provides the peak-to-average ratios that were calculated for the various dose components and locations. The peak-to-average ratios were essentially the same for all MPCs, therefore, only one set of values is shown. The values presented for the pocket trunnions are very conservative since the two-dimensional model represented the trunnion as infinite in height whereas the actual height is approximately 12 inches. In addition, the pocket trunnion was represented as being axially adjacent to the active fuel which is not completely accurate for the design basis fuel. The infinite two-dimensional model therefore does not represent any leakage out of the pocket trunnion in the axial direction which would reduce the peaking effect.

Table 5.4.11 presents the dose rates at Dose Point #2 (see Figure 5.1.1) and the adjusted dose rates at this point to account for the streaming effects. An additional dose point labeled 2a is listed in this table. This location is axially adjacent to the pocket trunnion and approximately 6 feet below Dose Point #2. Based on these results it can be concluded that the streaming effect is noticeable but is not of significant concern.

5.4.2 Damaged Fuel Post-Accident Shielding Evaluation

As discussed in Section 5.2.5.2, the analysis presented below, even though it is for damaged fuel, demonstrates the acceptability of storing intact Humboldt Bay 6x6 and intact Dresden 1 6x6 fuel assemblies.

For the damaged fuel and fuel debris accident condition, it is conservatively assumed that the damaged fuel cladding ruptures and all the fuel pellets fall and collect at the bottom of the damaged fuel container. The inner dimension of the damaged fuel container, specified in the Design Drawings of Section 1.5, and the design basis damaged fuel and fuel debris assembly dimensions in Table 5.2.2 are used to calculate the axial height of the rubble in the damaged fuel container assuming 50% compaction. Neglecting the fuel pellet to cladding inner diameter gap, the volume of cladding and fuel pellets available for deposit is calculated assuming the fuel rods are solid. Using the volume in conjunction with the damaged fuel container, the axial height of rubble is calculated to be 80 inches.

Dividing the total fuel gamma source for damaged fuel in Table 5.2.6 by the 80 inch rubble height provides a gamma source per inch of 9.68e+10 photon/s. Dividing the total neutron source for damaged fuel in Table 5.2.14 by 80 inches provides a neutron source per inch of 2.75e+5 neutron/s. These values are both bounded by the BWR design basis fuel gamma source significant gamma source from Cobalt-60 activation in the stainless steel. Therefore it is necessary to calculate the dose rates from the stainless steel clad fuel and compare them to the dose rates from the zircaloy clad fuel. In calculating the dose rates, the source term for the stainless steel fuel was calculated with an artificial active fuel length of 144 inches to permit a simple comparison of dose rates from stainless steel clad fuel and zircaloy clad fuel at the center of the HI-STAR 100 overpack. Since the true active fuel length is shorter than 144 inches and since the end fitting masses of the stainless steel clad fuel are assumed to be identical to the end fitting masses of the zircaloy clad fuel, the dose rates at the other locations on the overpack are bounded by the dose rates from the design basis zircaloy clad fuel, and therefore, no additional dose rates are presented.

5.4.6 BPRAs and TPDs

In order to verify that the BPRAs and TPDs do not affect the shielding analysis, the total dose rates were calculated for the HI-STAR 100 assuming all fuel assemblies in the MPC contained either BPRAs or TPDs. For this calculation, three separate burnups, slightly higher than the allowable burnups listed in Appendix B of the Certificate of Compliance were used with the corresponding cooling time. Tables 5.4.16 and 5.4.17 present the comparison of the total dose rates around the HI-STAR 100 overpack for PWR fuel with and without BPRAs or TPDs. The design basis dose rates are provided in these tables for easy comparison. A comparison of accident condition dose rates is only performed for assemblies with BPRAs since the TPDs, which are in the upper portion of the fuel assembly, will not have a noticeable impact on the accident dose rates at the centerline of the overpack. These tables illustrate that the dose rates for fuel assemblies containing BPRAs and TPDs are bounded by the design basis 40,000 MWD/MTU and 5 year cooling dose rates listed in Section 5.1.1 and Section 5.1.2. Therefore, the addition of BPRAs and TPDs to the MPC-24 is bounded by the shielding analysis presented in this chapter.

5.4.7 Dresden Unit 1 Antimony-Beryllium Neutron Sources

Dresden Unit 1 has antimony-beryllium neutron sources which are placed in the water rod location of their fuel assemblies. These sources are steel rods which contain a cylindrical antimony-beryllium source which is 77.25 inches in length. The steel rod is approximately 95 inches in length. Information obtained from Dresden Unit 1 characterizes these sources in the following manner: "About one-quarter pound of beryllium will be employed as a special neutron source material. The beryllium produces neutrons upon gamma irradiation. The gamma rays for the source at initial start-up will be provided by neutron-activated antimony (about 865 curies). The source strength is approximately 1E+8 neutrons/second."

As stated above, beryllium produces neutrons through gamma irradiation and in this particular case antimony is used as the gamma source. The threshold gamma energy for producing neutrons from beryllium is 1.666 MeV. The outgoing neutron energy increases as the incident gamma energy increases. Sb-124, which decays by Beta decay with a half life of 60.2 days, *produces a gamma of energy 1.69 MeV which is just energetic enough to produce a neutron from beryllium. Approximately 54% of the Beta decays for Sb-124 produce gammas with energies greater than or equal to 1.69 MeV. Therefore, the neutron production rate in the neutron source can be specified as 5.8E-6 neutrons per gamma (1E+8/865/3.7e+10/0.54) with energy greater than 1.666 MeV or 1.16E+5 neutrons/curie (1E+8/865) of Sb-124.*

With the short half life of 60.2 days all of the initial Sb-124 is decayed and any Sb-124 that was produced while the neutron source was in the reactor is also decayed since these neutron sources are assumed to have the same minimum cooling time as the Dresden 1 fuel assemblies (array classes 6x6A, 6x6B, 6x6C, and 8x8A) of 18 years. Therefore, there are only two possible gamma sources which can produce neutrons from this antimony-beryllium source. The first is the gammas from the decay of fission products in the fuel assemblies in the MPC. The second gamma source is from Sb-124 which is being produced in the MPC from neutron activation from neutrons from the decay of fission products.

MCNP calculations were performed to determine the gamma source as a result of decay gammas from fuel assemblies and Sb-124 activation. The calculations explicitly modeled the 6x6 fuel assembly described in Table 5.2.2. A single fuel rod was removed and replaced by a guide tube. In order to determine the amount of Sb-124 that is being activated from neutrons in the MPC it was necessary to estimate the amount of antimony in the neutron source. The O.D. of the source was assumed to be the I.D. of the steel rod encasing the source (0.345 in.). The length of the source is 77.25 inches. The beryllium is assumed to be annular in shape encompassing the antimony. Using the assumed O.D. of the beryllium and the mass and length, the I.D. of the beryllium was calculated to be 0.24 inches. The antimony is assumed to be a solid cylinder with an O.D. equal to the I.D. of the beryllium. These assumptions are conservative since the antimony and beryllium are probably encased in another material which would reduce the mass of antimony. A larger mass of antimony is conservative since the calculated activity of Sb-124 is directly proportional to the initial mass of antimony.

*The number of gammas from fuel assemblies with energies greater than 1.666 MeV entering the 77.25 inch long neutron source was calculated to be 1.04E+8 gammas/sec which would produce a neutron source of 603.2 neutrons/sec (1.04E+8 * 5.8E-6). The steady state amount of Sb-124 activated in the antimony was calculated to be 39.9 curies. This activity level would produce a neutron source of 4.63E+6 neutrons/sec (39.9 * 1.16E+5) or 6.0E+4 neutrons/sec/inch (4.63E+6/77.25). These calculations conservatively neglect the reduction in antimony and beryllium which would have occurred while the neutron sources were in the core and being irradiated at full reactor power.*

Since this is a localized source (77.25 inches in length) it is appropriate to compare the neutron source per inch from the design basis Dresden Unit 1 fuel assembly, 6x6, containing an Sb-Be neutron source to the design basis fuel neutron source per inch. This comparison, presented in Table 5.4.15, demonstrates that a Dresden Unit 1 fuel assembly containing an Sb-Be neutron source is bounded by the design basis fuel.

As stated above, the Sb-Be source is encased in a steel rod. Therefore, the gamma source from the activation of the steel was considered assuming a burnup of 120,000 MWD/MTU which is the maximum burnup assuming the Sb-Be source was in the reactor for the entire 18 year life of Dresden Unit 1. The cooling time assumed was 18 years which is the minimum cooling time for Dresden Unit 1 fuel. The source from the steel was bounded by the design basis fuel assembly. In conclusion, storage of a Dresden Unit 1 Sb-Be neutron source in a Dresden Unit 1 fuel assembly is acceptable and bounded by the current analysis.

5.4.8 Thoria Rod Canister

Based on a comparison of the gamma spectra from Tables 5.2.32 and 5.2.6 for the thoria rod canister and design basis 6x6 fuel assembly, respectively, it is difficult to determine if the thoria rods will be bounded by the 6x6 fuel assemblies. However, it is obvious that the neutron spectra from the 6x6, Table 5.2.14, bounds the thoria rod neutron spectra, Table 5.2.33, with a significant margin. In order to demonstrate that the gamma spectrum from the single thoria rod canister is bounded by the gamma spectrum from the design basis 6x6 fuel assembly, the gamma dose rate on the outer radial surface of the overpack was estimated conservatively assuming an MPC full of thoria rod canisters. This gamma dose rate was compared to an estimate of the dose rate from an MPC full of design basis 6x6 fuel assemblies. The gamma dose rate from the 6x6 fuel was higher than the dose rate from an MPC full of thoria rod canisters. This in conjunction with the significant margin in neutron spectrum and the fact that there is only one thoria rod canister clearly demonstrates that the thoria rod canister is acceptable for storage in the MPC-68 or the MPC-68F.

Table 5.4.15

COMPARISON OF NEUTRON SOURCE PER INCH PER SECOND FOR DESIGN BASIS 7X7 FUEL AND DESIGN BASIS DRESDEN UNIT 1 FUEL

Assembly	***Active fuel length (inch)***	***Neutrons per sec per inch***	***Neutrons per sec per inch with Sb-Be source***	***Reference for neutrons per sec per inch***
7x7 design basis	*144*	*5.60E+5*	*N/A*	*Table 5.2.13 - 35 GWD/MTU and 5 year cooling*
6x6 design basis	*110*	*2.0e+5*	*2.6E+5*	*Table 5.2.14*
6x6 design basis MOX	*110*	*3.06E+5*	*3.66E+5*	*Table 5.2.17*

Table 5.4.16

COMPARISON OF TOTAL DOSE RATES FOR DESIGN BASIS PWR FUEL AND PWR FUEL WITH BPRAS MPC-24 NORMAL AND ACCIDENT CONDITIONS

Dose Point† Location	**40 GWD/MTU 5 year cooling DESIGN BASIS (mrem/hr)**	**29 GWD/MTU 5 year cooling (mrem/hr)**	**39 GWD/MTU 10 year cooling (mrem/hr)**	**42.5 GWD/MTU 15 year cooling (mrem/hr)**
BPRAs ?	NO	YES	YES	YES
SURFACE - NORMAL CONDITION				
1	326.24	244.72	195.95	143.2
2	119.03	99.66	69.57	61.70
3	154.90	136.39	136.84	120.32
4	77.14	64.13	67.66	60.70
5	57.73	25.15	48.25	50.53
6 (dry MPC)††	439.28	445.46	389.94	324.45
7 (no temp. shield)	1929.94	1557.87	1165.15	810.77
ONE METER - NORMAL CONDITION				
1	43.79	34.47	25.62	19.12
2	51.47	44.42	29.32	25.50
3	30.21	28.68	24.86	21.27
4	28.61	27.06	24.19	20.68
5	17.11	7.55	14.3	14.95
7 (no temp. shield)	889.68	717.64	501.61	329.5
SURFACE - ACCIDENT CONDITION				
2	1371.34	699.45	1074.98	1101.53
ONE METER - ACCIDENT CONDITION				
2	491.73	263.82	378.91	384.75

† *Refer to Figure 5.1.1.*

†† *Overpack closure plate not present.*

Table 5.4.17

COMPARISON OF TOTAL DOSE RATES FOR DESIGN BASIS PWR FUEL AND PWR FUEL WITH TPDS
MPC-24 NORMAL CONDITIONS

Dose Point† Location	**40 GWD/MTU 5 year cooling DESIGN BASIS (mrem/hr)**	**29 GWD/MTU 5 year cooling (mrem/hr)**	**39 GWD/MTU 10 year cooling (mrem/hr)**	**42.5 GWD/MTU 15 year cooling (mrem/hr)**
TPDs ?	NO	YES	YES	YES
SURFACE - NORMAL CONDITION				
1	326.24	241.88	193.11	140.36
2	119.03	78.00	47.91	40.04
3	154.90	134.01	134.47	117.95
4	77.14	63.09	66.62	59.66
5	57.73	25.12	48.22	50.51
6 (dry MPC)††	439.28	439.39	383.86	318.38
7 (no temp. shield)	1929.94	1531.39	1138.67	784.28
ONE METER - NORMAL CONDITION				
1	43.79	32.23	23.39	16.88
2	51.47	34.70	19.61	15.78
3	30.21	27.55	23.74	20.15
4	28.61	26.11	23.25	19.73
5	17.11	7.54	14.29	14.94
7 (no temp. shield)	889.68	703.89	487.86	315.76

† Refer to Figure 5.1.1.

†† Overpack closure plate not present.

5.6 REFERENCES

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[5.1.3] O.W. Hermann, R.M. Westfall, "ORIGEN-S: SCALE System Module to Calculate Fuel Depletion, Actinide Transmutation, Fission Product Buildup and Decay, and Associated Radiation Source Terms," NUREG/CR-0200, Revision 5, (ORNL/NUREG/CSD-2/V2/R5), Oak Ridge National Laboratory, September 1995.

[5.2.1] NUREG-1536, SRP for Dry Cask Storage Systems, USNRC, Washington, DC, January 1997.

[5.2.2] ~~A. Luksic, "Spent Fuel Assembly Hardware: Characterization and 10CFR 61 Classification for Waste Disposal," PNL-6906-vol. 1, Pacific Northwest Laboratory, June 1989.~~ *A.G. Croff, M.A. Bjerke, G.W. Morrison, L.M. Petrie, "Revised Uranium-Plutonium Cycle PWR and BWR Models for the ORIGEN Computer Code," ORNL/TM-6051, Oak Ridge National Laboratory, September 1978.*

[5.2.3] ~~A.G. Croff, M.A. Bjerke, G.W. Morrison, L.M. Petrie, "Revised Uranium-Plutonium Cycle PWR and BWR Models for the ORIGEN Computer Code," ORNL/TM-6051, Oak Ridge National Laboratory, September 1978.~~ *A. Luksic, "Spent Fuel Assembly Hardware: Characterization and 10CFR 61 Classification for Waste Disposal," PNL-6906-vol. 1, Pacific Northwest Laboratory, June 1989.*

[5.2.4] J.W. Roddy et al., "Physical and Decay Characteristics of Commercial LWR Spent Fuel," ORNL/TM-9591/V1&R1, Oak Ridge National Laboratory, January 1996.

[5.2.5] "Characteristics of Spent Fuel, High Level Waste, and Other Radioactive Wastes Which May Require Long-Term Isolation," DOE/RW-0184, U.S. Department of Energy, December 1987.

[5.2.6] "Spent Nuclear Fuel Discharges from U.S. Reactors 1994,"

6.1 DISCUSSION AND RESULTS

In conformance with the principles established in NUREG-1536 [6.1.1], 10CFR72.124 [6.1.2], and NUREG-0800 Section 9.1.2 [6.1.3], the results in this chapter demonstrate that the effective multiplication factor (k_{eff}) of the HI-STAR 100 System, including all biases and uncertainties evaluated with a 95% probability at the 95% confidence level, does not exceed 0.95 under all credible normal, off-normal, and accident conditions. Moreover, these results demonstrate that the HI-STAR 100 System is designed and maintained such that at least two unlikely, independent, and concurrent or sequential changes must occur to the conditions essential to criticality safety before a nuclear criticality accident is possible. These criteria provide a large subcritical margin, sufficient to assure the criticality safety of the HI-STAR 100 System when fully loaded with fuel of the highest permissible reactivity.

Criticality safety of the HI-STAR 100 System depends on the following three principal design parameters:

1. The inherent geometry of the fuel basket designs within the MPC (and the flux-trap water gaps in the MPC-24);

2. The incorporation of permanent fixed neutron-absorbing panels (Boral) in the fuel basket structure; and

3. An administrative limit on the maximum enrichment for PWR fuel and maximum planar-average enrichment for BWR fuel.

The normal conditions for loading/unloading, handling, packaging, transfer, and storage of the HI-STAR 100 System conservatively include: full flooding with ordinary water corresponding to the highest reactivity, and the worst case (most conservative) combination of manufacturing and fabrication tolerances. The off-normal and accident conditions defined in Chapter 2 and considered in Chapter 11 have no adverse effect on the design parameters important to criticality safety, and thus, the off-normal and accident conditions are identical to those for normal conditions.

The HI-STAR 100 System is designed such that the fixed neutron absorber (Boral) will remain effective for a storage period greater than 20 years, and there are no credible means to lose it. ~~Therefore, in accordance with NUREG-1536, there is no need to provide a surveillance or monitoring program to verify the continued efficacy of the neutron absorber, as required by 10CFR72.124(b).~~

Table 6.1.1

BOUNDING MAXIMUM k_{eff} VALUES FOR EACH ASSEMBLY CLASS IN THE MPC-24

Fuel Assembly Class	**Maximum Allowable Enrichment (wt% ^{235}U)**	**Maximum† k_{eff}**
14x14A	4.6	0.9383
14x14B	4.6	0.9323
14x14C	4.6	0.9~~361~~*400*
14x14D	4.0	0.8576
15x15A	4.1	0.9301
15x15B	4.1	0.9473
15x15C	4.1	0.9444
15x15D	4.1	0.9440
15x15E	4.1	0.9475
15x15F	4.1	0.9478††
15x15G	4.0	0.8986
15x15H	*3.8*	*0.9411*
16x16A	4.6	0.9383
17x17A	4.0	0.9452
17x17B	4.0	0.9436
17x17C	4.0	0.9427

Note: These calculations are for single unreflected, fully flooded casks. However, comparable reactivities were obtained for fully reflected casks and for arrays of casks.

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† The term "maximum k_{eff}" as used here, and elsewhere in this document, means the highest possible k-effective, including bias, uncertainties, and calculational statistics, evaluated for the worst case combination of manufacturing tolerances.

†† KENO5a verification calculation resulted in a maximum k_{eff} of 0.9466.

Table 6.1.2

BOUNDING MAXIMUM k_{eff} VALUES FOR EACH ASSEMBLY CLASS IN THE MPC-68

Fuel Assembly Class	**Maximum Allowable Planar-Average Enrichment (wt% ^{235}U)**	**Maximum† k_{eff}**
6x6A	2.7††	0.7~~602~~*888*†††
6x6B‡	2.7††	0.7~~611~~*824*†††
6x6C	2.7††	0.8021†††
7x7A	2.7††	0.797~~3~~*4*†††
7x7B	4.2	0.93~~7~~*886*
8x8A	2.7††	0.76~~85~~*97*†††
8x8B	4.2	0.9~~368~~*416*
8x8C	4.2	0.9425
8x8D	4.2	0.9~~366~~*403*
8x8E	4.2	0.9312
8x8F	*4.2*	*0.9140*

Note: These calculations are for single unreflected, fully flooded casks. However, comparable reactivities were obtained for fully reflected casks and for arrays of casks.

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† The term "maximum k_{eff} " as used here, and elsewhere in this document, means the highest possible k-effective, including bias, uncertainties, and calculational statistics, evaluated for the worst case combination of manufacturing tolerances.

†† This calculation was performed for 3.0% planar-average enrichment, however, the actual fuel is limited, as specified in Appendix B to the CoC, to a maximum planar-average enrichment of 2.7%. Therefore, the listed maximum k_{eff} value is conservative.

††† This calculation was performed for a ^{10}B loading of 0.0067 g/cm^2, which is 75% of a minimum ^{10}B loading of 0.0089 g/cm^2. The minimum ^{10}B loading in the MPC-68 is 0.0372 g/cm^2. Therefore, the listed maximum k_{eff} value is conservative.

‡ Assemblies in this class contain both MOX and UO_2 pins. The composition of the MOX fuel pins is given in Table 6.3.4. The maximum allowable planar-average enrichment for the MOX pins is given in the Appendix B to the Certificate of Compliance.

Table 6.1.2 (continued)

BOUNDING MAXIMUM k_{eff} VALUES FOR EACH ASSEMBLY CLASS IN THE MPC-68

Fuel Assembly Class	**Maximum Allowable Planar-Average Enrichment (wt% ^{235}U)**	**Maximum† k_{eff}**
9x9A	4.2	0.9417
9x9B	4.2	0.9~~388~~*422*
9x9C	4.2	0.9395
9x9D	4.2	0.939~~2~~*4*
9x9E	4.~~2~~*1*	0.94~~06~~*24*
9x9F	4.~~2~~*1*	0.9~~377~~*424*
10x10A	4.2	0.9457††
10x10B	4.2	0.9436
10x10C	4.2	0.~~8990~~*9021*
10x10D	4.0	0.9376
10x10E	4.0	0.9185

Note: These calculations are for single unreflected, fully flooded casks. However, comparable reactivities were obtained for fully reflected casks and for arrays of casks.

† The term "maximum k_{eff} " as used here, and elsewhere in this document, means the highest possible k-effective, including bias, uncertainties, and calculational statistics, evaluated for the worst case combination of manufacturing tolerances.

†† KENO5a verification calculation resulted in a maximum k_{eff} of 0.9453.

Table 6.1.3

BOUNDING MAXIMUM k_{eff} VALUES FOR EACH ASSEMBLY CLASS IN THE MPC-68F

Fuel Assembly Class	**Maximum Allowable Planar-Average Enrichment (wt% ^{235}U)**	**Maximum† k_{eff}**
6x6A	2.7††	0.7~~602~~*888*
6x6B†††	2.7	0.7~~611~~*824*
6x6C	2.7	0.8021
7x7A	2.7	0.797~~3~~*4*
8x8A	2.7	0.76~~85~~*97*

Note:

1. These calculations are for single unreflected, fully flooded casks. However, comparable reactivities were obtained for fully reflected casks and for arrays of casks.

2. These calculations were performed for a ^{10}B loading of 0.0067 g/cm^2, which is 75% of a minimum ^{10}B loading of 0.0089 g/cm^2. The minimum ^{10}B loading in the MPC-68F is 0.010 g/cm^2. Therefore, the listed maximum k_{eff} values are conservative.

† The term "maximum k_{eff} " as used here, and elsewhere in this document, means the highest possible k-effective, including bias, uncertainties, and calculational statistics, evaluated for the worst case combination of manufacturing tolerances.

†† These calculations were performed for 3.0% planar-average enrichment, however, the actual fuel is limited, as specified in Appendix B to the CoC, to a maximum planar-average enrichment of 2.7%. Therefore, the listed maximum k_{eff} values are conservative.

††† Assemblies in this class contain both MOX and UO_2 pins. The composition of the MOX fuel pins is given in Table 6.3.4. The maximum allowable planar-average enrichment for the MOX pins is specified in Appendix B to the Certificate of Compliance.

assembly classes, the bounding assembly is artificial (i.e., based on bounding dimensions from more than one of the actual assemblies). In classes where the bounding assembly is artificial, the reactivity of the actual (real) assemblies is typically much less than that of the bounding assembly; thereby providing additional conservatism. As a result of these analyses, the Certificate of Compliance will define acceptability in terms of the bounding assembly parameters for each class.

To demonstrate that the aforementioned characteristics are bounding, a parametric study was performed for a reference BWR assembly, designated herein as 8x8C04 (identified generally as a GE8x8R). The results of this study are shown in Table 6.2.3, and verify the positive reactivity effect associated with (1) increasing the pellet diameter, (2) maximizing the cladding ID (while maintaining a constant cladding OD), (3) minimizing the cladding OD (while maintaining a constant cladding ID), (4) decreasing the water rod thickness, (5) artificially replacing the Zircaloy water rod tubes with water, and (6) maximizing the channel thickness. These results, and the many that follow, justify the approach for using bounding dimensions in the Certificate of Compliance. Where margins permit, the Zircaloy water rod tubes (BWR assemblies) are artificially replaced by water in the bounding cases to remove the requirement for water rod thickness from the Certificate of Compliance.

As mentioned, the bounding approach used in these analyses often results in a maximum k_{eff} value for a given class of assemblies that is much greater than the reactivity of any of the actual (real) assemblies within the class, and yet, is still below the 0.95 regulatory limit.

6.2.2 PWR Fuel Assemblies in the MPC-24

For PWR fuel assemblies (specifications listed in Table 6.2.2) the 15x15F01 fuel assembly at 4.1% enrichment has the highest reactivity (maximum k_{eff} of 0.9478). The 17x17A01 assembly (otherwise known as a Westinghouse 17x17 OFA) has a similar reactivity (see Table 6.2.16) and was used throughout this criticality evaluation as a reference PWR assembly. The 17x17A01 assembly is a representative PWR fuel assembly in terms of design and reactivity and is useful for the reactivity studies presented in Sections 6.3 and 6.4. Calculations for the various PWR fuel assemblies in the MPC-24 are summarized in Tables 6.2.4 through 6.2.189 for the fully flooded condition.

Tables 6.2.4 through 6.2.189 show the maximum k_{eff} values for the assembly classes that are acceptable for storage in the MPC-24. All maximum k_{eff} values include the bias, uncertainties, and calculational statistics, evaluated for the worst combination of manufacturing tolerances. All calculations for the MPC-24 were performed for a ^{10}B loading of 0.020 g/cm^2, which is 75% of the minimum loading, 0.0267 g/cm^2, specified on BM-1478, Bill of Materials for 24-Assembly HI-STAR 100 PWR MPC, in Section 1.5. The maximum allowable enrichment in the MPC-24 varies from 4.0 to 4.6 wt% ^{235}U, depending on the assembly class, and is defined in Tables 6.2.4 through 6.2.189. It should be noted that the maximum allowable enrichment does not vary within an assembly class. Table 6.1.1 summarizes the maximum allowable enrichments for each of the assembly classes that are acceptable for storage in the MPC-24.

Tables 6.2.4 through 6.2.189 are formatted with the assembly class information in the top row, the unique assembly designations, dimensions, and k_{eff} values in the following rows above the bold double lines, and the bounding dimensions selected for the Certificate of Compliance and corresponding bounding k_{eff} values in the final rows. Where the bounding assembly corresponds directly to one of the actual assemblies, the fuel assembly designation is listed in the bottom row in parentheses (e.g., Table 6.2.4). Otherwise, the bounding assembly is given a unique designation. For an assembly class that contains only a single assembly (e.g., 14x14D, see Table 6.2.7), the Certificate of Compliance dimensions are based on the assembly dimensions from that single assembly. All of the maximum k_{eff} values corresponding to the selected bounding dimensions are greater than or equal to those for the actual assembly dimensions and are below the 0.95 regulatory limit.

6.2.3 BWR Fuel Assemblies in the MPC-68

For BWR fuel assemblies (specifications listed in Table 6.2.1) the artificial bounding assembly for the 10x10A assembly class at 4.2% enrichment has the highest reactivity (maximum k_{eff} of 0.9457). Calculations for the various BWR fuel assemblies in the MPC-68 are summarized in Tables 6.2.1920 through 6.2.346 for the fully flooded condition. In all cases, the gadolinia (Gd_2O_3) normally incorporated in BWR fuel was conservatively neglected.

For calculations involving BWR assemblies, the use of a uniform (planar-average) enrichment, as opposed to the distributed enrichments normally used in BWR fuel, produces conservative results. Calculations confirming this statement are presented in Appendix 6.B for several representative BWR fuel assembly designs. These calculations justify the specification of planar-average enrichments to define acceptability of BWR fuel for loading into the MPC-68.

Tables 6.2.1920 through 6.2.346 show the maximum k_{eff} values for assembly classes that are acceptable for storage in the MPC-68. All maximum k_{eff} values include the bias, uncertainties, and calculational statistics, evaluated for the worst combination of manufacturing tolerances. With the exception of assembly classes 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A, which will be discussed in Section 6.2.4, all calculations for the MPC-68 were performed with a ^{10}B loading of 0.0279 g/cm^2, which is 75% of the minimum loading, 0.0372 g/cm^2, specified on BM-1479, Bill of Materials for 68-Assembly HI-STAR 100 BWR MPC, in Section 1.5. Calculations for assembly classes 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A were conservatively performed with a ^{10}B loading of 0.0067 g/cm^2. The maximum allowable enrichment in the MPC-68 varies from 2.7 to 4.2 wt% ^{235}U, depending on the assembly class. It should be noted that the maximum allowable enrichment does not vary within an assembly class. Table 6.1.2 summarizes the maximum allowable enrichments for all assembly classes that are acceptable for storage in the MPC-68.

Tables 6.2.~~19~~*20* through 6.2.34*6* are formatted with the assembly class information in the top row, the unique assembly designations, dimensions, and k_{eff} values in the following rows above the bold double lines, and the bounding dimensions selected for the Certificate of Compliance and corresponding bounding k_{eff} values in the final rows. Where an assembly class contains only a single assembly (e.g., 8x8E, see Table 6.2.2~~3~~*4*), the Certificate of Compliance dimensions are based on the assembly dimensions from that single assembly. For assembly classes that are suspected to contain assemblies with thicker channels (e.g., 120 mils), bounding calculations are also performed to qualify the thicker channels (e.g. 7x7B, see Table 6.2.~~19~~*20*). All of the maximum k_{eff} values corresponding to the selected bounding dimensions are shown to be greater than or equal to those for the actual assembly dimensions and are below the 0.95 regulatory limit.

For assembly classes that contain partial length rods (i.e., 9x9A, 10x10A, and 10x10B), calculations were performed for the actual (real) assembly configuration and for the axial segments (assumed to be full length) with and without the partial length rods. In all cases, the axial segment with only the full length rods present (where the partial length rods are absent) is bounding. Therefore, the bounding maximum k_{eff} values reported for assembly classes that contain partial length rods bound the reactivity regardless of the active fuel length of the partial length rods. As a result, the Certificate of Compliance have no minimum requirement for the active fuel length of the partial length rods.

For BWR fuel assembly classes where margins permit, the Zircaloy water rod tubes are artificially replaced by water in the bounding cases to remove the requirement for water rod thickness from the Certificate of Compliance. For these cases, the bounding water rod thickness is listed as zero.

As mentioned, the highest observed maximum k_{eff} value is 0.9457, corresponding to the artificial bounding assembly in the 10x10A assembly class. This assembly has the following bounding characteristics: (1) the partial length rods are assumed to be zero length (most reactive configuration); (2) the channel is assumed to be 120 mils thick; and (3) the active fuel length of the full length rods is 155 inches. Therefore, the maximum reactivity value is bounding compared to any of the real BWR assemblies listed.

6.2.4 Damaged BWR Fuel Assemblies and BWR Fuel Debris

In addition to storing intact PWR and BWR fuel assemblies, the HI-STAR 100 System is designed to store damaged BWR fuel assemblies and BWR fuel debris. Damaged fuel assemblies and fuel debris are defined in Section 2.1.3 and Appendix B to the Certificate of Compliance. Both damaged BWR fuel assemblies and BWR fuel debris are required to be loaded into Damaged Fuel Containers (DFCs) prior to being loaded into the MPC. *Two different DFC types with slightly different cross sections are considered.* DFCs containing fuel debris must be stored in the MPC-68F. DFCs containing damaged fuel assemblies may be stored in either the MPC-68 or MPC-68F. The criticality evaluation of various possible damaged conditions of the fuel is presented in Subsection 6.4.4 *for both DFC types.*

Tables 6.2.3~~5~~*7* through 6.2.~~39~~*41* show the maximum k_{eff} values for the six assembly classes that may be stored as damaged fuel or fuel debris. All maximum k_{eff} values include the bias, uncertainties, and calculational statistics, evaluated for the worst combination of manufacturing tolerances. All calculations were performed for a ^{10}B loading of 0.0067 g/cm^2, which is 75% of a minimum loading, 0.0089 g/cm^2. However, because the practical manufacturing lower limit for minimum ^{10}B loading is 0.01 g/cm^2, the minimum ^{10}B loading of 0.01 g/cm^2 is specified on BM-1479, Bill of Materials for 68-Assembly HI-STAR 100 BWR MPC, in Section 1.5, for the MPC-68F. As an additional level of conservatism in the analyses, the calculations were performed for an enrichment of 3.0 wt% ^{235}U, while the maximum allowable enrichment for these assembly classes is limited to 2.7 wt% ^{235}U in the Certificate of Compliance. Therefore, the maximum k_{eff} values for damaged BWR fuel assemblies and fuel debris are conservative. Calculations for the various BWR fuel assemblies in the MPC-68F are summarized in Tables 6.2.3~~5~~*7* through 6.2.~~39~~*41* for the fully flooded condition.

For the assemblies that may be stored as damaged fuel or fuel debris, the 6x6C01 assembly at 3.0 wt% ^{235}U enrichment has the highest reactivity (maximum k_{eff} of 0.8021). Considering all of the conservatism built into this analysis (e.g., higher than allowed enrichment and lower than actual ^{10}B loading), the actual reactivity will be lower.

Because the analysis for the damaged BWR fuel assemblies and fuel debris was performed for a ^{10}B loading of 0.0089 g/cm^2, which conservatively bounds damaged BWR fuel assemblies in a standard MPC-68 with a minimum ^{10}B loading of 0.0372 g/cm^2, damaged BWR fuel assemblies may also be stored in the standard MPC-68. However, fuel debris is limited to the MPC-68F by Appendix B to the Certificate of Compliance.

Tables 6.2.3~~5~~*7* through 6.2.~~39~~*41* are formatted with the assembly class information in the top row, the unique assembly designations, dimensions, and k_{eff} values in the following rows above the bold double lines, and the bounding dimensions selected for the Certificate of Compliance and corresponding bounding k_{eff} values in the final rows. Where an assembly class contains only a single assembly (e.g., 6x6C, see Table 6.2.3~~7~~*9*), the Certificate of Compliance dimensions are based on the assembly dimensions from that single assembly. All of the maximum k_{eff} values corresponding to the selected bounding dimensions are greater than or equal to those for the actual assembly dimensions and are well below the 0.95 regulatory limit.

6.2.5 Thoria Rod Canister

Additionally, th HI-STAR 100 System is designed to store a Thoria Rod Canister in the MPC68 or MPC68F. The canister is similar to a DFC and contains 18 intact Thoria Rods placed in a separator assembly. The reactivity of the canister in the MPC68 or MPC68F is very low compared to the reactivity of the approved fuel assemblies (The ^{235}U *content of these rods* *corresponds to UO_2 rods with an initial enrichment of approximately 1.7 wt% ^{235}U). It is therefore permissible to store the Thoria Rod Canister together with any other approved content in a MPC68 or MPC68F. Specifications of the canister and the Thoria Rods that are used in the criticality evaluation are given in Table 6.2.42. The criticality evaluation is presented in Subsection 6.4.6.*

Table 6.2.1 (page 1 of 46)
BWR FUEL CHARACTERISTICS AND ASSEMBLY CLASS DEFINITIONS
(all dimensions are in inches)

Fuel Assembly Designation	Clad Material	Pitch	Number of Fuel Rods	Cladding OD	Cladding Thickness	Pellet Diameter	Active Fuel Length	Number of Water Rods	Water Rod OD	Water Rod ID	Channel Thickness	Channel ID
6x6A Assembly Class												
6x6A01	Zr	0.694	36	0.5645	0.0350	0.4940	110.0	0	n/a	n/a	0.060	4.290
6x6A02	Zr	0.694	36	0.5645	0.0360	0.4820	110.0	0	n/a	n/a	0.060	4.290
6x6A03	Zr	0.694	36	0.5645	0.0350	0.4820	110.0	0	n/a	n/a	0.060	4.290
6x6A04	Zr	0.694	36	0.5550	0.0350	0.4820	110.0	0	n/a	n/a	0.060	4.290
6x6A05	*Zr*	*0.696*	*36*	*0.5625*	*0.0350*	*0.4820*	*110.0*	*0*	*n/a*	*n/a*	*0.060*	*4.290*
6x6A06	*Zr*	*0.696*	*35*	*0.5625*	*0.0350*	*0.4820*	*110.0*	*1*	*0.0*	*0.0*	*0.060*	*4.290*
6x6A07	*Zr*	*0.700*	*36*	*0.5555*	*0.03525*	*0.4780*	*110.0*	*0*	*n/a*	*n/a*	*0.060*	*4.290*
6x6A08	*Zr*	*0.710*	*36*	*0.5625*	*0.0260*	*0.4980*	*110.0*	*0*	*n/a*	*n/a*	*0.060*	*4.290*
6x6B (MOX) Assembly Class												
6x6B01	Zr	0.694	36	0.5645	0.0350	0.4820	110.0	0	n/a	n/a	0.060	4.290
6x6B02	Zr	0.694	36	0.5625	0.0350	0.4820	110.0	0	n/a	n/a	0.060	4.290
6x6B03	*Zr*	*0.696*	*36*	*0.5625*	*0.0350*	*0.4820*	*110.0*	*0*	*n/a*	*n/a*	*0.060*	*4.290*
6x6B04	*Zr*	*0.696*	*35*	*0.5625*	*0.0350*	*0.4820*	*110.0*	*1*	*0.0*	*0.0*	*0.060*	*4.290*
6x6B05	*Zr*	*0.710*	*35*	*0.5625*	*0.0350*	*0.4820*	*110.0*	*1*	*0.0*	*0.0*	*0.060*	*4.290*
6x6C Assembly Class												
6x6C01	Zr	0.740	36	0.5630	0.0320	0.4880	77.5	0	n/a	n/a	0.060	4.542
7x7A Assembly Class												
7x7A01	Zr	0.631	49	0.4860	0.03~~30~~*28*	0.4110	~~79~~*80*	0	n/a	n/a	0.060	4.542

Table 6.2.1 (page 2 of 56)

BWR FUEL CHARACTERISTICS AND ASSEMBLY CLASS DEFINITIONS

(all dimensions are in inches)

Fuel Assembly Designation	Clad Material	Pitch	Number of Fuel Rods	Cladding OD	Cladding Thickness	Pellet Diameter	Active Fuel Length	Number of Water Rods	Water Rod OD	Water Rod ID	Channel Thickness	Channel ID
7x7B Assembly Class												
7x7B01	Zr	0.738	49	0.5630	0.0320	0.4870	150	0	n/a	n/a	0.080	5.278
7x7B02	Zr	0.738	49	0.5630	0.0370	0.4770	150	0	n/a	n/a	0.102	5.291
7x7B03	Zr	0.738	49	0.5630	0.0370	0.4770	150	0	n/a	n/a	0.080	5.278
7x7B04	Zr	0.738	49	0.5700	0.0355	0.4880	150	0	n/a	n/a	0.080	5.278
7x7B05	Zr	0.738	49	0.5630	0.0340	0.4775	150	0	n/a	n/a	0.080	5.278
7x7B06	*Zr*	*0.738*	*49*	*0.5700*	*0.0355*	*0.4910*	*150*	*0*	*n/a*	*n/a*	*0.080*	*5.278*
8x8A Assembly Class												
8x8A01	Zr	0.523	64	0.4120	0.0250	0.3580	110	0	n/a	n/a	0.100	4.290
8x8A02	*Zr*	*0.523*	*63*	*0.4120*	*0.0250*	*0.3580*	*120*	*0*	*n/a*	*n/a*	*0.100*	*4.290*

Table 6.2.1 (page 23 of 46)
BWR FUEL CHARACTERISTICS AND ASSEMBLY CLASS DEFINITIONS
(all dimensions are in inches)

Fuel Assembly Designation	Clad Material	Pitch	Number of Fuel Rods	Cladding OD	Cladding Thickness	Pellet Diameter	Active Fuel Length	Number of Water Rods	Water Rod OD	Water Rod ID	Channel Thickness	Channel ID
8x8B Assembly Class												
8x8B01	Zr	0.641	63	0.4840	0.0350	0.4050	150	1	0.484	0.414	0.100	5.278
8x8B02	Zr	0.636	63	0.4840	0.0350	0.4050	150	1	0.484	0.414	0.100	5.278
8x8B03	Zr	0.640	63	0.4930	0.0340	0.4160	150	1	0.493	0.425	0.100	5.278
8x8B04	*Zr*	*0.642*	*64*	*0.5015*	*0.0360*	*0.4195*	*150*	*0*	*n/a*	*n/a*	*0.100*	*5.278*
8x8C Assembly Class												
8x8C01	Zr	0.641	62	0.4840	0.0350	0.4050	150	2	0.484	0.414	0.100	5.278
8x8C02	Zr	0.640	62	0.4830	0.0320	0.4100	150	2	0.591	0.531	0.000	no channel
8x8C03	Zr	0.640	62	0.4830	0.0320	0.4100	150	2	0.591	0.531	0.080	5.278
8x8C04	Zr	0.640	62	0.4830	0.0320	0.4100	150	2	0.591	0.531	0.100	5.278
8x8C05	Zr	0.640	62	0.4830	0.0320	0.4100	150	2	0.591	0.531	0.120	5.278
8x8C06	Zr	0.640	62	0.4830	0.0320	0.4110	150	2	0.591	0.531	0.100	5.278
8x8C07	Zr	0.640	62	0.4830	0.0340	0.4100	150	2	0.591	0.531	0.100	5.278
8x8C08	Zr	0.640	62	0.4830	0.0320	0.4100	150	2	0.493	0.425	0.100	5.278
8x8C09	Zr	0.640	62	0.4930	0.0340	0.4160	150	2	0.493	0.425	0.100	5.278
8x8C10	Zr	0.640	62	0.4830	0.0340	0.4100	150	2	0.591	0.531	0.120	5.278
8x8C11	Zr	0.640	62	0.4830	0.0340	0.4100	150	2	0.591	0.531	0.120	5.215
8x8C12	Zr	0.636	62	0.4830	0.0320	0.4110	150	2	0.591	0.531	0.120	5.215

Table 6.2.1 (page 34 of 46)
BWR FUEL CHARACTERISTICS AND ASSEMBLY CLASS DEFINITIONS
(all dimensions are in inches)

Fuel Assembly Designation	Clad Material	Pitch	Number of Fuel Rods	Cladding OD	Cladding Thickness	Pellet Diameter	Active Fuel Length	Number of Water Rods	Water Rod OD	Water Rod ID	Channel Thickness	Channel ID
8x8D Assembly Class												
8x8D01	Zr	0.640	60	0.4830	0.0320	0.4110	150	2 large/ 2 small	0.591/ 0.483	0.531/ 0.433	0.100	5.278
8x8D02	Zr	0.640	60	0.4830	0.0320	0.4110	150	4	0.591	0.531	0.100	5.278
8x8D03	Zr	0.640	60	0.4830	0.0320	0.4110	150	4	0.483	0.433	0.100	5.278
8x8D04	Zr	0.640	60	0.4830	0.0320	0.4110	150	1	1.34	1.26	0.100	5.278
8x8D05	Zr	0.640	60	0.4830	0.0320	0.4100	150	1	1.34	1.26	0.100	5.278
8x8D06	Zr	0.640	60	0.4830	0.0320	0.4110	150	1	1.34	1.26	0.120	5.278
8x8D07	Zr	0.640	60	0.4830	0.0320	0.4110	150	1	1.34	1.26	0.080	5.278
8x8D08	*Zr*	*0.640*	*61*	*0.4830*	*0.0300*	*0.4140*	*150*	*3*	*0.591*	*0.531*	*0.080*	*5.278*
8x8E Assembly Class												
8x8E01	Zr	0.640	59	0.4930	0.0340	0.4160	150	5	0.493	0.425	0.100	5.278
8x8F Assembly Class												
8x8F01	*Zr*	*0.609*	*64*	*0.4576*	*0.0290*	*0.3913*	*150*	*4*†	*0.291*†	*0.228*†	*0.055*	*5.390*
9x9A Assembly Class												
9x9A01	Zr	0.566	74	0.4400	0.0280	0.3760	150	2	0.98	0.92	0.100	5.278
9x9A02	Zr	0.566	66	0.4400	0.0280	0.3760	150	2	0.98	0.92	0.100	5.278
9x9A03	Zr	0.566	74/66	0.4400	0.0280	0.3760	150/90	2	0.98	0.92	0.100	5.278
9x9A04	Zr	0.566	74/66	0.4400	0.0280	0.3760	150/90	2	0.98	0.92	0.120	5.278

† *Four rectangular water cross segments dividing the assembly into four quadrants*

BWR FUEL CHARACTERISTICS AND ASSEMBLY CLASS DEFINITIONS
(all dimensions are in inches)

Fuel Assembly Designation	Clad Material	Pitch	Number of Fuel Rods	Cladding OD	Cladding Thickness	Pellet Diameter	Active Fuel Length	Number of Water Rods	Water Rod OD	Water Rod ID	Channel Thickness	Channel ID
9x9B Assembly Class												
9x9B01	Zr	0.569	72	0.4330	0.0262	0.3737	150	1	1.516	1.459	0.100	5.278
9x9B02	Zr	0.569	72	0.4330	0.0260	0.3737	150	1	1.516	1.459	0.100	5.278
9x9B03	*Zr*	*0.572*	*72*	*0.4330*	*0.0260*	*0.3737*	*150*	*1*	*1.516*	*1.459*	*0.100*	*5.278*
9x9C Assembly Class												
9x9C01	Zr	0.572	80	0.4230	0.0295	0.3565	150	1	0.512	0.472	0.100	5.278
9x9D Assembly Class												
9x9D01	Zr	0.572	79	0.4240	0.0300	0.3565	150	2	0.42~~5~~*4*	0.364	0.100	5.278
9x9E Assembly Class†												
9x9E01	Zr	0.572	76	0.4170	0.02~~90~~*65*	0.35~~25~~*30*	150	5	0.~~425~~*546*	0.~~364~~*522*	0.~~100~~*120*	5.2~~78~~*15*
9x9E02	*Zr*	*0.572*	*48* *28*	*0.4170* *0.4430*	*0.0265* *0.0285*	*0.3530* *0.3745*	*150*	*5*	*0.546*	*0.522*	*0.120*	*5.215*
9x9F Assembly Class†												
9x9F01	Zr	0.572	76	0.4430	0.0~~310~~*285*	0.3745	150	5	0.~~425~~*546*	0.~~364~~*522*	0.~~100~~*120*	5.2~~78~~*15*
9x9F02	*Zr*	*0.572*	*48* *28*	*0.4170* *0.4430*	*0.0265* *0.0285*	*0.3530* *0.3745*	*150*	*5*	*0.546*	*0.522*	*0.120*	*5.215*

† *The 9x9E and 9x9F fuel assembly classes represent a single fuel type containing fuel rods with different dimensions (SPC 9x9-5). In addition to the actual configuration (9x9E02 and 9x9F02), the 9x9E class contains a hypothetical assembly with only small fuel rods (9x9E01), and the 9x9F class contains a hypothetical assembly with only large rods (9x9F01). This was done in order to simplify the specification of this assembly in the CoC.*

Table 6.2.1 (page 6 of 6)
BWR FUEL CHARACTERISTICS AND ASSEMBLY CLASS DEFINITIONS
(all dimensions are in inches)

Fuel Assembly Designation	Clad Material	Pitch	Number of Fuel Rods	Cladding OD	Cladding Thickness	Pellet Diameter	Active Fuel Length	Number of Water Rods	Water Rod OD	Water Rod ID	Channel Thickness	Channel ID
10x10A Assembly Class												
10x10A01	Zr	0.510	92	0.4040	0.0260	0.3450	155	2	0.980	0.920	0.100	5.278
10x10A02	Zr	0.510	78	0.4040	0.0260	0.3450	155	2	0.980	0.920	0.100	5.278
10x10A03	Zr	0.510	92/78	0.4040	0.0260	0.3450	155/90	2	0.980	0.920	0.100	5.278
10x10B Assembly Class												
10x10B01	Zr	0.510	91	0.3957	0.0239	0.3413	155	1	1.378	1.321	0.100	5.278
10x10B02	Zr	0.510	83	0.3957	0.0239	0.3413	155	1	1.378	1.321	0.100	5.278
10x10B03	Zr	0.510	91/83	0.3957	0.0239	0.3413	155/90	1	1.378	1.321	0.100	5.278
10x10C Assembly Class												
10x10C01	Zr	0.488	96	0.37~~90~~*80*	0.024*3*~~8~~	0.3224	150	5	~~0.4930~~ *1.227*	~~0.4250~~ *1.165*	0.055	5.457
10x10D Assembly Class												
10x10D01	SS	0.565	100	0.3960	0.0200	0.3500	83	0	n/a	n/a	0.08	5.663
10x10E Assembly Class												
10x10E01	SS	0.557	96	0.3940	0.0220	0.3430	83	4	0.3940	0.3500	0.08	5.663

Table 6.2.2 (page 1 of 3)
PWR FUEL CHARACTERISTICS AND ASSEMBLY CLASS DEFINITIONS
(all dimensions are in inches)

Fuel Assembly Designation	Clad Material	Pitch	Number of Fuel Rods	Cladding OD	Cladding Thickness	Pellet Diameter	Active Fuel Length	Number of Guide Tubes	Guide Tube OD	Guide Tube ID	Guide Tube Thickness
14x14A Assembly Class											
14x14A01	Zr	0.556	179	0.400	0.0243	0.3444	150	17	0.527	0.493	0.0170
14x14A02	Zr	0.556	179	0.400	0.0243	0.3444	150	17	0.528	0.490	0.0190
14x14A03	Zr	0.556	179	0.400	0.0243	0.3444	150	17	0.526	0.492	0.0170
14x14B Assembly Class											
14x14B01	Zr	0.556	179	0.422	0.0243	0.3659	150	17	0.539	0.505	0.0170
14x14B02	Zr	0.556	179	0.417	0.0295	0.3505	150	17	0.541	0.507	0.0170
14x14B03	Zr	0.556	179	0.424	0.0300	0.3565	150	17	0.541	0.507	0.0170
14x14B04	Zr	0.556	179	0.426	0.0310	0.3565	150	17	0.541	0.507	0.0170
14x14C Assembly Class											
14x14C01	Zr	0.580	176	0.440	0.0280	0.3765	150	5	1.115	1.035	0.0400
14x14C02	Zr	0.580	176	0.440	0.0280	0.3770	150	5	1.115	1.035	0.0400
14x14C03	*Zr*	*0.580*	*176*	*0.440*	*0.0260*	*0.3805*	*150*	*5*	*1.111*	*1.035*	*0.0380*
14x14D Assembly Class											
14x14D01	SS	0.556	180	0.422	0.0165	0.3835	144	16	0.543	0.514	0.0145
15x15A Assembly Class											
15x15A01	Zr	0.550	204	0.418	0.0260	0.3580	150	21	0.533	0.500	0.0165

Table 6.2.2 (page 2 of 3)
PWR FUEL CHARACTERISTICS AND ASSEMBLY CLASS DEFINITIONS
(all dimensions are in inches)

Fuel Assembly Designation	Clad Material	Pitch	Number of Fuel Rods	Cladding OD	Cladding Thickness	Pellet Diameter	Active Fuel Length	Number of Guide Tubes	Guide Tube OD	Guide Tube ID	Guide Tube Thickness
15x15B Assembly Class											
15x15B01	Zr	0.563	204	0.422	0.0245	0.3660	150	21	0.533	0.499	0.0170
15x15B02	Zr	0.563	204	0.422	0.0245	0.3660	150	21	0.546	0.512	0.0170
15x15B03	Zr	0.563	204	0.422	0.0243	0.3660	150	21	0.533	0.499	0.0170
15x15B04	Zr	0.563	204	0.422	0.0243	0.3659	150	21	0.545	0.515	0.0150
15x15B05	Zr	0.563	204	0.422	0.0242	0.3659	150	21	0.545	0.515	0.0150
15x15B06	Zr	0.563	204	0.420	0.0240	0.3671	150	21	0.544	0.514	0.0150
15x15C Assembly Class											
15x15C01	Zr	0.563	204	0.424	0.0300	0.3570	150	21	0.544	0.493	0.0255
15x15C02	Zr	0.563	204	0.424	0.0300	0.3570	150	21	0.544	0.511	0.0165
15x15C03	Zr	0.563	204	0.424	0.0300	0.3565	150	21	0.544	0.511	0.0165
15x15C04	Zr	0.563	204	0.417	0.0300	0.3565	150	21	0.544	0.511	0.0165
15x15D Assembly Class											
15x15D01	Zr	0.568	208	0.430	0.0265	0.3690	150	17	0.530	0.498	0.0160
15x15D02	Zr	0.568	208	0.430	0.0265	0.3686	150	17	0.530	0.498	0.0160
15x15D03	Zr	0.568	208	0.430	0.0265	0.3700	150	17	0.530	0.499	0.0155
15x15D04	Zr	0.568	208	0.430	0.0250	0.3735	150	17	0.530	0.500	0.0150
15x15E Assembly Class											
15x15E01	Zr	0.568	208	0.428	0.0245	0.3707	150	17	0.528	0.500	0.0140
15x15F Assembly Class											
15x15F01	Zr	0.568	208	0.428	0.0230	0.3742	150	17	0.528	0.500	0.0140

Table 6.2.2 (page 3 of 3)
PWR FUEL CHARACTERISTICS AND ASSEMBLY CLASS DEFINITIONS
(all dimensions are in inches)

Fuel Assembly Designation	Clad Material	Pitch	Number of Fuel Rods	Cladding OD	Cladding Thickness	Pellet Diameter	Active Fuel Length	Number of Guide Tubes	Guide Tube OD	Guide Tube ID	Guide Tube Thickness
15x15G Assembly Class											
15x15G01	SS	0.563	204	0.422	0.0165	0.3825	144	21	0.543	0.514	0.0145
15x15H Assembly Class											
15x15H01	*Zr*	*0.568*	*208*	*0.414*	*0.0220*	*0.3622*	*150*	*17*	*0.528*	*0.500*	*0.0140*
16x16A Assembly Class											
16x16A01	Zr	0.506	236	0.382	0.0250	0.3255	150	5	0.980	0.900	0.0400
16x16A02	Zr	0.506	236	0.382	0.0250	0.3250	150	5	0.980	0.900	0.0400
17x17A Assembly Class											
17x17A01	Zr	0.496	264	0.360	0.0225	0.3088	144	25	0.474	0.442	0.0160
17x17A02	Zr	0.496	264	0.360	0.0225	0.3088	150	25	0.474	0.442	0.0160
17x17A03	Zr	0.496	264	0.360	0.0250	0.3030	150	25	0.480	0.448	0.0160
17x17B Assembly Class											
17x17B01	Zr	0.496	264	0.374	0.0225	0.3225	150	25	0.482	0.450	0.0160
17x17B02	Zr	0.496	264	0.374	0.0225	0.3225	150	25	0.474	0.442	0.0160
17x17B03	Zr	0.496	264	0.376	0.0240	0.3215	150	25	0.480	0.448	0.0160
17x17B04	Zr	0.496	264	0.372	0.0205	0.3232	150	25	0.427	0.399	0.0140
17x17B05	Zr	0.496	264	0.374	0.0240	0.3195	150	25	0.482	0.450	0.0160
17x17B06	Zr	0.496	264	0.372	0.0205	0.3232	150	25	0.480	0.452	0.0140
17x17C Assembly Class											
17x17C01	Zr	0.502	264	0.379	0.0240	0.3232	150	25	0.472	0.432	0.0200
17x17C02	Zr	0.502	264	0.377	0.0220	0.3252	150	25	0.472	0.432	0.0200

Table 6.2.6
MAXIMUM KEFF VALUES FOR THE 14X14C ASSEMBLY CLASS IN THE MPC-24
(all dimensions are in inches)

14x14C (4.6% Enrichment, Boral ^{10}B minimum loading of 0.02 g/cm^2) 176 fuel rods, 5 guide tubes, pitch=0.580, Zr clad									
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	guide tube thickness
14x14C01	0.9361	0.9317	0.0009	0.440	0.3840	0.0280	0.3765	150	0.040
14x14C02	0.9355	0.9312	0.0008	0.440	0.3840	0.0280	0.3770	150	0.040
14x14C03	*0.9400*	*0.9357*	*0.0008*	*0.440*	*0.3880*	*0.0260*	*0.3805*	*150*	*0.038*
Dimensions Listed in Certificate of Compliance				0.440 (min.)	0.384~~40~~*80* (max.)		0.3~~770~~*805*‡ (max.)	150 (max.)	0.04~~0~~*38* (min.)
bounding dimensions (14x14C01)	0.9~~361~~*400*	0.93~~17~~*57*	0.000~~9~~*8*	0.440	0.384~~0~~*80*	0.028~~0~~*060*	0.3~~765~~*805*	150	0.04~~0~~*38*

‡ ~~Because the k_{eff} values are statistically equivalent (within 1σ) for the small variation in pellet diameter, the pellet diameter listed in the Certificate of Compliance is the larger of the two values.~~

Table 6.2.15
MAXIMUM K_{EFF} VALUES FOR THE 15X15H ASSEMBLY CLASS IN THE MPC-24
(all dimensions are in inches)

15x15H (3.8% Enrichment, Boral ^{10}B minimum loading of 0.02 g/cm^2) 208 fuel rods, 17 guide tubes, pitch=0.568, Zr clad									
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	guide tube thickness
15x15H01	0.9411	0.9368	0.0008	0.414	0.3700	0.0220	0.3622	150	0.0140
Dimensions Listed in Certificate of Compliance				0.414 (min.)	0.3700 (max.)		0.3622 (max.)	150 (max.)	0.0140 (min.)

Table 6.2.156

MAXIMUM K_{EFF} VALUES FOR THE 16X16A ASSEMBLY CLASS IN THE MPC-24

(all dimensions are in inches)

16x16A (4.6% Enrichment, Boral ^{10}B minimum loading of 0.02 g/cm^2) 236 fuel rods, 5 guide tubes, pitch=0.506, Zr clad									
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	guide tube thickness
16x16A01	0.9383	0.9339	0.0009	0.382	0.3320	0.0250	0.3255	150	0.0400
16x16A02	0.9371	0.9328	0.0008	0.382	0.3320	0.0250	0.3250	150	0.0400
Dimensions Listed in Certificate of Compliance				0.382 (min.)	0.3320 (max.)		0.3255 (max.)	150 (max.)	0.0400 (min.)
bounding dimensions (16x16A01)	0.9383	0.9339	0.0009	0.382	0.3320	0.0250	0.3255	150	0.0400

Table 6.2.167
MAXIMUM K_{EFF} VALUES FOR THE 17X17A ASSEMBLY CLASS IN THE MPC-24
(all dimensions are in inches)

17x17A (4.0% Enrichment, Boral ^{10}B minimum loading of 0.02 g/cm^2) 264 fuel rods, 25 guide tubes, pitch=0.496, Zr clad									
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	guide tube thickness
17x17A01	0.9449	0.9400	0.0011	0.360	0.3150	0.0225	0.3088	144	0.016
17x17A02	0.9452†	0.9408	0.0008	0.360	0.3150	0.0225	0.3088	150	0.016
17x17A03	0.9406	0.9364	0.0008	0.360	0.3100	0.0250	0.3030	150	0.016
Dimensions Listed in Certificate of Compliance				0.360 (min.)	0.3150 (max.)		0.3088 (max.)	150 (max.)	0.016 (min.)
bounding dimensions (17x17A02)	0.9452	0.9408	0.0008	0.360	0.3150	0.0225	0.3088	150	0.016

† KENO5a verification calculation resulted in a maximum k_{eff} of 0.9434.

Table 6.2.1~~7~~*8*

MAXIMUM K_{EFF} VALUES FOR THE 17X17B ASSEMBLY CLASS IN THE MPC-24

(all dimensions are in inches)

17x17B (4.0% Enrichment, Boral ^{10}B minimum loading of 0.02 g/cm^2) 264 fuel rods, 25 guide tubes, pitch=0.496, Zr clad									
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	guide tube thickness
17x17B01	0.9377	0.9335	0.0008	0.374	0.3290	0.0225	0.3225	150	0.016
17x17B02	0.9379	0.9337	0.0008	0.374	0.3290	0.0225	0.3225	150	0.016
17x17B03	0.9330	0.9288	0.0008	0.376	0.3280	0.0240	0.3215	150	0.016
17x17B04	0.9407	0.9365	0.0007	0.372	0.3310	0.0205	0.3232	150	0.014
17x17B05	0.9349	0.9305	0.0009	0.374	0.3260	0.0240	0.3195	150	0.016
17x17B06	0.9436	0.9393	0.0008	0.372	0.3310	0.0205	0.3232	150	0.014
Dimensions Listed in Certificate of Compliance				0.372 (min.)	0.3310 (max.)		0.3232 (max.)	150 (max.)	0.014 (min.)
bounding dimensions (17x17B06)	0.9436	0.9393	0.0008	0.372	0.3310	0.0205	0.3232	150	0.014

Table 6.2.189
MAXIMUM K_{EFF} VALUES FOR THE 17X17C ASSEMBLY CLASS IN THE MPC-24
(all dimensions are in inches)

17x17C (4.0% Enrichment, Boral ^{10}B minimum loading of 0.02 g/cm^2) 264 fuel rods, 25 guide tubes, pitch=0.502, Zr clad									
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	guide tube thickness
17x17C01	0.9383	0.9339	0.0008	0.379	0.3310	0.0240	0.3232	150	0.020
17x17C02	0.9427	0.9384	0.0008	0.377	0.3330	0.0220	0.3252	150	0.020
Dimensions Listed in Certificate of Compliance				0.377 (min.)	0.3330 (max.)		0.3252 (max.)	150 (max.)	0.020 (min.)
bounding dimensions (17x17C02)	0.9427	0.9384	0.0008	0.377	0.3330	0.0220	0.3252	150	0.020

Table 6.2.~~19~~*20*
MAXIMUM K_{EFF} VALUES FOR THE 7X7B ASSEMBLY CLASS IN THE MPC-68
(all dimensions are in inches)

7x7B (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 49 fuel rods, 0 water rods, pitch=0.738, Zr clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
7x7B01	0.9372	0.9330	0.0007	0.5630	0.4990	0.0320	0.4870	150	n/a	0.080
7x7B02	0.9301	0.9260	0.0007	0.5630	0.4890	0.0370	0.4770	150	n/a	0.102
7x7B03	0.9313	0.9271	0.0008	0.5630	0.4890	0.0370	0.4770	150	n/a	0.080
7x7B04	0.9311	0.9270	0.0007	0.5700	0.4990	0.0355	0.4880	150	n/a	0.080
7x7B05	0.9350	0.9306	0.0008	0.5630	0.4950	0.0340	0.4775	150	n/a	0.080
7x7B06	*0.9298*	*0.9260*	*0.0006*	*0.5700*	*0.4990*	*0.0355*	*0.4910*	*150*	*n/a*	*0.080*
Dimensions Listed in Certificate of Compliance				0.5630 (min.)	0.4990 (max.)		0.4~~880~~*910* (max.)	150 (max.)	n/a	0.120 (max.)
bounding dimensions (B7x7B01)	0.937~~8~~*5*	0.933~~5~~*2*	0.0008	0.5630	0.4990	0.0320	0.4~~880~~*910*	150	n/a	0.102
bounding dimensions with 120 mil channel (B7x7B02)	0.93~~75~~*86*	0.93~~32~~*44*	0.000~~8~~*7*	0.5630	0.4990	0.0320	0.4~~880~~*910*	150	n/a	0.120

Table 6.2.2~~0~~*1*
MAXIMUM K_{EFF} VALUES FOR THE 8X8B ASSEMBLY CLASS IN THE MPC-68
(all dimensions are in inches)

8x8B (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 63 *or 64* fuel rods†, 1 *or 0* water rods†, pitch† = 0.636-0.64~~1~~2, Zr clad												
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	*Fuel rods*	pitch	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
8x8B01	0.9310	0.9265	0.0009	*63*	0.641	0.4840	0.4140	0.0350	0.4050	150	0.035	0.100
8x8B02	0.9227	0.9185	0.0007	*63*	0.636	0.4840	0.4140	0.0350	0.4050	150	0.035	0.100
8x8B03	0.9299	0.9257	0.0008	*63*	0.640	0.4930	0.4250	0.0340	0.4160	150	0.034	0.100
8x8B04	*0.9236*	*0.9194*	*0.0008*	*64*	*0.642*	*0.5015*	*0.4295*	*0.0360*	*0.4195*	*150*	*n/a*	*0.100*
Dimensions Listed in Certificate of Compliance				*63 or 64*	0.636-0.64~~1~~2	0.4840 (min.)	0.42~~50~~*95* (max.)		0.41~~60~~*95* (max.)	150 (max.)	0.034	0.120 (max.)
bounding (pitch=0.636) (B8x8B01)	0.93~~17~~*46*	0.9~~274~~*301*	0.000~~8~~*9*	*63*	0.636	0.4840	0.42~~50~~*95*	0.02~~95~~*725*	0.41~~60~~*95*	150	0.034	0.120
bounding (pitch=0.640) (B8x8B02)	0.93~~57~~*85*	0.93~~15~~*43*	0.0008	*63*	0.640	0.4840	0.42~~50~~*95*	0.02~~95~~*725*	0.41~~60~~*95*	150	0.034	0.120
bounding (pitch=0.64~~1~~2) (B8x8B03)	0.9~~368~~*416*	0.93~~27~~*75*	0.0007	*63*	0.64~~1~~2	0.4840	0.42~~50~~*95*	0.02~~95~~*725*	0.41~~60~~*95*	150	0.034	0.120

† This assembly class was analyzed and qualified for a small variation in the pitch *and a variation in the number of fuel and water rods.*

Table 6.2.2~~1~~2

MAXIMUM K_{EFF} VALUES FOR THE 8X8C ASSEMBLY CLASS IN THE MPC-68

(all dimensions are in inches)

Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	pitch	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
8x8C (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2)											
62 fuel rods, 2 water rods, pitch† = 0.636-0.641, Zr clad											
8x8C01	0.9315	0.9273	0.0007	0.641	0.4840	0.4140	0.0350	0.4050	150	0.035	0.100
8x8C02	0.9313	0.9268	0.0009	0.640	0.4830	0.4190	0.0320	0.4100	150	0.030	0.000
8x8C03	0.9329	0.9286	0.0008	0.640	0.4830	0.4190	0.0320	0.4100	150	0.030	0.800
8x8C04	0.9348††	0.9307	0.0007	0.640	0.4830	0.4190	0.0320	0.4100	150	0.030	0.100
8x8C05	0.9353	0.9312	0.0007	0.640	0.4830	0.4190	0.0320	0.4100	150	0.030	0.120
8x8C06	0.9353	0.9312	0.0007	0.640	0.4830	0.4190	0.0320	0.4110	150	0.030	0.100
8x8C07	0.9314	0.9273	0.0007	0.640	0.4830	0.4150	0.0340	0.4100	150	0.030	0.100
8x8C08	0.9339	0.9298	0.0007	0.640	0.4830	0.4190	0.0320	0.4100	150	0.034	0.100
8x8C09	0.9301	0.9260	0.0007	0.640	0.4930	0.4250	0.0340	0.4160	150	0.034	0.100
8x8C10	0.9317	0.9275	0.0008	0.640	0.4830	0.4150	0.0340	0.4100	150	0.030	0.120
8x8C11	0.9328	0.9287	0.0007	0.640	0.4830	0.4150	0.0340	0.4100	150	0.030	0.120
8x8C12	0.9285	0.9242	0.0008	0.636	0.4830	0.4190	0.0320	0.4110	150	0.030	0.120
Dimensions Listed in Certificate of Compliance				0.636-0.641	0.4830 (min.)	0.4250 (max.)		0.4160 (max.)	150 (max.)	0.000 (min.)	0.120 (max.)
bounding (pitch=0.636) (B8x8C01)	0.9357	0.9313	0.0009	0.636	0.4830	0.4250	0.0290	0.4160	150	0.000	0.120
bounding (pitch=0.640) (B8x8C02)	0.9425	0.9384	0.0007	0.640	0.4830	0.4250	0.0290	0.4160	150	0.000	0.120
Bounding (pitch=0.641) (B8x8C03)	0.9418	0.9375	0.0008	0.641	0.4830	0.4250	0.0290	0.4160	150	0.000	0.120

† This assembly class was analyzed and qualified for a small variation in the pitch.

†† KENO5a verification calculation resulted in a maximum k_{eff} of 0.9343.

Table 6.2.2~~2~~*3*
MAXIMUM K_{EFF} VALUES FOR THE 8X8D ASSEMBLY CLASS IN THE MPC-68
(all dimensions are in inches)

8x8D (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 60-*61* fuel rods, 1-4 water rods†, pitch=0.640, Zr clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
8x8D01	0.9342	0.9302	0.0006	0.4830	0.4190	0.0320	0.4110	150	0.03/0.025	0.100
8x8D02	0.9325	0.9284	0.0007	0.4830	0.4190	0.0320	0.4110	150	0.030	0.100
8x8D03	0.9351	0.9309	0.0008	0.4830	0.4190	0.0320	0.4110	150	0.025	0.100
8x8D04	0.9338	0.9296	0.0007	0.4830	0.4190	0.0320	0.4110	150	0.040	0.100
8x8D05	0.9339	0.9294	0.0009	0.4830	0.4190	0.0320	0.4100	150	0.040	0.100
8x8D06	0.9365	0.9324	0.0007	0.4830	0.4190	0.0320	0.4110	150	0.040	0.120
8x8D07	0.9341	0.9297	0.0009	0.4830	0.4190	0.0320	0.4110	150	0.040	0.080
8x8D08	*0.9376*	*0.9332*	*0.0009*	*0.4830*	*0.4230*	*0.0300*	*0.4140*	*150*	*0.030*	*0.080*
Dimensions Listed in Certificate of Compliance				0.4830 (min.)	0.4~~190~~*230* (max.)		0.41~~10~~*40* (max.)	150 (max.)	0.000 (min.)	0.120 (max.)
bounding dimensions (B8x8D01)	0.9~~366~~*403*	0.93~~23~~*63*	0.000~~7~~*8*	0.4830	0.4~~190~~*230*	0.03~~20~~*00*	0.41~~10~~*40*	150	0.000	0.120

† Fuel assemblies 8x8D01 through 8x8D03 have 4 water rods that are similar in size to the fuel rods, while assemblies 8x8D04 through 8x8D07 have 1 large water rod that takes the place of the 4 water rods. *Fuel assembly 8x8D08 contains 3 water rods that are similar in size to the fuel rods.*

Table 6.2.234

MAXIMUM K_{EFF} VALUES FOR THE 8X8E ASSEMBLY CLASS IN THE MPC-68

(all dimensions are in inches)

8x8E (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 59 fuel rods, 5 water rods, pitch=0.640, Zr clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
8x8E01	0.9312	0.9270	0.0008	0.4930	0.4250	0.0340	0.4160	150	0.034	0.100
Dimensions Listed in Certificate of Compliance				0.4930 (min.)	0.4250 (max.)		0.4160 (max.)	150 (max.)	0.034 (min.)	0.100 (max.)

Table 6.2.25
MAXIMUM K_{EFF} VALUES FOR THE 8X8F ASSEMBLY CLASS IN THE MPC-68
(all dimensions are in inches)

8x8F (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) *64 fuel rods, 4 rectangular water cross segments dividing the assembly into four quadrants, pitch=0.609, Zr clad*										
Fuel Assembly Designation	*maximum k_{eff}*	*calculated k_{eff}*	*standard deviation*	*cladding OD*	*cladding ID*	*cladding thickness*	*pellet OD*	*fuel length*	*water rod thickness*	*channel thickness*
8x8F01	*0.9140*	*0.9097*	*0.0008*	*0.4576*	*0.3996*	*0.0290*	*0.3913*	*150*	*0.0315*	*0.055*
Dimensions Listed in Certificate of Compliance				*0.4576 (min.)*	*0.3996 (max.)*		*0.3913 (max.)*	*150 (max.)*	*0.0315 (min.)*	*0.055 (max.)*

Table 6.2.246
MAXIMUM K_{EFF} VALUES FOR THE 9X9A ASSEMBLY CLASS IN THE MPC-68
(all dimensions are in inches)

9x9A (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 74/66 fuel rods†, 2 water rods, pitch=0.566, Zr clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
9x9A01 (axial segment with all rods)	0.9353	0.9310	0.0008	0.4400	0.3840	0.0280	0.3760	150	0.030	0.100
9x9A02 (axial segment with only the full length rods)	0.9388	0.9345	0.0008	0.4400	0.3840	0.0280	0.3760	150	0.030	0.100
9x9A03 (actual three-dimensional representation of all rods)	0.9351	0.9310	0.0007	0.4400	0.3840	0.0280	0.3760	150/90	0.030	0.100
9x9A04 (axial segment with only the full length rods)	0.9396	0.9355	0.0007	0.4400	0.3840	0.0280	0.3760	150	0.030	0.120
Dimensions Listed in Certificate of Compliance				0.4400 (min.)	0.3840 (max.)		0.3760 (max.)	150 (max.)	0.000 (min.)	0.120 (max.)
bounding dimensions (axial segment with only the full length rods) (B9x9A01)	0.9417	0.9374	0.0008	0.4400	0.3840	0.0280	0.3760	150	0.000	0.120

† This assembly class contains 66 full length rods and 8 partial length rods. In order to eliminate a requirement on the length of the partial length rods, separate calculations were performed for the axial segments with and without the partial length rods.

Table 6.2.2~~5~~*7*

MAXIMUM K_{EFF} VALUES FOR THE 9X9B ASSEMBLY CLASS IN THE MPC-68

(all dimensions are in inches)

9x9B (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 72 fuel rods, 1 water rod (square, replacing 9 fuel rods), pitch=0.569 *to 0.572*†, Zr clad											
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	*pitch*	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
9x9B01	0.9368	0.9326	0.0007	*0.569*	0.4330	0.3807	0.0262	0.3737	150	0.0285	0.100
9x9B02	0.9377	0.9334	0.0008	*0.569*	0.4330	0.3810	0.0260	0.3737	150	0.0285	0.100
9x9B03	*0.9416*	*0.9373*	*0.0008*	*0.572*	*0.4330*	*0.3810*	*0.0260*	*0.3737*	*150*	*0.0285*	*0.100*
Dimensions Listed in Certificate of Compliance				*0.572*	0.4330 (min.)	0.3810 (max.)		0.3740 (max.)	150 (max.)	0.000 (min.)	0.120 (max.)
bounding dimensions (B9x9B01)	0.9~~388~~*422*	0.934~~6~~*80*	0.0007	*0.572*	0.4330	0.3810	0.0260	0.3740††	150	0.000	0.120

† *This assembly class was analyzed and qualified for a small variation in the pitch.*

†† This value was conservatively defined to be larger than any of the actual pellet diameters.

Table 6.2.268

MAXIMUM K_{EFF} VALUES FOR THE 9X9C ASSEMBLY CLASS IN THE MPC-68

(all dimensions are in inches)

9x9C (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 80 fuel rods, 1 water rods, pitch=0.572, Zr clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
9x9C01	0.9395	0.9352	0.0008	0.4230	0.3640	0.0295	0.3565	150	0.020	0.100
Dimensions Listed in Certificate of Compliance				0.4230 (min.)	0.3640 (max.)		0.3565 (max.)	150 (max.)	0.020 (min.)	0.100 (max.)

Table 6.2.279
MAXIMUM K_{EFF} VALUES FOR THE 9X9D ASSEMBLY CLASS IN THE MPC-68
(all dimensions are in inches)

9x9D (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 79 fuel rods, 2 water rods, pitch=0.572, Zr clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
9x9D01	0.93924	0.934950	0.00089	0.4240	0.3640	0.0300	0.3565	150	0.03050	0.100
Dimensions Listed in Certificate of Compliance				0.4240 (min.)	0.3640 (max.)		0.3565 (max.)	150 (max.)	0.03050 (min.)	0.100 (max.)

Table 6.2.2830
MAXIMUM K_{EFF} VALUES FOR THE 9X9E ASSEMBLY CLASS IN THE MPC-68
(all dimensions are in inches)

9x9E (4.21% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2)

76 fuel rods, 5 water rods, pitch=0.572, Zr clad

Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
9x9E01	0.940602	0.9362359	0.0008	0.4170	0.3590640	0.029065	0.352530	150	0.0305120	0.10020
9x9E02	*0.9424*	*0.9380*	*0.0008*	*0.4170* *0.4430*	*0.3640* *0.3860*	*0.0265* *0.0285*	*0.3530* *0.3745*	*150*	*0.0120*	*0.120*
Dimensions Listed in Certificate of Compliance†				0.4170 (min.)	0.3590640 (max.)		0.352530 (max.)	150 (max.)	0.0305120 (min.)	0.10020 (max.)
bounding dimensions (9x9E02)	*0.9424*	*0.9380*	*0.0008*	*0.4170* *0.4430*	*0.3640* *0.3860*	*0.0265* *0.0285*	*0.3530* *0.3745*	*150*	*0.0120*	*0.120*

† *This fuel assembly, also known as SPC 9x9-5, contains fuel rods with different cladding and pellet diameters which do not bound each other. To be consistent in the way fuel assemblies are listed in the Certificate of Compliance, two assembly classes (9x9E and 9x9F) are required to specify this assembly. Each class contains the actual geometry (9x9E02 and 9x9F02), as well as a hypothetical geometry with either all small rods (9x9E01) or all large rods (9x9F01). The Certificate of Compliance lists the small rod dimensions for class 9x9E and the large rod dimensions for class 9x9F, and a note that both classes are used to qualify the assembly. The analyses demonstrate that all configurations, including the actual geometry, are acceptable.*

Table 6.2.~~29~~*31*
MAXIMUM K_{EFF} VALUES FOR THE 9X9F ASSEMBLY CLASS IN THE MPC-68
(all dimensions are in inches)

9x9F (4.~~2~~*1*% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 76 fuel rods, 5 water rods, pitch=0.572, Zr clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
9x9F01	0.93~~77~~*69*	0.93~~35~~*26*	0.0007	0.4430	0.38~~10~~*60*	0.0~~310~~*285*	0.3745	150	0.0~~305~~*120*	0.1~~00~~*20*
9x9F02	*0.9424*	*0.9380*	*0.0008*	*0.4170* *0.4430*	*0.3640* *0.3860*	*0.0265* *0.0285*	*0.3530* *0.3745*	*150*	*0.0120*	*0.120*
Dimensions Listed in Certificate of Compliance†				0.4430 (min.)	0.38~~10~~*60* (max.)		0.3745 (max.)	150 (max.)	0.0~~305~~*120* (min.)	0.1~~00~~*20* (max.)
bounding dimensions (9x9F02)	*0.9424*	*0.9380*	*0.0008*	*0.4170* *0.4430*	*0.3640* *0.3860*	*0.0265* *0.0285*	*0.3530* *0.3745*	*150*	*0.0120*	*0.120*

† *This fuel assembly, also known as SPC 9x9-5, contains fuel rods with different cladding and pellet diameters which do not bound each other. To be consistent in the way fuel assemblies are listed in the Certificate of Compliance, two assembly classes (9x9E and 9x9F) are required to specify this assembly. Each class contains the actual geometry (9x9E02 and 9x9F02), as well as a hypothetical geometry with either all small rods (9x9E01) or all large rods (9x9F01). The Certificate of Compliance lists the small rod dimensions for class 9x9E and the large rod dimensions for class 9x9F, and a note that both classes are used to qualify the assembly. The analyses demonstrate that all configurations, including the actual geometry, are acceptable.*

Table 6.2.3~~0~~2

MAXIMUM K_{EFF} VALUES FOR THE 10X10A ASSEMBLY CLASS IN THE MPC-68

(all dimensions are in inches)

10x10A (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 92/78 fuel rods†, 2 water rods, pitch=0.510, Zr clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
10x10A01 (axial segment with all rods)	0.9377	0.9335	0.0008	0.4040	0.3520	0.0260	0.3450	155	0.030	0.100
10x10A02 (axial segment with only the full length rods)	0.9426	0.9386	0.0007	0.4040	0.3520	0.0260	0.3450	155	0.030	0.100
10x10A03 (actual three-dimensional representation of all rods)	0.9396	0.9356	0.0007	0.4040	0.3520	0.0260	0.3450	155/90	0.030	0.100
Dimensions Listed in Certificate of Compliance				0.4040 (min.)	0.3520 (max.)		0.3455 (max.)	150†† (max.)	0.030 (min.)	0.120 (max.)
bounding dimensions (axial segment with only the full length rods) (B10x10A01)	0.9457†††	0.9414	0.0008	0.4040	0.3520	0.0260	0.3455‡	155	0.030	0.120

† This assembly class contains 78 full-length rods and 14 partial-length rods. In order to eliminate the requirement on the length of the partial length rods, separate calculations were performed for axial segments with and without the partial length rods.

†† Although the analysis qualifies this assembly for a maximum active fuel length of 155 inches, the Certificate of Compliance limits the active fuel length to 150 inches. This is due to the fact that the Boral panels are 156 inches in length.

††† KENO5a verification calculation resulted in a maximum k_{eff} of 0.9453.

‡ This value was conservatively defined to be larger than any of the actual pellet diameters.

Table 6.2.3~~1~~*3*

MAXIMUM K_{EFF} VALUES FOR THE 10X10B ASSEMBLY CLASS IN THE MPC-68

(all dimensions are in inches)

10x10B (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2)

91/83 fuel rods†, 1 water rods (square, replacing 9 fuel rods), pitch=0.510, Zr clad

Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
10x10B01 (axial segment with all rods)	0.9384	0.9341	0.0008	0.3957	0.3480	0.0239	0.3413	155	0.0285	0.100
10x10B02 (axial segment with only the full length rods)	0.9416	0.9373	0.0008	0.3957	0.3480	0.0239	0.3413	155	0.0285	0.100
10x10B03 (actual three-dimensional representation of all rods)	0.9375	0.9334	0.0007	0.3957	0.3480	0.0239	0.3413	155/90	0.0285	0.100
Dimensions Listed in Certificate of Compliance				0.3957 (min.)	0.3480 (max.)		0.3420 (max.)	150†† (max.)	0.000 (min.)	0.120 (max.)
bounding dimensions (axial segment with only the full length rods) (B10x10B01)	0.9436	0.9395	0.0007	0.3957	0.3480	0.0239	0.3420†††	155	0.000	0.120

† This assembly class contains 83 full length rods and 8 partial length rods. In order to eliminate a requirement on the length of the partial length rods, separate calculations were performed for the axial segments with and without the partial length rods.

†† Although the analysis qualifies this assembly for a maximum active fuel length of 155 inches, the Certificate of Compliance limits the active fuel length to 150 inches. This is due to the fact that the Boral panels are 156 inches in length.

††† This value was conservatively defined to be larger than any of the actual pellet diameters.

Table 6.2.3~~2~~*4*

MAXIMUM K_{EFF} VALUES FOR THE 10X10C ASSEMBLY CLASS IN THE MPC-68

(all dimensions are in inches)

10x10C (4.2% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 96 fuel rods, 5 water rods (1 center diamond and 4 rectangular), pitch=0.488, Zr clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
10x10C01	0.~~8990~~*9021*	0.89~~49~~*80*	0.0007	0.37~~90~~*80*	0.3294	0.02~~4~~3*8*	0.3224	150	0.034*1*	0.055
Dimensions Listed in Certificate of Compliance				0.37~~90~~*80* (min.)	0.3294 (max.)		0.3224 (max.)	150 (max.)	0.034*1* (min.)	0.055 (max.)

Table 6.2.335
MAXIMUM K_{EFF} VALUES FOR THE 10X10D ASSEMBLY CLASS IN THE MPC-68
(all dimensions are in inches)

10x10D (4.0% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 100 fuel rods, 0 water rods, pitch=0.565, SS clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
10x10D01	0.9376	0.9333	0.0008	0.3960	0.3560	0.0200	0.350	83	n/a	0.080
Dimensions Listed in Certificate of Compliance				0.3960 (min.)	0.3560 (max.)		0.350 (max.)	83 (max.)	n/a	0.080 (max.)

Table 6.2.346
MAXIMUM K_{EFF} VALUES FOR THE 10X10E ASSEMBLY CLASS IN THE MPC-68
(all dimensions are in inches)

10x10E (4.0% Enrichment, Boral ^{10}B minimum loading of 0.0279 g/cm^2) 96 fuel rods, 4 water rods, pitch=0.557, SS clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
10x10E01	0.9185	0.9144	0.0007	0.3940	0.3500	0.0220	0.3430	83	0.022	0.080
Dimensions Listed in Certificate of Compliance				0.3940 (min.)	0.3500 (max.)		0.3430 (max.)	83 (max.)	0.022 (min.)	0.080 (max.)

Table 6.2.3~~5~~7
MAXIMUM K_{EFF} VALUES FOR THE 6X6A ASSEMBLY CLASS IN THE MPC-68F
(all dimensions are in inches)

6x6A (3.0% Enrichment†, Boral ^{10}B minimum loading of 0.0067 g/cm^2)

35 or 36 fuel rods††, *1 or* 0 water rods††, pitch††=0.694 *to 0.710*, Zr clad

Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	*pitch*	*fuel rods*	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
6x6A01	0.7539	0.7498	0.0007	*0.694*	*36*	0.5645	0.4945	0.0350	0.4940	110	n/a	0.060
6x6A02	0.7517	0.7476	0.0007	*0.694*	*36*	0.5645	0.4925	0.0360	0.4820	110	n/a	0.060
6x6A03	0.7545	0.7501	0.0008	*0.694*	*36*	0.5645	0.4945	0.0350	0.4820	110	n/a	0.060
6x6A04	0.7537	0.7494	0.0008	*0.694*	*36*	0.5550	0.4850	0.0350	0.4820	110	n/a	0.060
6x6A05	*0.7555*	*0.7512*	*0.0008*	*0.696*	*36*	*0.5625*	*0.4925*	*0.0350*	*0.4820*	*110*	*n/a*	*0.060*
6x6A06	*0.7618*	*0.7576*	*0.0008*	*0.696*	*35*	*0.5625*	*0.4925*	*0.0350*	*0.4820*	*110*	*0.0*	*0.060*
6x6A07	*0.7588*	*0.7550*	*0.0007*	*0.700*	*36*	*0.5555*	*0.4850*	*0.03525*	*0.4780*	*110*	*n/a*	*0.060*
6x6A08	*0.7808*	*0.7766*	*0.0007*	*0.710*	*36*	*0.5625*	*0.5105*	*0.0260*	*0.4980*	*110*	*n/a*	*0.060*
Dimensions Listed in Certificate of Compliance				*0.710 (max.)*	*35 or 36*	0.5550 (min.)	~~0.4945~~ *0.5105* (max.)	*0.02225*	~~0.4940~~ *0.4980* (max.)	~~110~~ *120* (max.)	~~n/a~~*0.0*	0.060 (max.)
bounding dimensions (B6x6A01)	~~0.7602~~ *0.7727*	~~0.7562~~ *0.7685*	0.00~~6~~7	*0.694*	*35*	0.5550	~~0.4945~~ *0.5105*	~~0.3030~~ *0.02225*	~~0.4940~~ *0.4980*	~~110~~ *120*	~~n/a~~*0.0*	0.060
bounding dimensions (B6x6A02)	*0.7782*	*0.7738*	*0.0008*	*0.700*	*35*	*0.5550*	*0.5105*	*0.02225*	*0.4980*	*120*	*0.0*	*0.060*
bounding dimensions (B6x6A03)	*0.7888*	*0.7846*	*0.0007*	*0.710*	*35*	*0.5550*	*0.5105*	*0.02225*	*0.4980*	*120*	*0.0*	*0.060*

† Although the calculations were performed for 3.0%, the enrichment is limited in the Certificate of Compliance to 2.7%.

†† *This assembly class was analyzed and qualified for a small variation in the pitch and a variation in the number of fuel and water rods.*

Table 6.2.3~~6~~*8*

MAXIMUM K_{EFF} VALUES FOR THE 6X6B ASSEMBLY CLASS IN THE MPC-68F

(all dimensions are in inches)

6x6B (3.0% Enrichment†, Boral ^{10}B minimum loading of 0.0067 g/cm^2) *35 or* 36 fuel rods†† *(up to* 9 MOX rods), *1 or* 0 water rods††, pitch††=0.694 *to 0.710*, Zr clad												
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	*pitch*	*fuel rods*	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
6x6B01	~~0.7598~~ *0.7604*	~~0.7555~~ *0.7563*	~~0.0008~~ *0.0007*	*0.694*	*36*	0.5645	0.4945	0.0350	0.4820	110	n/a	0.060
6x6B02	~~0.7609~~ *0.7618*	~~0.7567~~ *0.7577*	~~0.0007~~ *0.0007*	*0.694*	*36*	0.5625	0.4925	0.0350	0.4820	110	n/a	0.060
6x6B03	*0.7619*	*0.7578*	*0.0007*	*0.696*	*36*	*0.5625*	*0.4925*	*0.0350*	*0.4820*	*110*	*n/a*	*0.060*
6x6B04	*0.7686*	*0.7644*	*0.0008*	*0.696*	*35*	*0.5625*	*0.4925*	*0.0350*	*0.4820*	*110*	*0.0*	*0.060*
6x6B05	*0.7824*	*0.7785*	*0.0006*	*0.710*	*35*	*0.5625*	*0.4925*	*0.0350*	*0.4820*	*110*	*0.0*	*0.060*
Dimensions Listed in Certificate of Compliance				*0.710 (max.)*	*35 or 36*	0.5625 (min.)	0.4945 (max.)		0.4820 (max.)	~~110~~ *120* (max.)	~~n/a~~*0.0*	0.060 (max.)
bounding dimensions (B6x6B01)	~~0.7611~~ *0.7822*†††	~~0.7570~~ *0.7783*	~~0.0007~~ *0.0006*	*0.710*	*35*	0.5625	0.4945	0.0340	0.4820	~~110~~ *120*	~~n/a~~*0.0*	0.060

Note:

1. These assemblies ~~consist of~~ *contain up to* 9 MOX pins~~-and 27 UO_2 pins~~. The composition of the MOX fuel pins is given in Table 6.3.4.

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† The ^{235}U enrichment of the MOX and UO_2 pins is assumed to be 0.711% and 3.0%, respectively.

†† *This assembly class was analyzed and qualified for a small variation in the pitch and a variation in the number of fuel and water rods.*

††† *The k_{eff} value listed for the 6x6B05 case is slightly higher than that for the case with the bounding dimensions. However, the difference (0.0002) is well within the statistical uncertainties, and thus, the two values are statistically equivalent (within 1σ). Therefore, the 0.7824 value is listed in Tables 6.1.2 and 6.1.3 as the maximum.*

Table 6.2.3~~7~~9
MAXIMUM K_{EFF} VALUES FOR THE 6X6C ASSEMBLY CLASS IN THE MPC-68F
(all dimensions are in inches)

6x6C (3.0% Enrichment†, Boral ^{10}B minimum loading of 0.0067 g/cm^2) 36 fuel rods, 0 water rods, pitch=0.740, Zr clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
6x6C01	0.8021	0.7980	0.0007	0.5630	0.4990	0.0320	0.4880	77.5	n/a	0.060
Dimensions Listed in Certificate of Compliance				0.5630 (min.)	0.4990 (max.)		0.4880 (max.)	77.5 (max.)	n/a	0.060 (max.)

† Although the calculations were performed for 3.0%, the enrichment is limited in the Certificate of Compliance to 2.7%.

Table 6.2.~~38~~*40*
MAXIMUM K_{EFF} VALUES FOR THE 7X7A ASSEMBLY CLASS IN THE MPC-68F
(all dimensions are in inches)

7x7A (3.0% Enrichment†, Boral ^{10}B minimum loading of 0.0067 g/cm^2) 49 fuel rods, 0 water rods, pitch=0.631, Zr clad										
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
7x7A01	0.797~~3~~*4*	0.793~~0~~2	0.0008	0.4860	0.420~~0~~*4*	0.03~~30~~*28*	0.4110	~~79~~*80*	n/a	0.060
Dimensions Listed in Certificate of Compliance				0.4860 (min.)	0.420~~0~~*4* (max.)		0.4110 (max.)	~~79~~*80* (max.)	n/a	0.060 (max.)

† Although the calculations were performed for 3.0%, the enrichment is limited in the Certificate of Compliance to 2.7%.

Table 6.2.~~39~~41
MAXIMUM K_{EFF} VALUES FOR THE 8X8A ASSEMBLY CLASS IN THE MPC-68F
(all dimensions are in inches)

8x8A (3.0% Enrichment†, Boral ^{10}B minimum loading of 0.0067 g/cm²) *63 or* 64 fuel rods††, 0 water rods, pitch=0.523, Zr clad											
Fuel Assembly Designation	maximum k_{eff}	calculated k_{eff}	standard deviation	*fuel rods*	cladding OD	cladding ID	cladding thickness	pellet OD	fuel length	water rod thickness	channel thickness
8x8A01	0.7685	0.7644	0.0007	*64*	0.4120	0.3620	0.0250	0.3580	110	n/a	0.100
8x8A02	*0.7697*	*0.7656*	*0.0007*	*63*	*0.4120*	*0.3620*	*0.0250*	*0.3580*	*120*	*n/a*	*0.100*
Dimensions Listed in Certificate of Compliance				*63*	0.4120 (min.)	0.3620 (max.)		0.3580 (max.)	~~110~~*120* (max.)	n/a	0.100 (max.)
bounding dimensions (8x8A02)	*0.7697*	*0.7656*	*0.0007*	*63*	*0.4120*	*0.3620*	*0.0250*	*0.3580*	*120*	*n/a*	*0.100*

† Although the calculations were performed for 3.0%, the enrichment is limited in the Certificate of Compliance to 2.7%.

†† *This assembly class was analyzed and qualified for a variation in the number of fuel rods.*

Table 6.2.42

SPECIFICATION OF THE THORIA ROD CANISTER AND THE THORIA RODS

Canister ID	*4.81"*
Canister Wall Thickness	*0.11"*
Separator Assembly Plates Thickness	*0.11"*
Cladding OD	*0.412"*
Cladding ID	*0.362"*
Pellet OD	*0.358"*
Active Length	*110.5"*
Fuel Composition	*1.8% UO_2 and 98.2% ThO_2*
Initial Enrichment	*93.5 wt% ^{235}U for 1.8% of the fuel*
Maximum k_{eff}	*0.1813*
Calculated k_{eff}	*0.1779*
Standard Deviation	*0.0004*

Table 6.3.4

COMPOSITION OF THE MAJOR COMPONENTS OF THE HI-STAR 100 SYSTEM

MPC-24		
UO_2 4.0% ENRICHMENT, DENSITY (g/cc) = 10.522		
Nuclide	**Atom-Density**	**Wgt. Fraction**
8016	4.693E-02	1.185E-01
92235	9.505E-04	3.526E-02
92238	2.252E-02	8.462E-01
BORAL (0.02 g ^{10}B/cm sq), DENSITY (g/cc) = 2.660		
Nuclide	**Atom-Density**	**Wgt. Fraction**
5010	8.707E-03	5.443E-02
5011	3.512E-02	2.414E-01
6012	1.095E-02	8.210E-02
13027	3.694E-02	6.222E-01

Table 6.3.4 (continued)

COMPOSITION OF THE MAJOR COMPONENTS OF THE HI-STAR 100 SYSTEM

MPC-68		
UO_2 4.2% ENRICHMENT, DENSITY (g/cc) = 10.522		
Nuclide	**Atom-Density**	**Wgt. Fraction**
8016	4.697E-02	1.185E-01
92235	9.983E-04	3.702E-02
92238	2.248E-02	8.445E-01
UO_2 3.0% ENRICHMENT, DENSITY (g/cc) = 10.522		
Nuclide	**Atom-Density**	**Wgt. Fraction**
8016	4.695E-02	1.185E-01
92235	7.127E-04	2.644E-02
92238	2.276E-02	8.550E-01
MOX FUEL†, DENSITY (g/cc) = 10.522		
Nuclide	**Atom-Density**	**Wgt. Fraction**
8016	4.714E-02	1.190E-01
92235	1.~~659~~*719*E-04	6.~~150~~*380*E-03
92238	2.285E-02	8.58~~6~~*4*E-01
94239	3.876E-04	1.461E-02
94240	9.177E-06	3.400E-04
94241	3.247E-05	1.240E-03
94242	2.118E-06	7.000E-05

† The Pu-238, which is an absorber, was conservatively neglected in the MOX description for analysis purposes.

Table 6.3.4 (continued)

COMPOSITION OF THE MAJOR COMPONENTS OF THE HI-STAR 100 SYSTEM

BORAL (0.0279 g ^{10}B/cm sq), DENSITY (g/cc) = 2.660		
Nuclide	**Atom-Density**	**Wgt. Fraction**
5010	8.071E-03	5.089E-02
5011	3.255E-02	2.257E-01
6012	1.015E-02	7.675E-02
13027	3.805E-02	6.467E-01
FUEL IN THORIA RODS, DENSITY (g/cc) = 10.522		
Nuclide	***Atom-Density***	***Wgt. Fraction***
8016	*4.798E-02*	*1.212E-01*
92235	*4.001E-04*	*1.484E-02*
92238	*2.742E-05*	*1.030E-03*
90232	*2.357E-02*	*8.630E-01*

Table 6.3.4 (continued)

COMPOSITION OF THE MAJOR COMPONENTS OF THE HI-STAR 100 SYSTEM

COMMON MATERIALS		
ZR CLAD, DENSITY (g/cc) = 6.550		
Nuclide	**Atom-Density**	**Wgt. Fraction**
40000	4.323E-02	1.000E+00
MODERATOR (H_2O), DENSITY (g/cc) = 1.000		
Nuclide	**Atom-Density**	**Wgt. Fraction**
1001	6.688E-02	1.119E-01
8016	3.344E-02	8.881E-01
STAINLESS STEEL, DENSITY (g/cc) = 7.840		
Nuclide	**Atom-Density**	**Wgt. Fraction**
24000	1.761E-02	1.894E-01
25055	1.761E-03	2.001E-02
26000	5.977E-02	6.905E-01
28000	8.239E-03	1.000E-01
ALUMINUM, DENSITY (g/cc) = 2.700		
Nuclide	**Atom-Density**	**Wgt. Fraction**
13027	6.026E-02	1.000E+00

6.4.3 Criticality Results

Results of the criticality safety calculations for the condition of flooding with clean unborated water are presented in Section 6.2 and summarized in Section 6.1. These data confirm that for each of the candidate fuel types and basket configurations the effective multiplication factor (k_{eff}), including all biases and uncertainties at a 95-percent confidence level, do not exceed 0.95 under all credible normal, off-normal, and accident conditions.

Additional calculations (CASMO-3) at elevated temperatures confirm that the temperature coefficients of reactivity are negative as shown in Table 6.3.1. This confirms that the calculations for the storage baskets are conservative.

In calculating the maximum reactivity, the analysis used the following equation:

$$k_{eff}^{max} = k_c + K_c \sigma_c + Bias + \sigma_B$$

where:

- ⇒ k_c is the calculated k_{eff} under the worst combination of tolerances;
- ⇒ K_c is the K multiplier for a one-sided statistical tolerance limit with 95% probability at the 95% confidence level [6.1.8]. Each final k_{eff} value calculated by MCNP4a (or KENO5a) is the result of averaging 100 (or more) cycle k_{eff} values, and thus, is based on a sample size of 100. The K multiplier corresponding to a sample size of 100 is 1.93. However, for this analysis a value of 2.00 was assumed for the K multiplier, which is larger (more conservative) than the value corresponding to a sample size of 100;
- ⇒ σ_c is the standard deviation of the calculated k_{eff}, as determined by the computer code (MCNP4a or KENO5a);
- ⇒ ***Bias*** is the systematic error in the calculations (code dependent) determined by comparison with critical experiments in Appendix 6.A; and
- ⇒ σ_B is the standard error of the bias (which includes the K multiplier for 95% probability at the 95% confidence level; see Appendix 6.A).

Appendix 6.A presents the critical experiment benchmarking and the derivation of the bias and standard error of the bias (95% probability at the 95% confidence level).

6.4.4 Damaged Fuel Container

Both damaged BWR fuel assemblies and BWR fuel debris are required to be loaded into Damaged Fuel Containers (DFCs) prior to being loaded into the MPC. *Two different DFC types with slightly different cross sections are analyzed.* DFCs containing fuel debris must be stored in the MPC-68F. DFCs containing damaged fuel assemblies may be stored in either the MPC-68 or MPC-68F. Evaluation of the capability of storing damaged fuel and fuel debris (loaded in DFCs) is limited to very low reactivity fuel in the MPC-68F. Because the MPC-68 has a higher specified ^{10}B loading, the evaluation of the MPC-68F conservatively bounds the storage of damaged BWR fuel assemblies in a standard MPC-68 Although the maximum planar-average enrichment of the damaged fuel is limited to 2.7% ^{235}U as specified in Appendix B to the Certificate of Compliance, analyses have been made for three possible scenarios, conservatively assuming fuel†† of 3.0% enrichment. The scenarios considered included the following:

1. Lost or missing fuel rods, calculated for various numbers of missing rods in order to determine the maximum reactivity. The configurations assumed for analysis are illustrated in Figures 6.4.2 through 6.4.8.
2. Broken fuel assembly with the upper segments falling into the lower segment creating a close-packed array (described as a 8x8 array). For conservatism, the array analytically retained the same length as the original fuel assemblies in this analysis. This configuration is illustrated in Figure 6.4.9.
3. Fuel pellets lost from the assembly and forming powdered fuel dispersed through a volume equivalent to the height of the original fuel. (Flow channel and clad material assumed to disappear).

Results of the analyses, shown in Table 6.4.5, confirm that, in all cases, the maximum reactivity is well below the regulatory limit. *There is no significant difference in reactivity between the two DFC types.* Collapsed fuel reactivity (simulating fuel debris) is low because of the reduced moderation. Dispersed powdered fuel results in low reactivity because of the increase in ^{238}U neutron capture (higher effective resonance integral for ^{238}U absorption).

The loss of fuel rods results in a small increase in reactivity (i.e., rods assumed to collapse, leaving a smaller number of rods still intact). The peak reactivity occurs for 8 missing rods, and a smaller (or larger) number of intact rods will have a lower reactivity, as indicated in Table 6.4.5.

The analyses performed and summarized in Table 6.4.5 provides the relative magnitude of the effects on the reactivity. This information coupled with the maximum k_{eff} values listed in Table 6.1.3 and the conservatism in the analyses, demonstrate that the maximum k_{eff} of the damaged fuel in the most adverse post-accident condition will remain well below the regulatory requirement of $k_{eff} < 0.95$.

Appendix 6.D provides sample input files for the damaged fuel analysis.

†† 6x6A01 and 7x7A01 fuel assemblies were used as representative assemblies.

6.4.5 Fuel Assemblies with Missing Rods

For fuel assemblies that are qualified for damaged fuel storage, missing and/or damaged fuel rods are acceptable. However, for fuel assemblies to meet the limitations of intact fuel assembly storage, missing fuel rods must be replaced with dummy rods that displace a volume of water that is equal to, or larger than, that displaced by the original rods.

6.4.6 Thoria Rod Canister

The Thoria Rod Canister is similar to a DFC with an internal separator assembly containing 18 intact fuel rods. The configuration is illustrated in Figure 6.4.10. The k_{eff} value for an MPC-68F filled with Thoria Rod Canisters is calculated to be 0.1813. This low reactivity is attributed to the relatively low content in ^{235}U (equivalent to UO_2 fuel with an enrichment of approximately 1.7 wt% ^{235}U), the large spacing between the rods (the pitch is approximately 1", the cladding OD is 0.412") and the absorption in the separator assembly. Together with the maximum k_{eff} values listed in Tables 6.1.2 and 6.1.3 this result demonstrates, that the k_{eff} for a Thoria Rod Canister loaded into the MPC68 or the MPC68F together with other approved fuel assemblies or DFCs will remain well below the regulatory requirement of $k_{eff} < 0.95$.

6.4.7 Sealed Rods replacing BWR Water Rods

Some BWR fuel assemblies contain sealed rods filled with a non-fissile instead of water rods. Compared to the configuration with water rods, the configuration with sealed rods has a reduced amount of moderator, while the amount of fissile material is maintained. Thus, the reactivity of the configuration with sealed rods will be lower compared to the configuration with water rods. Any configuration containing sealed rods instead of water rods is therefore bounded by the analysis for the configuration with water rods and no further analysis is required to demonstrate the acceptability. Therefore, for all BWR fuel assemblies analyzed, it is permissible that water rods are replaced by sealed rods filled with a non-fissile material.

6.4.8 Inserts in PWR Fuel Assemblies

Inserts into PWR fuel assemblies such as Thimble Plugs (TPs) and Burnable Poison Rod Assemblies (BPRAs) and similar devices are permitted for storage with all PWR fuel types. The reactivity of any PWR assembly with inserts is bounded by (i.e. lower than) the reactivity of the same assembly without the insert. This is due to the fact that the insert reduces the amount of moderator in the assembly, while the amount of fissile material remains unchanged. Therefore, from a criticality safety perspective, inserts into PWR assemblies are acceptable for all allowable PWR types, and increase the safety margin.

6.4.9 *Neutron Sources in Fuel Assemblies*

Fuel assemblies containing start-up neutron sources are permitted for storage in the HI-STAR 100 System. The reactivity of a fuel assembly is not affected by the presence of a neutron source (other than by the presence of the material of the source, which is discussed later). This true because in a system with a keff less than 1.0, any given neutron population at any time, regardless of its origin or size, will decrease over time. Therefore, a neutron source of any strength will not increase reactivity, but only the neutron flux in a system, and no additional criticality analyses are required. Sources are inserted as rods into fuel assemblies, i.e. they replace either a fuel rod or water rod (moderator). Therefore, the insertion of the material of the source into a fuel assembly will not lead to an increase of reactivity either.

Table 6.4.5

MAXIMUM k_{eff} VALUES† IN THE DAMAGED FUEL CONTAINER

Condition	MCNP4a Maximum†† k_{eff}	
	DFC Dimensions: ID 4.93" THK. 0.12"	*DFC Dimensions: ID 4.81" THK. 0.11"*
<u>6x6 Fuel Assembly</u>		
6x6 Intact Fuel	0.7086	*0.7016*
w/32 Rods Standing	0.7183	*0.7117*
w/28 Rods Standing	0.7315	*0.7241*
w/24 Rods Standing	0.7086	*0.7010*
w/18 Rods Standing	0.6524	*0.6453*
Collapsed to 8x8 array	0.7845	*0.7857*
Dispersed Powder	0.7628	*0.7440*
<u>7x7 Fuel Assembly</u>		
7x7 Intact Fuel	0.7463	*0.7393*
w/41 Rods Standing	0.7529	*0.7481*
w/36 Rods Standing	0.7487	*0.7444*
w/25 Rods Standing	0.6718	*0.6644*

† These calculations were performed with a planar-average enrichment of 3.0% and a ^{10}B loading of 0.0067 g/cm^2, which is 75% of a minimum ^{10}B loading of 0.0089 g/cm^2. The minimum ^{10}B loading in the MPC-68F is 0.010 g/cm^2. Therefore, the listed maximum k_{eff} values are conservative.

†† Maximum k_{eff} includes bias, uncertainties, and calculational statistics, evaluated for the worst case combination of manufacturing tolerances.

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

FIGURE 6.4.2; FAILED FUEL CALCULATION MODEL (PLANAR CROSS-SECTION) WITH 6X6 ARRAY WITH 4 MISSING RODS IN THE MPC-68 BASKET (SEE CHAPTER 1 FOR TRUE BASKET DIMENSIONS)

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

FIGURE 6.4.3; FAILED FUEL CALCULATION MODEL (PLANAR CROSS-SECTION) WITH 6X6 ARRAY WITH 8 MISSING RODS IN THE MPC-68 BASKET (SEE CHAPTER 1 FOR TRUE BASKET DIMENSIONS)

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

FIGURE 6.4.4; FAILED FUEL CALCULATION MODEL (PLANAR CROSS-SECTION) WITH 6X6 ARRAY WITH 12 MISSING RODS IN THE MPC-68 BASKET (SEE CHAPTER 1 FOR TRUE BASKET DIMENSIONS)

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

FIGURE 6.4.5; FAILED FUEL CALCULATION MODEL (PLANAR CROSS-SECTION) WITH 6X6 ARRAY WITH 18 MISSING RODS IN THE MPC-68 BASKET (SEE CHAPTER 1 FOR TRUE BASKET DIMENSIONS)

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

FIGURE 6.4.6; FAILED FUEL CALCULATION MODEL (PLANAR CROSS-SECTION) WITH 7X7 ARRAY WITH 8 MISSING RODS IN THE MPC-68 BASKET (SEE CHAPTER 1 FOR TRUE BASKET DIMENSIONS)

FIGURE WITHHELD AS
SENSITIVE UNCLASSIFIED
INFORMATION

FIGURE 6.4.7; FAILED FUEL CALCULATION MODEL (PLANAR CROSS-SECTION) WITH 7X7 ARRAY WITH 13 MISSING RODS IN THE MPC-68 BASKET (SEE CHAPTER 1 FOR TRUE BASKET DIMENSIONS)

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

FIGURE 6.4.8; FAILED FUEL CALCULATION MODEL (PLANAR CROSS-SECTION) WITH 7X7 ARRAY WITH 24 MISSING RODS IN THE MPC-68 BASKET (SEE CHAPTER 1 FOR TRUE BASKET DIMENSIONS)

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

FIGURE 6.4.9; FAILED FUEL CALCULATION MODEL (PLANAR CROSS-SECTION) WITH DAMAGED FUEL COLLAPSED INTO 8X8 ARRAY IN THE MPC-68 BASKET (SEE CHAPTER 1 FOR TRUE BASKET DIMENSIONS)

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

FIGURE 6.4.10; THORIA ROD CANISTER (PLANAR CROSS-SECTION) WITH 18 THORIA RODS IN THE MPC-68 BASKET (SEE CHAPTER 1 FOR TRUE BASKET DIMENSIONS)

Table 6.C.1
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-24				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
14x14A01	0.9378	0.9332	0.0010	0.2147
14x14A02	0.9374	0.9328	0.0009	0.2137
14x14A03	0.9383	0.9340	0.0008	0.2125
14x14B01	0.9268	0.9225	0.0008	0.2788
14x14B02	0.9243	0.9200	0.0008	0.2398
14x14B03	0.9196	0.9152	0.0009	0.2598
14x14B04	0.9163	0.9118	0.0009	0.2631
B14x14B01	0.9323	0.9280	0.0008	0.2730
14x14C01	0.9361	0.9317	0.0009	0.2821
14x14C02	0.9355	0.9312	0.0008	0.2842
14x14C03	*0.9400*	*0.9357*	*0.0008*	*0.2900*
14x14D01	0.8576	0.8536	0.0007	0.3414
15x15A01	0.9301	0.9259	0.0008	0.2660
15x15B01	0.9427	0.9384	0.0008	0.2704
15C15B02	0.9441	0.9396	0.0009	0.2711
15x15B03	0.9462	0.9420	0.0008	0.2708
15x15B04	0.9452	0.9407	0.0009	0.2692
15x15B05	0.9473	0.9431	0.0008	0.2693
15x15B06	0.9448	0.9404	0.0008	0.2732
B15x15B01	0.9471	0.9428	0.0008	0.2722
15x15C01	0.9332	0.9290	0.0007	0.2563

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-24				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
15x15C02	0.9373	0.9330	0.0008	0.2536
15x15C03	0.9377	0.9335	0.0007	0.2525
15x15C04	0.9378	0.9338	0.0007	0.2499
B15x15C01	0.9444	0.9401	0.0008	0.2456
15x15D01	0.9423	0.9380	0.0008	0.2916
15x15D02	0.9430	0.9386	0.0009	0.2900
15x15D03	0.9419	0.9375	0.0009	0.2966
15x15D04	0.9440	0.9398	0.0007	0.3052
15x15E01	0.9475	0.9433	0.0007	0.2916
15x15F01	0.9478	0.9436	0.0008	0.3006
15x15G01	0.8986	0.8943	0.0008	0.3459
15x15H01	*0.9411*	*0.9368*	*0.0008*	*0.2425*
16x16A01	0.9383	0.9339	0.0009	0.2786
16x16A02	0.9371	0.9328	0.0008	0.2768
17x17A01	0.9449	0.9400	0.0011	0.2198
17x17A02	0.9452	0.9408	0.0008	0.2205
17x17A03	0.9406	0.9364	0.0008	0.2082
17x17B01	0.9377	0.9335	0.0008	0.2697
17x17B02	0.9379	0.9337	0.0008	0.2710
17x17B03	0.9330	0.9288	0.0008	0.2714
17x17B04	0.9407	0.9365	0.0007	0.2666
17x17B05	0.9349	0.9305	0.0009	0.2629

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-24				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
17x17B06	0.9436	0.9393	0.0008	0.2657
17x17C01	0.9383	0.9339	0.0008	0.2683
17x17C02	0.9427	0.9384	0.0008	0.2703

MPC-68				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
6x6A01	0.7539	0.7498	0.0007	0.2754
6x6A02	0.7517	0.7476	0.0007	0.2510
6x6A03	0.7545	0.7501	0.0008	0.2494
6x6A04	0.7537	0.7494	0.0008	0.2494
6x6A05	*0.7555*	*0.7512*	*0.0008*	*0.2470*
6x6A06	*0.7618*	*0.7576*	*0.0008*	*0.2298*
6x6A07	*0.7588*	*0.7550*	*0.0005*	*0.2360*
6x6A08	*0.7808*	*0.7766*	*0.0007*	*0.2527*
B6x6A01	0.~~7602~~*7888*	0.~~7562~~*7846*	0.000~~6~~*7*	0.~~2677~~*2310*
6x6B01	0.~~7598~~*7604*	0.~~7555~~*7563*	0.000~~8~~*7*	0.~~2463~~*2461*
6x6B02	0.~~7609~~*7618*	0.~~7567~~*7577*	0.000~~7~~*6*	0.~~2461~~*2450*
6x6B03	*0.7619*	*0.7578*	*0.0007*	*0.2439*
6x6B04	*0.7686*	*0.7644*	*0.0008*	*0.2286*
6x6B05	*0.7824*	*0.7785*	*0.0006*	*0.2184*
B6x6B01	0.~~7611~~*7822*	0.~~7570~~*7783*	0.000~~7~~*6*	0.~~2442~~*2190*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES AND BASKET CONFIGURATIONS

MPC-68				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
6x6C01	0.8021	0.7980	0.0007	0.2139
7x7A01	0.7973	0.7930	0.0008	0.2015
7x7B01	0.9372	0.9330	0.0007	0.3658
7x7B02	0.9301	0.9260	0.0007	0.3524
7x7B03	0.9313	0.9271	0.0008	0.3438
7x7B04	0.9311	0.9270	0.0007	0.3816
7x7B05	0.9350	0.9306	0.0008	0.3382
7x7B06	*0.9298*	*0.9260*	*0.0006*	*0.3957*
B7x7B01	0.~~9378~~*9375*	0.~~9335~~*9332*	0.0008	0.~~3794~~*3887*
B7x7B02	0.~~9375~~*9386*	0.~~9332~~*9344*	0.000~~8~~*7*	0.~~3839~~*3983*
8x8A01	0.7685	0.7644	0.0007	0.2227
8x8A02	*0.7697*	*0.7656*	*0.0007*	*0.2158*
8x8B01	0.9310	0.9265	0.0009	0.2935
8x8B02	0.9227	0.9185	0.0007	0.2993
8x8B03	0.9299	0.9257	0.0008	0.3319
8x8B04	*0.9236*	*0.9194*	*0.0008*	*0.3700*
B8x8B01	0.~~9317~~*9346*	0.~~9274~~*9301*	0.000~~8~~*9*	0.~~3319~~*3389*
B8x8B02	0.~~9357~~*9385*	0.~~9315~~*9343*	0.0008	0.~~3245~~*3329*
B8x8B03	0.~~9368~~*9416*	0.~~9327~~*9375*	0.0007	0.~~3231~~*3293*
8x8C01	0.9315	0.9273	0.0007	0.2822
8x8C02	0.9313	0.9268	0.0009	0.2716
8x8C03	0.9329	0.9286	0.0008	0.2877

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES AND BASKET CONFIGURATIONS

MPC-68				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
8x8C04	0.9348	0.9307	0.0007	0.2915
8x8C05	0.9353	0.9312	0.0007	0.2971
8x8C06	0.9353	0.9312	0.0007	0.2944
8x8C07	0.9314	0.9273	0.0007	0.2972
8x8C08	0.9339	0.9298	0.0007	0.2915
8x8C09	0.9301	0.9260	0.0007	0.3183
8x8C10	0.9317	0.9275	0.0008	0.3018
8x8C11	0.9328	0.9287	0.0007	0.3001
8x8C12	0.9285	0.9242	0.0008	0.3062
B8x8C01	0.9357	0.9313	0.0009	0.3141
B8x8C02	0.9425	0.9384	0.0007	0.3081
B8x8C03	0.9418	0.9375	0.0008	0.3056
8x8D01	0.9342	0.9302	0.0006	0.2733
8x8D02	0.9325	0.9284	0.0007	0.2750
8x8D03	0.9351	0.9309	0.0008	0.2731
8x8D04	0.9338	0.9296	0.0007	0.2727
8x8D05	0.9339	0.9294	0.0009	0.2700
8x8D06	0.9365	0.9324	0.0007	0.2777
8x8D07	0.9341	0.9297	0.0009	0.2694
8x8D08	*0.9376*	*0.9332*	*0.0009*	*0.2841*
B8x8D01	0.~~9366~~*9403*	0.~~9323~~*9363*	0.000~~8~~*7*	0.~~2740~~*2778*
8x8E01	0.9312	0.9270	0.0008	0.2831

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES AND BASKET CONFIGURATIONS

MPC-68				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
8x8F01	*0.9140*	*0.9097*	*0.0008*	*0.2505*
9x9A01	0.9353	0.9310	0.0008	0.2875
9x9A02	0.9388	0.9345	0.0008	0.2228
9x9A03	0.9351	0.9310	0.0007	0.2837
9x9A04	0.9396	0.9355	0.0007	0.2262
B9x9A01	0.9417	0.9374	0.0008	0.2236
9x9B01	0.9368	0.9326	0.0007	0.2561
9x9B02	0.9377	0.9334	0.0008	0.2547
9x9B03	*0.9416*	*0.9373*	*0.0008*	*0.2517*
B9x9B01	0.~~9388~~*9422*	0.~~9346~~*9380*	0.0007	0.~~2530~~*2501*
9x9C01	0.9395	0.9352	0.0008	0.2698
9x9D01	0.~~9392~~*9394*	0.~~9349~~*9350*	0.000~~8~~*9*	0.~~2628~~*2625*
9x9E01	0.~~9406~~*9402*	0.~~9362~~*9359*	0.0008	0.~~2283~~*2249*
9x9E02	*0.9424*	*0.9380*	*0.0008*	*0.2088*
9x9F01	0.~~9377~~*9369*	0.~~9335~~*9326*	0.000~~7~~*8*	0.~~3028~~*2954*
9x9F02	*0.9424*	*0.9380*	*0.0008*	*0.2088*
10x10A01	0.9377	0.9335	0.0008	0.3170
10x10A02	0.9426	0.9386	0.0007	0.2159
10x10A03	0.9396	0.9356	0.0007	0.3169
B10x10A01	0.9457	0.9414	0.0008	0.2212
10x10B01	0.9384	0.9341	0.0008	0.2881
10x10B02	0.9416	0.9373	0.0008	0.2333

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-68				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
10x10B03	0.9375	0.9334	0.0007	0.2856
B10x10B01	0.9436	0.9395	0.0007	0.2366
10x10C01	0.~~8990~~*9021*	0.~~8949~~*8980*	0.0007	0.~~2656~~*2610*
10x10D01	0.9376	0.9333	0.0008	0.3355
10x10E01	0.9185	0.9144	0.0007	0.2936

Note: Maximum k_{eff} = Calculated k_{eff} + $K_c \times \sigma_c$ + Bias + σ_B
where:
K_c = 2.0
σ_c = Std. Dev. (1-sigma)
Bias = 0.0021
σ_B = 0.0006
See Subsection 6.4.3 for further explanation.

CHAPTER 7: CONFINEMENT

7.0 INTRODUCTION

Confinement of all radioactive materials in the HI-STAR 100 System is provided by the MPC. The design of the HI-STAR 100 confinement boundary assures that there are no credible design basis events that would result in a radiological release to the environment. The HI-STAR 100 Overpack is designed to provide physical protection for an MPC during normal, off-normal, and postulated accident conditions to assure that the integrity of the MPC confinement boundary is maintained. The inert atmosphere in the MPC and the passive heat removal capabilities of the HI-STAR 100 also assure that the SNF assemblies remain protected from degradation, which might otherwise lead to gross cladding ruptures during dry storage.

The HI-STAR 100 System is classified as important to safety. Therefore, the individual structures, systems, and components (SSC's) that make up the HI-STAR 100 System shall be designed, fabricated, assembled, inspected, tested, accepted, and maintained in accordance with a quality program commensurate with the particular SSC's graded quality category. Tables 2.2.6 and 8.1.4 provide the quality category for each major item or component of the HI-STAR 100 System and required ancillary equipment and systems.

A detailed description of the confinement structures, systems, and components important to safety is provided in Chapter 2. The structural adequacy of the MPC is demonstrated by the analyses documented in Chapter 3. The physical protection of the MPC provided by the overpack for normal conditions of storage is demonstrated by the structural analyses documented in Chapter 3 and for off-normal and postulated accident conditions in Chapter 11. The heat removal capabilities of the HI-STAR 100 System are demonstrated by the thermal analyses documented in Chapter 4.

This chapter describes the HI-STAR 100 confinement boundary design and describes how the design satisfies the confinement requirements of 10CFR72 [7.0.1]. *It also provides an evaluation of postulated radiological releases to the environment under normal, off-normal, and accident conditions of storage to ensure compliance with the limits established by the regulations.*

This chapter is in compliance with NUREG-1536 except as noted in Table 1.0.3.

7.1 CONFINEMENT BOUNDARY

The primary confinement boundary against the release of radionuclides is the cladding of the individual fuel rods. The spent fuel rods are protected from degradation by maintaining an inert gas atmosphere (helium) inside the MPC and keeping the fuel cladding temperatures below the design basis values specified in Chapter 2.

The HI-STAR 100 confinement boundary consists of any one of the two fully-welded MPC designs described in Chapter 1. Each MPC is identical from a confinement perspective. ~~Therefore,~~ *so* the following discussion applies to *all* ~~both~~ MPCs. The confinement boundary of the MPC consists of:

- MPC shell
- Bottom baseplate
- MPC lid (including the vent and drain port cover plates)
- MPC closure ring
- Associated welds

The above items form a totally seal-welded vessel for the storage of design basis spent fuel assemblies.

The MPC requires no valves, gaskets or mechanical seals for confinement. Figure 7.1.1 shows an elevation cross-section of the MPC confinement boundary. All components of the confinement boundary are Important to Safety, Category A, as specified in Table 2.2.6. The MPC confinement boundary is designed and fabricated in accordance with the ASME Code, Section III, Subsection NB [7.1.1] to the maximum extent practicable. Chapter 2 provides design criteria for the confinement design. Section 2.2.4 and Table 2.2.7 provide applicable Code requirements. Exceptions to specific Code requirements with complete justifications are presented in Table 2.2.15.

No additional credit is required or taken for confinement of the radionuclides by the overpack. The overpack helium retention boundary (containment boundary), which surrounds the MPC confinement boundary consists of the following (see Figure 7.1.2):

- inner shell, top flange, and bottom plate welded together with full penetration radiographed welds
- a bolted closure plate with two concentric metallic seals to form a closure between the top flange surface and the closure plate, and redundant sealing of the inner metallic seal with a threaded test port plug containing a metallic seal which is

compressed between the underside of the threaded plug head and the recessed seating surface on the closure plate

- vent and drain ports with threaded plugs containing a metallic seal which is compressed between the underside of the threaded plug head and the overpack body

- redundant sealing of the vent and drain ports by a bolted cover plate with a metallic seal which is compressed between the cover plate and the the overpack body

Table 7.1.1 provides design operating limits for the seals described above.

The HI-STAR helium retention boundary described above is identical to the HI-STAR 100 containment boundary defined and analyzed in the HI-STAR Safety Analysis Report submitted for transport certification [7.1.2].

7.1.1 Confinement Vessel

The HI-STAR 100 confinement vessel is the MPC. The MPC is designed to provide confinement of all radionuclides under normal, off-normal and accident conditions. The MPC is designed, fabricated, and tested in accordance with the applicable requirements of ASME, Section III, Subsection NB [7.1.1] to the maximum extent practicable. The MPC shell and baseplate assembly and basket structure are delivered to the loading facility as one complete component. The MPC lid, vent and drain port cover plates, and closure ring are supplied separately and are installed following fuel loading. The MPC lid (with the vent and drain port cover plates welded to the MPC lid) and closure ring are welded to the upper part of the MPC shell at the loading site to provide redundant sealing of the confinement boundary. The vent and drain port cover plates are welded to the MPC lid after the lid is welded to the MPC. The welds forming the confinement boundary are described in detail in Section 7.1.3. Figure 7.1.3 provides MPC closure weld details.

The MPC lid is made intentionally thick to minimize radiation exposure to workers during MPC closure operations, and is welded to the MPC shell. The vent and drain port cover plates are welded to the MPC lid following completion of MPC draining, vacuum drying, and helium backfill activities to close the MPC vent and drain openings. The MPC lid has a stepped recess around the perimeter for ~~installation of~~ *accommodating* the closure ring. The MPC closure ring is welded to the MPC lid on the inner diameter of the ring and to the MPC shell on the outer diameter. The combination of the welded MPC lid and closure ring form the redundant closure of the MPC.

Table 7.1.1 provides a summary of the design ratings for normal, off-normal and accident conditions for the MPC confinement vessel. Tables 1.2.2, 2.2.1, and 2.2.3 provide additional design basis information.

~~The design basis leakage rate for the MPC confinement boundary is provided in Table 7.1.1.~~ The MPC shell and baseplate are helium leakage tested during fabrication in accordance with the requirements defined in Chapter 9. Following fuel loading and MPC lid welding, the MPC lid-to-shell weld is examined by liquid penetrant method (root and final), volumetrically examined (if volumetric examination is not performed, multi-layer liquid penetrant examination must be performed), helium leakage tested, and hydrostatically tested. If the MPC lid weld is acceptable, the vent and drain port cover plates are welded in place, examined by the liquid penetrant method (root and final), and a leakage rate test is performed. Finally, the MPC closure ring is installed, welded and inspected by the liquid penetrant method (root and final), volumetrically examined (if volumentric examination is not performed, multi-layer liquid penetrant examination must be performed), helium leakage tested, and hydrostatically tested. If the MPC lid weld is acceptable, the vent and drain port cover plates are welded in place, examined by liquid penetrant method (root and final), and a leakage rate test is performed. Finally, the MPC closure ring is installed, welded and inspected by the liquid penetrant method (root, *if multiple pass*, and final). Chapters 8, 9, and the Certificate of Compliance provide procedural guidance, acceptance criteria, and Technical Specifications, respectively, for performance and acceptance of liquid penetrant examinations, volumetric examination, hydrostatic testing, and leakage rate testing of the field welds on the MPC.

After final vacuum drying, the MPC cavity is backfilled with helium. The helium backfill provides an inert atmosphere within the MPC cavity that precludes oxidation and hydride attack of the SNF cladding. Use of a helium atmosphere within the MPC contributes to the long-term integrity of the fuel cladding, reducing the potential for release of fission gas or other radioactive products to the MPC cavity. Helium also aids in heat transfer within the MPC and reduces the maximum fuel cladding temperatures. MPC inerting, in conjunction with the thermal design features of the MPC and storage cask, assures that the fuel assemblies are sufficiently protected against degradation, which might otherwise lead to gross cladding ruptures during long-term storage.

7.1.2 Confinement Penetrations

The MPC penetrations are designed to prevent the release of radionuclides under all normal, off-normal and accident conditions of storage. Two penetrations (the MPC vent and drain ports) are provided in the MPC lid for MPC draining, vacuum drying and backfilling during MPC loading operations, and for fuel cool-down and MPC flooding during unloading operations. No other confinement penetrations exist in the MPC. The MPC vent and drain ports are equipped with metal-to-metal seals to minimize leakage and withstand the long-term effects of temperature and radiation. The vent and drain connectors allow the vent and drain ports to be operated like valves and prevent the need to hot tap into the penetrations during unloading operations. The MPC vent and drain ports are sealed by cover plates which are seal welded to the MPC lid. No credit is taken for the seal provided by the vent and drain ports. The MPC closure ring covers the vent and drain port cover plate welds and the MPC lid-to-shell weld providing the redundant closure of the MPC vessel. The redundant closures of the MPC satisfy the requirements of 10CFR72.236(e) [7.0.1].

The MPC has no bolted closures or mechanical seals. The confinement boundary contains no external penetrations for pressure monitoring or overpressure protection.

7.1.3 Seals and Welds

The MPC is designed, fabricated, and tested in accordance with the applicable requirements of ASME, Section III, Subsection NB [7.1.1] to the maximum extent practicable. The MPC has no bolted closures or mechanical seals. Section 7.1.1 describes the design of the confinement vessel welds. The welds forming the confinement boundary are summarized in Table 7.1.2.

Confinement boundary welds are performed, inspected, and tested in accordance with the applicable requirements of ASME Section III, Subsection NB [7.1.1] to the maximum extent practicable. The use of multi-pass welds, root pass *for multiple pass welds* and final surface liquid penetrant inspection, and volumetric examination (if volumetric examination is not performed, multi-layer liquid penetrant examination must be performed) essentially eliminates the chance of a pinhole leak through the weld. Welds are also helium leak tested, providing added assurance of weld integrity. Additionally, a hydrostatic test is performed on the MPC lid-to-shell weld to confirm the weld's structural integrity. Fit-up of all field-welded components performed at the licensee's facility will result in a uniform root opening of the minimum size and will eliminate the need for backing that could restrain the weld joint and induce residual weld stresses. The ductile stainless steel material used for the MPC confinement boundary is not susceptible to delamination or hydrogen-induced weld degradation. The closure weld redundancy assures that failure of any single MPC confinement boundary closure weld does not result in release of radioactive material to the environment. Table 7.1.3 provides a summary of the closure weld examinations and tests.

7.1.4 Closure

The MPC is a totally seal-welded pressure vessel. The MPC has no bolted closure or mechanical seals. The MPC's redundant closures are designed to maintain confinement integrity during normal conditions of storage, and off-normal and postulated accident conditions. There are no unique or special closure devices. Primary closure welds are examined and leakage tested to ensure their integrity. A description of the MPC weld examinations is provided in ~~Table 9.1.3 of this TSAR.~~ Chapter 9.

Since the MPC uses an entirely welded redundant closure system, no direct monitoring of the closure is required. Section 11.2.1.4 describes requirements for verifying the continued confinement capabilities of the MPC in the event of off-normal or accident conditions. As discussed in Section 2.3.3.2, no instrumentation is required or provided for HI-STAR 100 storage operations, other than normal security service instruments and TLDs.

7.1.5 Damaged Fuel Container

The MPC is designed to allow for the storage of specified damaged fuel assemblies and fuel debris in a specially designed damaged fuel container (DFC). *Fuel assemblies classified as damaged fuel or fuel debris (assembly array/class 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A) as specified in the Technical Specifications have been evaluated.*

To aid in loading and unloading, damaged fuel assemblies and fuel debris will be loaded into stainless steel DFCs ~~provided with 250 micron fine mesh screens~~ prior to placement in the HI-STAR 100 System. ~~The storage of fuel debris in DFC's is limited by the Technical Specifications to four (4) DFCs containing Dresden 1 and Humboldt Bay BWR SNF types in a MPC-68F.~~ Up to 68 damaged fuel assemblies in DFC's may be stored in an MPC-68 or MPC-68F. The DFC is shown in Figure 2.1.1 and detailed in the Design Drawings in Section 1.5. The DFC is designed to provide SNF loose component retention and handling capabilities. The DFC consists of a smooth-walled, welded stainless steel container with a removable lid. The canister lid provides the means of DFC closure and handling. The DFC is provided with stainless steel wire mesh screens in the top and bottom for draining, vacuum drying and helium backfill operations. The screens are specified as a 250-by-250-mesh with an effective opening of 0.0024 inches. There are no other openings in the DFC. The Technical Specifications specify the fuel assembly characteristics for damaged fuel acceptable for loading in the MPC-68 or MPC-68F and for fuel debris acceptable for loading in the MPC-68F.

Since the DFC has screens on the top and bottom, the DFC provides no pressure retention function. The confinement function of the DFC is limited to minimizing the release of loose particulates within the sealed MPC. The storage design basis leakage rates are not altered by the presence of the DFCs. The radioactive material available for release from the ~~Dresden -1 and Humboldt Bay fuel assemblies~~ *specified fuel assemblies* are bounded by the design basis fuel assemblies analyzed herein.

Table 7.1.1

SUMMARY OF CONFINEMENT AND HELIUM RETENTION BOUNDARY DESIGN SPECIFICATIONS

Design Attribute	Design Rating
Internal Design Pressure (normal)	100 psig
Design Temperature (normal)	550°F (MPC lid)
Internal Design Pressure (off-normal)	100 psig
Design Temperature (off-normal)	775°F (MPC lid)
Internal Design Pressure (accident)	125 psig
Design Temperature (accident)	950°F (MPC basket)
Design Basis Leakage Rate	$5x10^{-6}$ atm cm^3/sec (helium)
Closure Plate Mechanical Seals†,††	
Design Temperature	1200°F
Pressure Limits	~~10000~~*1000* psig
Design Leakage Rate	$1x10^{-6}$ cm^3/sec, Helium
Overpack Vent and Drain Port Cover Plate Mechanicla Seals†,††	
Design Temperature	1300°F
Pressure Limits	~~5,000~~*1000* psig
Design Leakage Rate	$1x10^{-6}$ cm^3/sec, Helium
Overpack Vent and Drain Port Plug Mechanical Seals†,††	
Design Temperature	1300°F
Pressure Limits	~~5,000~~*1000* psig
Design Leakage Rate	$1x10^{-6}$ cm^3/sec, Helium

† For overpack helium retention only. No confinement credit is taken for the overpack mechanical seals.

†† Per Manufacturer's recommended operating limits

Table 7.1.2

MPC CONFINEMENT BOUNDARY WELDS

Confinement Boundary Welds		
MPC Weld Location	**Weld Type**†	**ASME Code Category (Section III, Subsection NB)**
Shell longitudinal seam	Full Penetration Groove (shop weld)	A
Shell circumferential seam	Full Penetration Groove (shop weld)	B
Baseplate to shell	Full Penetration Groove (shop weld)	C
MPC lid to shell	Partial Penetration Groove (field weld)	C
MPC closure ring to shell	Fillet (field weld)	††
Vent and drain port cover plates to MPC lid	Partial Penetration Groove (field weld)	D
MPC closure ring to closure ring radial	~~Full~~ *Partial* Penetration Groove (field weld)	††
MPC closure ring to MPC lid	Partial Penetration Groove (field weld)	C

† The tests and inspections for the confinement boundary welds are listed in Section 9.1.1.

†† This joint is governed by NB-5271 (liquid penetrant examination).

Table 7.1.3

CLOSURE WELD EXAMINATIONS AND TESTS

Closure Weld Description	Inspections/Tests	ASME Acceptance Criteria
MPC Lid-to-Shell	VT on Tack Welds PT Root Pass PT Final Pass VT Final Pass Volumetric Examination of Weld (UT) or multi-layer PT Hydrostatic Test Post Hydrostatic Test - PT Helium Leakage Test	NF-5360 NB-5350 NB-5350 NF-5360 NB-5332 NB-6000 NB-5350 Sect. V and ANSI N14.5
Vent/Drain Cover Plate to MPC Lid	VT on Tack Welds PT Root Pass PT Final Pass VT Final Pass Helium Leakage Test	NF-5360 NB-5350 NB-5350 NF-5360 Sect. V and ANSI N14.5
Closure Ring Radial Welds	VT on Tack Welds PT Root Pass *(if multiple pass)* PT Final Pass VT Final Pass	NF-5360 NB-5350 NB-5350 NF-5360
Closure Ring-to-MPC Shell	VT on Tack Welds PT Root Pass *(if multiple pass)* PT Final Pass VT Final Pass	NF-5360 NB-5350 NB-5350 NF-5360
Closure Ring-to-MPC Lid	VT on Tack Welds PT Root Pass PT Final Pass VT Final Pass	NF-5360 NB-5350 NB-5350 NF-5360

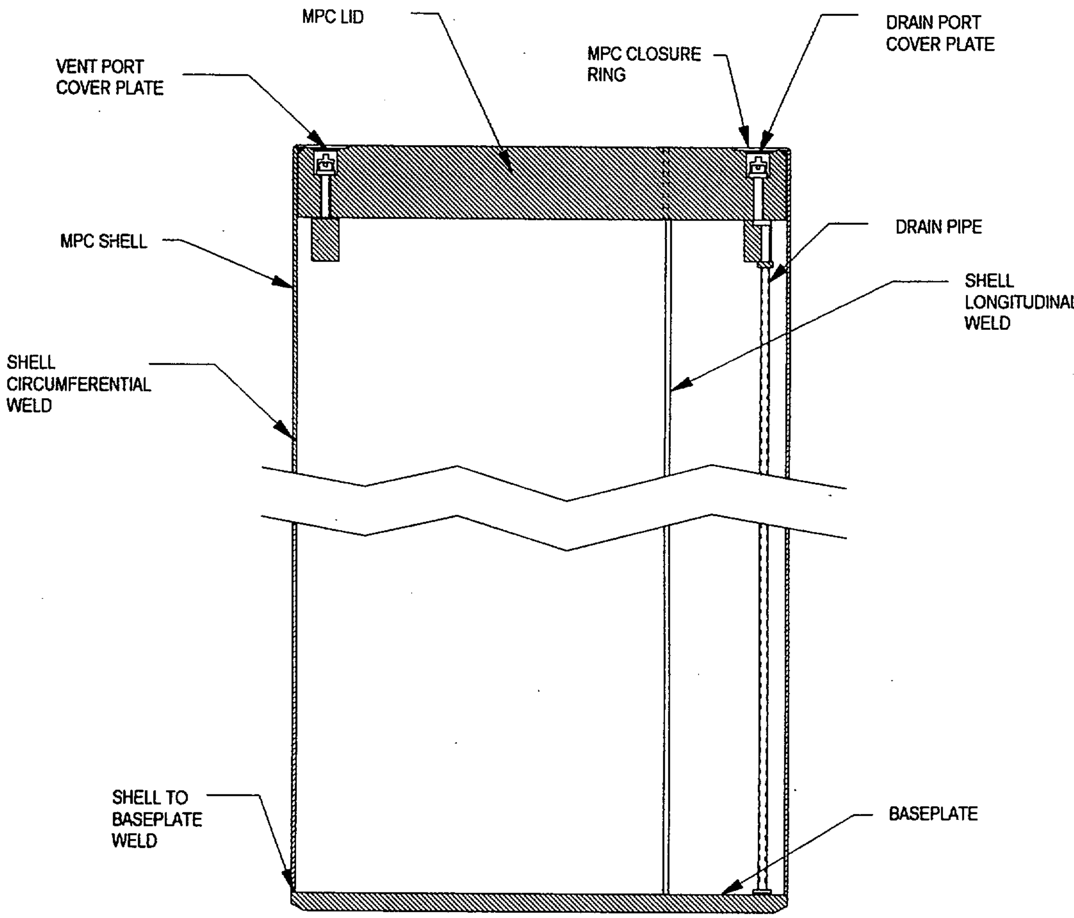

Figure 7.1.1; HI-STAR 100 System Confinement Boundary

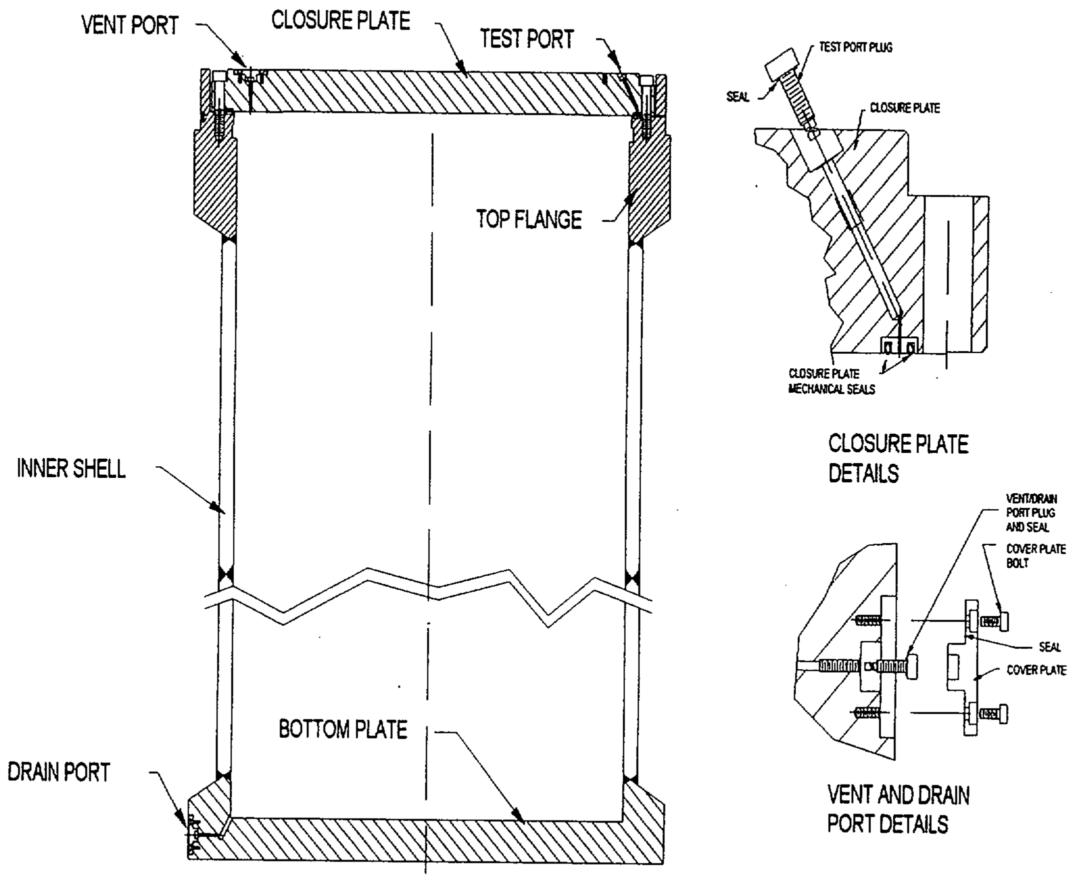

Figure 7.1.2; HI-STAR 100 System Containment Boundary

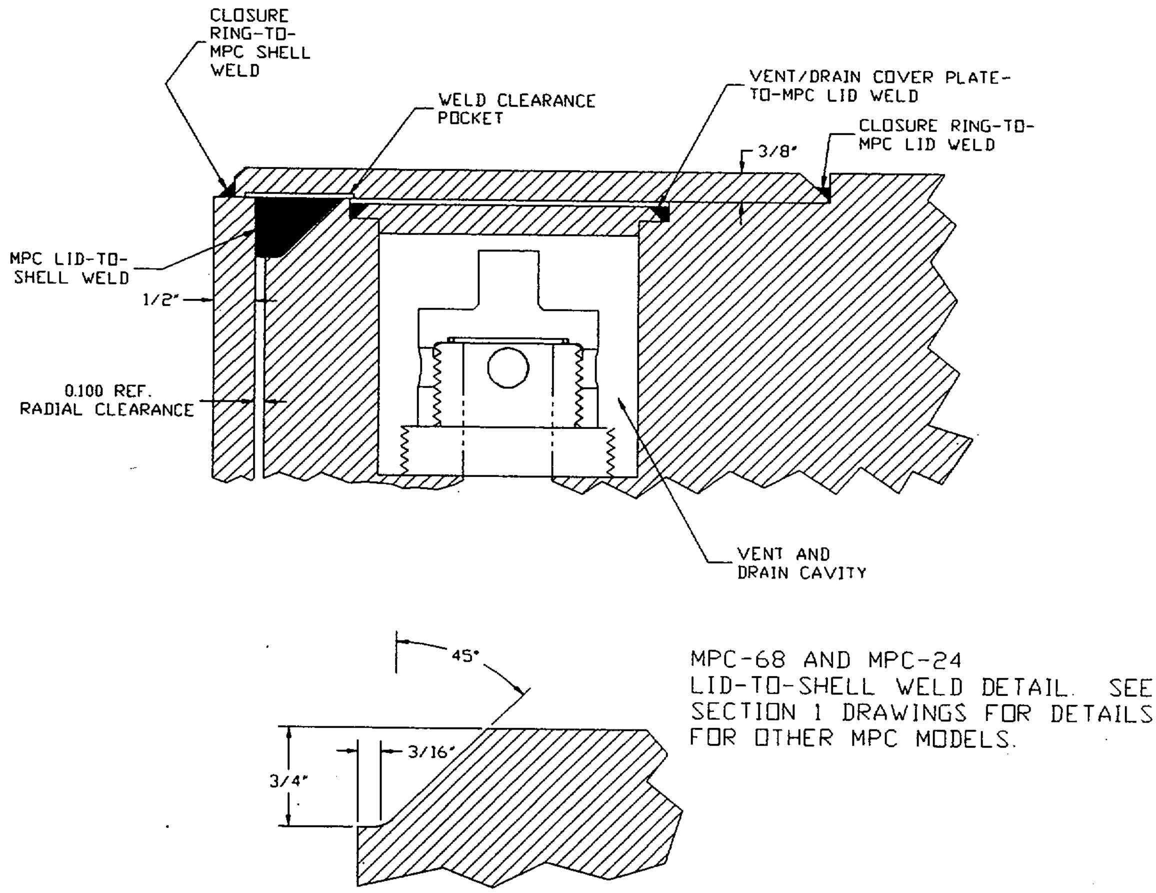

FIGURE 7.1.3; HI-STAR 100 SYSTEM MPC CLOSURE WELD DETAILS

7.2 REQUIREMENTS FOR NORMAL AND OFF-NORMAL CONDITIONS OF STORAGE

The MPC uses multiple confinement barriers provided by the fuel cladding and the MPC enclosure vessel to assure that there is no release of radioactive material to the environment. Chapter 3 shows that all confinement boundary components are maintained within their Code-allowable stress limits during normal storage conditions. Chapter 4 shows that the peak confinement boundary component temperatures and pressures are within the design basis limits for all normal conditions of storage ~~(Tables 4.4.15 and 4.4.22)~~. Since the MPC confinement vessel remains intact, and the design bases temperatures and pressure are not exceeded, the design basis leakage rate is not exceeded during normal conditions of storage.

7.2.1 Release of Radioactive Material

The MPC is closed by the MPC lid, the vent and drain port cover plates, and the MPC closure ring. Weld examinations, including multiple surface examinations, volumetric examination, hydrostatic testing, and leakage rate testing on the MPC lid weld, and multiple surface examinations and leakage rate testing of the vent and drain port cover plate welds, assure the integrity of the MPC closure. The MPC is a seal-welded pressure vessel designed to meet the stress criteria of the ASME Code, Section III, Subsection NB [7.1.1]. The all-welded construction of the MPC with redundant closure provided by the fully welded MPC closure ring, and extensive inspections and testing ensures that no release of fission gas or crud for normal storage and transfer conditions will occur. The above discussion notwithstanding, an analysis is performed in Section 7.2.7 to calculate the annual dose at 100 meters based on an assumed leakage rate of $5x10^{-6}$ ~~std~~*atm*-cm^3/sec plus the minimum test sensitivity of $2.5x10^{-6}$ ~~std~~*atm*-cm^3/sec under normal and off-normal conditions of storage.

7.2.2 Pressurization of the Confinement Vessel

The loaded and sealed MPC is drained, vacuum dried, and backfilled with helium gas. This process provides a chemically non-reactive environment for storage of spent fuel assemblies. First, air in the MPC is displaced with water and then the water is displaced by helium or nitrogen gas during MPC blowdown. The MPC is then vacuum dried, and backfilled with a predetermined mass of helium as specified in the Technical Specifications. Chapter 8 describes the steps of these processes and the Technical Specifications provide the acceptance criteria. This drying and backfilling process ensures that the resulting inventory of oxidizing gases in the MPC remains below 0.25% by volume, and that the MPC pressure is maintained within the design limitations. In addition, the MPC basket fluid contact areas are stainless steel alloy material or aluminum of extremely high corrosion and erosion resistance. The aluminum oxide layer on the aluminum components (e.g., heat conduction elements and Boral neutron absorption plates) ensures that there is no reaction during the short duration of exposure to the fuel pool water. Carbon steels are not employed in the construction of the MPCs. Therefore, no protective coatings which could interact with borated spent fuel pool water are used.

The only means of pressure increase in the MPC is from the temperature rise to normal heat-up to normal operating temperatures and the release of backfill and fission gas contents from fuel rods into the MPC cavity. Under the most adverse conditions of normal ambient temperature, full insolation, and design basis decay heat, the calculated pressure increase assuming 1% fuel rod failure is well below the system design pressure as shown in Chapter 4. The heavy HI-STAR 100 overpack provides protection from ambient day-night temperature swings thereby providing a relatively stable thermal environment for fuel storage. For off-normal conditions of storage, failure of up to 10% of the fuel rods has been analyzed and would result in an MPC internal pressure below the value specified as the normal design pressure.

7.2.3 Confinement Integrity During Dry Storage

There is no credible mechanism or event that results in a release of radioactive material from the MPC under normal conditions. Since the MPC remains structurally intact and provides redundant welded closures as discussed above, the postulated leakage of radioactive material from the MPC will be limited to a leakage rate equivalent to the acceptance test criteria specified for the MPC helium leak tests. Leakage from the MPC during normal conditions of storage could result in the release of gaseous fission products, fines, volatiles and airborne crud particulates as discussed in Section 7.3.1. The conservative assumption is made that 1% of the fuel inventory is available for release ~~in accordance with NUREG-1536 [7.0.7] for normal conditions of storage~~ *under normal conditions of storage and 10% of the fuel inventory is available for release under off-normal conditions of storage.* ~~The maximum internal pressure of 58.7 psig with 1% fuel rod failure (Table 4.4.15), is assumed as an initial condition for this evaluation. The resulting Total Effective Dose Equivalent (TEDE) and thyroid doses at a distance of 100 meters are evaluated for each MPC type.~~ *The maximum cavity internal operating pressure with 10% fuel rod failure reported in Chapter 4 is bounded by the use of an internal cavity pressure of 58.7 psia (4.99 ATM), which is assumed as an initial condition for this evaluation.*

The following doses to an individual at the site boundary (100 meters) as a result of an assumed effluent release under normal and off-normal conditions of storage were determined; the inhaled committed dose equivalent for critical organs and tissues (gonad, breast, lung, red marrow, bone surface, thyroid, skin, lens of the eye), the effective dose from external submersion in the plume, and the resulting Total Effective Dose Equivalent (TEDE). These doses were determined for each type of MPC. The ISFSI controlled area boundary must be at least 100 meters from the nearest loaded HI-STAR 100 System in accordance with 10CFR72.106(b) [7.0.1]. *The doses are compared to the regulatory limits specified in 10CFR72.104 [7.0.1].*

Confinement boundary welds performed at the fabricator's facility are inspected by volumetric and liquid penetrant examination methods as detailed in Section 9.1. Field welds are performed on the MPC lid, the MPC vent and drain port covers, and MPC closure ring. The weld of the MPC lid-to-shell is liquid penetrant examined on the root and final pass, volumetrically (or multilayer liquid penetrant) examined, hydrostatically tested, and leak rate tested. The vent and drain port cover plates are liquid penetrant examined on the root and final pass and leak rate tested. The MPC closure ring welds are inspected by the liquid penetrant examination method on the root *pass, if multiple pass,* and final pass. In Chapter 11, the MPC lid-to-shell weld is postulated to fail to confirm the safety of the HI-STAR 100 confinement boundary. The failure of the MPC lid weld is equivalent to the MPC drain or vent port cover weld failing. The MPC lid weld failure affects the MPC confinement boundary; however, no leakage will occur due to redundant sealing provided by the MPC closure ring.

7.2.4 Control of Radioactive Material During Fuel Loading Operations

The procedures for closure of the MPC, described in Section 8.1, are intended to assure that there is no unintended release of gas, liquid, or solid materials from the MPC during dry storage. During MPC closure operations, the lines used for venting or draining are routed to the plant's spent fuel pool or radioactive waste processing systems. MPC closure operations are performed inside the plant's fuel building in a controlled and monitored environment.

Radioactive effluent handling during fuel loading and MPC draining, vacuum drying, helium backfilling, and sealing operations is in accordance with the plant's 10CFR50 license and radioactive waste management system.

7.2.5 External Contamination Control

The external surface of the MPC is protected from contamination by preventing it from coming in contact with the spent fuel pool water. Prior to submergence in the spent fuel pool, an inflatable seal is installed at the top of the annulus formed between the MPC shell and the HI-TRAC transfer cask cavity. This annulus is filled with clean demineralized water and the seal is inflated. The inflated seal, backed by the demineralized water maintained at a slight positive pressure, is sufficient to preclude the entry of contaminated water into the annulus. These steps assure that the MPC surface is free of contamination that could become airborne during storage.

Additionally, following fuel loading operations and removal from the spent fuel pool, the upper end of the MPC shell is surveyed for loose surface contamination in accordance with the Technical Specifications.

7.2.6 Confinement Vessel Releasable Source Term

As discussed in Section 7.3.1, the source term used to evaluate the annual dose at the minimum controlled area boundary of 100 meters due to leakage from the MPC confinement boundary consists of gaseous fission products, fines, volatiles and airborne crud particulates. For this evaluation, it is conservatively assumed that 1% of the fuel inventory is available for release *under normal conditions of storage and 10% of the fuel inventory is available for release under off-normal conditions of storage.* A summary of the isotopes available for release is provided in Table 7.3.1.

7.2.7 Release of Contents Under Normal *and Off-Normal* Storage Conditions

7.2.7.1 Seal Leakage Rate

The methodology presented in Section 7.3.3.1 was used to determine the leakage rate at the upstream conditions. Using the capillary diameter determined in Section 7.3.3.1, and the parameters for normal *and off-normal* conditions provided in Table 7.3.6, Equation 7-3 was solved for the leakage rate at the upstream conditions. The resultant normal *and off-normal* condition leakage rate, 8.8×10^{-6} cm^3/s (at 499.2 K, 4.99 ATM) was calculated.

7.2.7.2 Fraction of Volume Released

The minimum free volume of the confinement vessel is presented in Table 4.4.14 (6.53×10^6 cm^3 for the MPC-24 and 5.99×10^6 cm^3 for MPC-68 and MPC-68F). Using these volumes and the upstream normal and *off-normal condition* leakage rate of 8.8×10^{-6} cm^3/s, the fraction of the volume released per second is calculated.

7.2.7.3 Release Fraction

The release fraction is that portion of the total radionuclide inventory that is released from the confinement boundary to the atmosphere (i.e., outside the MPC). The release fractions provided in NUREG/CR-6487 [7.3.2] are used. A summary of the release fractions is provided in Table 7.3.1.

7.2.7.4 Radionuclide Release Rate

The radionuclide release rate is the product of the quantity of isotopes available for release, the number of assemblies, the fraction of volume released, and the release fraction.

7.2.7.5 Atmospheric Dispersion Factor

For the evaluation of the dose at the controlled area boundary, the instantaneous χ/Q calculated for accident conditions (8.0×10^{-3} sec/m^3) was reduced to 1.6×10^{-4} sec/m^3 based on the long term nature of the release (1 year); the height of the release being essentially a ground level release ($h_e = 0$); all 16 compass directions (22.5 degree sectors) will be similarly affected due to the long term nature of the continuous release (over one year); the increase in average wind speeds (>1 m/s); and the additional effects of a reduction in atmospheric stability. Therefore, the χ/Q reduction factor of 50 used to correct the short term accident release χ/Q is conservative.

7.2.7.6 Dose Conversion Factors

Dose Conversion Factors (DCF) from EPA Federal Guidance Report No. 11, Table 2.1 [7.3.5] and EPA Federal Guidance Report No. 12, Table III.1 [7.3.6] were used for the analysis. The DCFs are provided on the spread sheets included as Appendix 7.A.

7.2.7.7 Occupancy Time

An occupancy time of 8,760 hours is used for the analysis [7.0.2]. This conservatively assumes that the individual is exposed 24 hours per day for 365 days at the minimum controlled area boundary of 100 meters.

7.2.7.8 Breathing Rate

A breathing rate of 3.3 x 10^{-4} m^3/sec for a worker is used for the analysis. This assumption is in accordance with the guidance provided in NUREG-1536 [7.0.2] for a worker.

7.2.8 Postulated Doses Under Normal and Off-Normal Conditions of Storage

~~The dose to the individual at the site boundary is determined for the whole body and the thyroid. These doses are determined for each type of MPC and are summarized in Table 7.3.2. Appendix 7.A presents the Excel spread sheets used for the dose calculations~~

The following doses to an individual at the site boundary (100 meters) as a result of an assumed effluent release under normal and off-normal conditions of storage were determined; the inhaled committed dose equivalent for critical organs and tissues (gonad, breast, lung, red marrow, bone surface, thyroid, skin, lens of the eye), the effective dose from external submersion in the plume, and the resulting Total Effective Dose Equivalent (TEDE). These doses are determined for each type of MPC and for each condition of storage (i.e., normal and off-normal). The postulated doses as a result of exposure to soil with ground surface contamination and soil contaminated to a depth of 15 cm were also determined. The resultant doses were negligible compared to the those resulting from submersion in the plume and are therefore not reported.

The doses were determined using spreadsheet software. The resultant doses are summarized for each MPC type in Tables 7.3.2, 7.3.3, and 7.3.4. Example spread sheets used for the dose estimates are presented in Appendix 7.A.

7.2.8.1 Whole Body Dose (Total Effective Dose Equivalent)

The whole body dose is the sum of the *inhaled* committed effective dose equivalent (CEDE) and the external exposure from submersion *in the plume. The postulated doses were determined using spreadsheet software. Example spread sheets are provided in Appendix 7.A.*

The CEDE is the product of radionuclide release rate, the atmospheric dispersion factor, the occupancy time, the breathing rate, and the effective dose conversion factor.

External exposure from submersion is the product of the nuclide release rate, the atmospheric dispersion factor, the occupancy time, and the effective dose conversion factor.

~~7.2.8.2 Thyroid Dose~~

~~The organ dose is a product of the quantity of isotope(s) available for release, the number of assemblies, the fraction of the volume released per second, the release fraction, the atmospheric dispersion factor, the breathing rate, the occupancy time and the dose conversion factor. The only organ to receive a significan tdose is the thyroid which recieves a dose as a result of the iodine released. Therefore, the thyroid dose is the only organ considered in this analysis.~~

7.2.8.2 Critical Organ Dose

The dose to the critical organ (or tissue) is the sum of the committed dose equivalent to the critical organ or tissue from inhalation and the dose equivalent to the organ or tissue from submersion in the plume. The postulated doses as a result of exposure to soil with ground surface contamination and soil contaminated to a depth of 15 cm were also determined. The resultant doses were negligible compared to the those resulting from submersion in the plume and are therefore not reported.

The committed dose equivalent to the organ or tissue from inhalation is the product of radionuclide release rate, the atmospheric dispersion factor, the occupancy time, the breathing rate, and the organ/tissue dose conversion factor. The dose equivalent to the organ or tissue from submersion in the plume is the product of the nuclide release rate, the atmospheric dispersion factor, the occupancy time, and the organ/tissue dose conversion factor.

The doses for tissues and organs other than lens of the eye were determined using spreadsheet software. The dose to the lens of the eye as a result of submersion in the plume was estimated using guidance from Dr. James Turner in his book, Atoms, Radiation, and Radiation Protection [7.3.10]]. Dr. Turner states that alpha particles and low-energy beta particles, such as those from tritium, cannot penetrate to the lens of the eye (at a depth of 3 mm). The discussion continues that many noble gases emit photons and energetic beta particles, which in turn must be considered in the dose estimate. Dr. Turner states that the dose-equivalent rate to tissues near the surface of the body (e.g., lens of the eye) is more than 130 times the dose-equivalent rate in the lung from gases contained in the lung. The estimated dose to the lens of the eye is greatest using the accident condition of storage for the MPC-68. Section 7.3.4.2 presents the detailed discussion of the dose to the lens of the eye.

7.2.9 Site Boundary

The estimated annual dose at the controlled area boundary is highest due to anticipated occurrences (off-normal) using the MPC-68. The estimated TEDE (0.87 mrem/yr) is a small fraction of the annual 25 mrem whole body limit imposed by 10 CFR 72.104(a). The estimated thyroid dose (0.10 *mrem/yr) is a small fraction of the annual 75 mrem thyroid limit imposed by 10 CFR 72.104(a). Additionally, the dose estimates to other critical organs are small fractions of the annual 25 mrem critical organ limit imposed by 10 CFR 72.104(a). The highest of the "other critical organs" is 8.01 mrem to the bone surface.*

~~7.2.9~~ *7.2.10* <u>Assumptions</u>

The following presents a summary of assumptions for the normal and off-normal condition confinement analysis of the HI-STAR 100 System.

- The distance from the cask to the site boundary is 100 meters.
- *Under normal conditions of storage*, 1% of the fuel rods have ruptured. This assumption is in accordance with NUREG-1536 for normal storage conditions.
- *Under off-normal conditions of storage, 10% of the fuel rods have ruptured. This assumption is in accordance with ISG-5 and NUREG-1536 for off-normal storage conditions.*
- Unchoked flow correlations were used as the unchoked flow correlations better approximate the true measured flow rate for the leakage rates associated with transportation packages..
- *The capillary length required for Equation 7-3 was chosen to be the smaller of the MPC lid closure weld sizes (MPC 24 and MPC-68, a=1.9cm and MPC-68F, a=3.2) which is 1.9 cm. The shorter leak path assumptions conservatively over estimates the leak rate in the thicker (MPC-68F) weld.*
- For conservatism, the upstream pressure at test conditions (inside of the MPC) is assumed to be 2 ATM and the down stream pressure (outside of the MPC) is assumed to be 1 ATM.
- The temperature at test conditions is assumed to be equal to a temperature, 212° F based on the maximum temperature achievable by the water in the MPC during performance of the leak test. This is conservative because the leak hole diameter computed from test conditions is larger.
- ~~Normal storage conditions (i.e., MPC cavity at a pressure of 58.7 psia (4.99 ATM) at MPC cavity average temperature of 499.2 K) are postulated for this analysis *as these condition bound the off-normal conditions of storage.*~~
- The majority of the activity associated with crud is due to ^{60}Co. This assumption follows from the discussion provided in NUREG/CR-6487 [7.3.2].

- The normal *and off-normal* condition leakage rate persists for one year without a decrease in the rate or nuclide concentration.

- The individual at the site boundary is exposed for 8,760 hours [7.0.2]. This conservatively assumes that the individual is exposed 24 hours per day for 365 days.

- In accordance with the International Commission on Radiological Protection (ICRP) Publication 30 [7.3.7 *"for exposure in radioisotopes of the noble gases, external irraditaion will be of such overridding importance that it alone need be considered."* Therefore, the contribution to the committed effective dose equivalent from ^{85}Kr is neglected.

- A breathing rate of 3.3×10^{-4} m^3/sec for a worker is used for the analysis [7.0.2]. This assumption is in accordance with the guidance provided in NUREG-1536 for a worker.

- All fuel stored in the MPC is of the design basis type with a bounding burnup and cooling time.

- *Exposure to dose conversion factors for inhalation reported in EPA Federal Guidance Report No. 11, Table 2.1 [7.3.5] were selected by lung clearance class which reports the most conservative values.*

- ~~*The only organ to receive an appreciable dose is the thyroid. Therefore, the thyroid is the only organ considered. This is because the solubility of the noble gases in body tissue is very low, where inhaled radioiodine tends to concentrate in the thyroid.*~~

- ~~*Only ^{129}I contributes significantly to the dose recieved by the thyroid.*~~

- ~~*The capillary length required for Equation 7-3 was conservatively chosen to be the MPC lid closure weld which is 1.9cm.*~~

7.3 CONFINEMENT REQUIREMENTS FOR HYPOTHETICAL ACCIDENT CONDITIONS

The MPC uses redundant confinement closures to assure that there is no release of radioactive materials, including fission gases, volatiles, fuel fines or crud, for postulated storage accident conditions. The analyses presented in Chapters 3 and 11 demonstrate that the MPC remains intact during all normal, off-normal and postulated accident conditions, including the associated increased internal pressure due to decay heat generated by the stored fuel. The MPC is designed, fabricated, and tested in accordance with the applicable requirements of ASME, Section III, Subsection NB [7.1.1] to the maximum extent practicable. In summary, there is no mechanistic failure that results in a breach of the MPC confinement boundary.

The above discussion notwithstanding, this section evaluates the consequences of a non-mechanistic postulated ground level breach of the MPC confinement boundary. This breach could result in the release of gaseous fission products, fines, volatiles and airborne crud particulates. The internal accident pressure of 125 psig, as specified in Table 7.1.1, is assumed as an initial condition for this evaluation. ~~The resulting Total Effective Dose Equivalent (TEDE) and thyroid doses at a distance of 100 meters are evaluated for each MPC type.~~ *The following doses to an individual at the site boundary (100 meters) as a result of an assumed effluent release under accident conditions of storage were determined; the inhaled committed dose equivalent for critical organs and tissues (gonad, breast, lung, red marrow, bone surface, thyroid, skin, lens of the eye), the effective dose from external submersion in the plume, and the resulting Total Effective Dose Equivalent (TEDE). These doses were determined for each type of MPC.* The ISFSI controlled area boundary must be at least 100 meters from the nearest loaded HI-STAR 100 System in accordance with 10CFR72.106(b) [7.0.1]. The doses are compared to the regulatory ~~limit of 5 rem to the whole body or any organ, per~~ *limits specified in* 10CFR72.106(b) [7.0.1].

7.3.1 Confinement Vessel Releasable Source Term

In accordance with NUREG/CR-6487 [7.3.2], the following contributions are considered in determining the releasable source term for packages designed to transport irradiated fuel rods: (1) the radionuclides comprising the fuel rods, (2) the radionuclides on the surface of the fuel rods, and (3) the residual contamination on the inside surfaces of the vessel. NUREG/CR-6487 goes on to state that a radioactive aerosol can be generated inside a vessel when radioactive material from the fuel rods or from the inside surfaces of the container become airborne. The sources for the airborne material are (1) residual activity on the cask interior, (2) fission and activation-product activity associated with corrosion-deposited material (crud) on the fuel assembly surface, and (3) the radionuclides within the individual fuel rods. In accordance with NUREG/CR-6487, contamination due to residual activity on the cask interior surfaces is negligible as compared to crud deposits on the fuel rods themselves and therefore may be neglected. The source term considered for this calculation results from the spallation of crud from the fuel rods and from the fines, gases and volatiles which result from cladding breaches. The methodology of NUREG/CR-6487 is conservatively applied to the storage confinement accident analysis as dry storage conditions are less severe than transport conditions.

The inventory for isotopes other than ^{60}Co is calculated with the SAS2H and ORIGEN-S modules of the SCALE 4.3 system as described in Section 5.2. The inventory for the MPC-24 was conservatively based on the B&W 15x15 fuel assembly with a burnup of 40,000 MWD/MTU, 5 years of cooling time, and an enrichment of 3.4%. The inventory for the MPC-68 was based the GE 7x7 fuel assembly with a burnup of 40,000 MWD/MTU, 5 years of cooling time, and 3.0% enrichment. The Technical Specifications limit the fuel assembly burnup well below 40,000 MWD/MTU for both BWR and PWR fuel at 5 years of cooling time. This ensures that the inventory used in this calculation exceeds that of the fuel authorized for storage in accordance with the Technical Specifications. The inventory for the MPC-68F was based on the GE 6x6 fuel assembly with a burnup of 30,000 MWD/MTU, 18 years of cooling time, and 2.24% enrichment. The Technical Specifications limit the burnup and cooling time of fuel debris in an MPC-68F to a maximum of 30,000 MWD/MTU at a minimum of 18 years cooling time. *Additionally, an MPC-68F was analyzed containing 67 GE 6x6 assemblies and a DFC containing 18 thorium rods. Finally, an Sb-Be source stored in one fuel rod in one assembly with 67 GE 6x6 assemblies was analyzed.* The isotopes which contribute greater than 0.1% to the total curie inventory for the fuel assembly are considered in the evaluation as fines. ~~*Plutonium isotopes are also included in the fines as the dose conversion factors for these isotopes are in general, orders of magnitude greater than other isotopes.*~~ *The analysis also includes actinides as the dose conversion factors for these isotopes are in general, orders of magnitude greater than other isotopes (e.g., isotopes of plutonium, americium, curium, and neptunium were included regardless of their contribution to the inventory).* A summary of the isotopes available for release is provided in Table 7.3.1.

7.3.2 Crud Radionuclides

The majority of the activity associated with crud is due to ^{60}Co [7.3.2]. The inventory for ^{60}Co was determined by using the crud surface activity for PWR rods (140×10^{-6} Ci/cm^2) and for BWR rods (1254×10^{-6} Ci/cm^2) provided in NUREG/CR-6487 [7.3.2] multiplied by the surface area per assembly (3×10^5 cm^2 and 1×10^5 cm^2 for PWR and BWR, respectively, also provided in NUREG/CR-6487). The source terms were then decay corrected (5 years for the MPC-24 and MPC-68; 18 years for the MPC-68F) using the basic radioactive decay equation:

Equation 7-1

$$A(t) = A_0 e^{-\lambda t}$$

where:
A(t) is activity at time t [Ci]

A_0 is the initial activity [Ci]
λ is the $\ln 2/t_{1/2}$ (where $t_{1/2}$ = 5.272 years for ^{60}Co)
t is the time in years (5 years for the MPC-24 and MPC-68; 18 years for the MPC-68F)

Total ^{60}Co crud is 140 μCi/cm^2 for PWR and 1254 μCi/cm^2 for BWR [7.3.2].

PWR
Surface area per Assy = 3.0E+05 cm^2
140 μCi/cm^2 x 3.0E+05 cm^2 = 42.0 Ci

BWR
Surface area per Assy = 1.0E+05 cm^2
1254 μCi/cm^2 x 1.0E+05 cm^2 = 125.4 Ci

$^{60}Co(t) = {}^{60}Co_0\ e^{-(\lambda t)}$, where $\lambda = \ln 2/t_{1/2}$, t = 5 years (for the MPC-24 and MPC-68), t = 18 years (MPC-68F), $t_{1/2}$ = 5.272 years for ^{60}Co [7.3.3]

MPC-24

$^{60}Co(5) = 42.0\ Ci\ e^{-(\ln 2/5.272)(5)}$
$^{60}Co(5) = 21.77\ Ci$

MPC-68

$^{60}Co(5) = 125.4\ Ci\ e^{-(\ln 2/5.272)(5)}$
$^{60}Co(5) = 64.98\ Ci$

MPC-68F

$^{60}Co(18) = 125.4\ Ci\ e^{-(\ln 2/5.272)(18)}$
$^{60}Co(18) = 11.76\ Ci$

A summary of the ^{60}Co inventory available for release is provided in Table 7.3.1.

7.3.3 Release of Contents Under Non-Mechanistic Accident Conditions of Storage

7.3.3.1 Seal Leakage Rate

The helium leak rate testing performed on the MPC confinement boundary verifies the helium leak rate to be less than or equal to 5×10^{-6} atm-cm^3/s [1] as required by the Technical Specifications with a minimum sensitivity of 2.5×10^{-6} atm-cm^3/s. As demonstrated by analysis, the MPC confinement boundary is not compromised as a result of normal, off-normal, and accident conditions. Based on the robust nature of the MPC confinement boundary, the NDE inspection of the welds, and the measurement of the helium leakage rate, there is essentially no leakage. However, it is conservatively assumed that the maximum possible leakage rate from the confinement vessel is the maximum leakage

[1] *According to ANSI N14.5 (1997), the mass-like leakage rate specified herein is often used in leakage testing. This is defined as the rate of change of the pressure-volume product of the leaking fluid at test conditions.*

rate acceptance criteria plus the sensitivity. This yields an assumed helium leakage rate of 7.5x10^{-6} atm-cm^3/s.

~~The Ideal Gas Law is used to convert this leakage rate to a cooresponding leakage rate at test conditions The test leakage rate at upstream conditions (2 atm, 212 F (373K)) is used and equal to:~~

~~Equation 7-2~~

$$L_u(2\ ATM,\ 373\ K) = 7.5x10^{-6} cm^3/s * \frac{1ATM}{2ATM} * \frac{373K}{298.0K}$$

~~=4.69x10^{-6} cm^3/s~~

Equation B-1 of ANSI N14.5 (1997) [7.3.8] is used to express this mass-like helium flow rate (Q_u) measured in atm-cm^3/s as a function of the upstream volumetric leakage rate (L_u) as follows:

Equation 7-2

$$Q_u = L_u * P_u \quad \text{atm-cm}^3\text{/sec (Equation B-1 from ANSI N14.5(1997))}$$

$$L_u = Q_u/P_u \quad \text{cm}^3\text{/sec}$$

where:

L_u *is the upstream volumetric leakage rate [cm^3/s],*
Q_u *is the mass-like helium leak rate [atm cm^3/s], and*
P_u *is the upstream pressure [ATM]*

The corresponding leakage rate at accident conditions is determined using the following methodology. For conservatism, unchoked flow correlations were used as the unchoked flow correlations better approximate the true measured flowrate for the leakage rates.

For conservatism, the upstream pressure at test conditions (inside of the MPC) is assumed to be 2 ATM (minimum) and the down stream pressure (outside of the MPC) is assumed to be 1 ATM (at 298 K), therefore, the average pressure is 1.5 ATM. The evaluation was performed using the helium gas temperature at test conditions of both 70°F and 212°F. These temperatures are representative of the possible temperature of the helium gas in the confinement vessel during the helium leak test. The 212°F helium temperature is the upper bound because the water inside the MPC is shown not to boil in Chapter 4 as long as the "time-to-boil" time limit is not exceeded. From the two calculations using the two temperatures, it was determined that the higher temperature (212°F) results in a greater capillary diameter.

Using the equations for molecular and continuum flow, Equation B-5 provided in ANSI N14.5-1997 [7.3.8], the corresponding capillary diameter, D, was calculated. The capillary length required for Equation 7-3 was conservatively chosen to be the minimum MPC lid closure weld which is 1.9 cm. Table ~~7.3.4~~ *7.3.6* provides a summary of the parameters used in the calculation.

Equation 7-3

$$L_u = \left[\frac{2.49x10^6\, D^4}{a\, u} + \frac{3.81x10^3\, D^3 \sqrt{\frac{T}{M}}}{a\, P_a}\right][P_u - P_d]\left[\frac{P_a}{P_u}\right]$$

where:

L_u	is the allowable leakage rate at the upstream pressure [cm^3/s],
a	is the capillary length [cm],
T	is the temperature [°K],
M	is the gas molecular weight [g/mole] from ANSI N14.5, Table B1 [7.3.8],
u	is the fluid viscosity for helium [cP] from Rosenhow and Hartnett [7.3.9]
P_u	is the upstream pressure [ATM],
P_d	is the downstream pressure [ATM], and
P_a	is the average pressure; $P_a = (P_u + P_d)/2$ [ATM].
D	is the capillary diameter [cm].

The capillary diameter (D) computed from the above equation is equal to ~~5.268x10^{-4} cm~~ *4.96x10^{-4} cm.*

Using the capillary diameter determined above, and the parameters for accident conditions provided in Table 7.3.6, Equation 7-3 was solved for the leakage rate at the upstream conditions. The resultant hypothetical accident leakage rate, ~~1.58x10^{-5}~~ *1.25x10^{-5}* cm^3/s (at 843 K, 9.5 ATM) was calculated.

7.3.3.2 Fraction of Volume Released

The minimum free volume of the confinement vessel is presented in Table 4.4.14 (6.53 x 10^6 cm^3 for the MPC-24 and 5.99 x 10^6 cm^3 for MPC-68 and MPC-68F). Using these volumes and the upstream hypothetical accident leakage rate of ~~1.58x10^-5~~ *1.25x10^-5* cm^3/s, the fraction of the volume released per second is calculated.

7.3.3.3 Release Fraction

The release fraction is that portion of the total radionuclide inventory that is released from the confinement boundary to the atmosphere (i.e., outside the MPC). The release fractions provided in NUREG/CR-6487 [7.3.2] are used. A summary of the release fractions is provided in Table 7.3.1.

7.3.3.4 Radionuclide Release Rate

The radionuclide release rate is the product of the quantity of isotopes available for release, the number of assemblies, the fraction of volume released, and the release fraction.

7.3.3.5 Atmospheric Dispersion Factor

The short-term accident condition atmospheric dispersion factor at 100 meters was determined using Regulatory Guide 1.145 [7.3.4]. In accordance with NUREG-1536 [7.0.2], the dispersion factor was determined on the basis of F-stability diffusion, a wind speed of 1 m/s, and plume meandering.

Reg Guide 1.145 [7.3.4] specifies that χ/Q be calculated using the following three equations. The values determined using Equations 7-4 and 7-5 should be compared and the higher value selected. This value should be compared with the value determined using Equation 7-6, and the lower value of these two should be selected as the appropriate χ/Q value. This methodology was used to determine the value for χ/Q.

Equation 7-4

$$\frac{\chi}{Q} = \frac{1}{U(\pi\ \sigma_y\ \sigma_z\ +\ A/2)}$$

Equation 7-5

$$\frac{\chi}{Q} = \frac{1}{U(3\ \pi\ \sigma_y\ \sigma_z)}$$

Equation 7-6

$$\frac{\chi}{Q} = \frac{1}{U \pi \Sigma_y \sigma_z}$$

where:

χ/Q is relative concentration, in sec/m^3,
π is 3.14159,
U is windspeed at 10 meters above plant grade, in m/sec,
σ_y is lateral plume spread, in meters, a function of atmospheric stability and distance (Figure 1, Reg Guide 1.145 [7.3.4]),
σ_z is vertical plume spread, in meters, a function of atmospheric stability and distance (Figure 2, Reg Guide 1.145 [7.3.4]),
Σ_y is lateral plume spread with meander and building wake effects, in m, = M σ_y, where M is determined from Figure 3, Reg Guide 1.145 [7.3.4], and
A is the smallest vertical-plane cross-sectional area of the structure (cross section of the MPC), m^2.

Equations 7-4 through 7-6 were solved using the parameters presented in Table 7.3.5. The atmospheric dispersion factor, χ/Q, at 100 meters was selected in accordance with the methodology described above. The χ/Q value used to determine the dose is 8.0 x 10^{-3} sec/m^3. This short term accident condition χ/Q is deemed conservative for an accident evaluation period of 30 days.

7.3.3.6 Dose Conversion Factors

Dose Conversion Factors (DCF) from EPA Federal Guidance Report No. 11, Table 2.1 [7.3.5] and EPA Federal Guidance Report No. 12, Table III.1 [7.3.6] were used for the analysis. The DCFs are provided on the spread sheets included as Appendix 7.A.

7.3.3.7 Occupancy Time

An occupancy time of 720 hours (30 days) is used for the analysis [7.0.2]. This conservatively assumes that the individual is exposed 24 hours per day for 30 days at the minimum controlled area boundary of 100 meters. The accident event duration is considered conservative as any accident condition of storage resulting in the failure of 100% of the stored fuel rods would be detected by the routine security and surveillance inspections and corrective actions would be completed prior to the end of this 30-day period.

7.3.3.8 Breathing Rate

A breathing rate of 3.3×10^{-4} m^3/sec for a worker is used for the analysis. This assumption is in accordance with the guidance provided in NUREG-1536 [7.0.2] for a worker.

7.3.4 Postulated Accident Doses

~~The dose to an individual at the site boundary is determined for the whole body and the thyroid. These doses are determined for each type of MPC and are summarized in Table 7.3.2. Appendix 7.B presents the Excel spreadsheets used for the dose calculations.~~

The following doses to an individual at the site boundary (100 meters) as a result of an assumed effluent release under accident conditions of storage were determined; the inhaled committed dose equivalent for critical organs and tissues (gonad, breast, lung, red marrow, bone surface, thyroid, skin, lens of the eye), the effective dose from external submersion in the plume, and the resulting Total Effective Dose Equivalent (TEDE). These doses are determined for each type of MPC. The postulated doses as a result of exposure to soil with ground surface contamination and soil contaminated to a depth of 15 cm were also determined. The resultant doses were negligible compared to the those resulting from submersion in the plume and are therefore not reported.

The doses were determined using spreadsheet software. The resultant doses are summarized for each MPC type in Tables 7.3.2, 7.3.3, and 7.3.4 of the HI-STAR TSAR. Example spread sheets used for the dose estimates are presented in Appendix 7.A.

7.3.4.1 Whole Body Dose *(Total Effective Dose Equivalent)*

The whole body dose is the sum of the *inhaled* committed effective dose equivalent (CEDE) and the external exposure from submersion *in the plume. The postulated doses were determined using spreadsheet software. Example spread sheets are provided in Appendix 7.A.*

The CEDE is the product of radionuclide release rate, the atmospheric dispersion factor, the occupancy time, the breathing rate, and the effective dose conversion factor.

External exposure from submersion is the product of the nuclide release rate, the atmospheric dispersion factor, the occupancy time, and the effective dose conversion factor.

7.3.4.2 ~~Thyroid Dose~~ *Critical Organ Dose*

~~The organ dose is the product of the quantity of isotope(s) available for release, the number of assemblies, the fraction of the volume released per second, the release fraction, the atmospheric dispersion factor, the breathing rate, the occupancy time, and the dose conversion factor. The only organ to receive a significant dose is the thyroid which recieves a dose as a result of the iodine released. Therefore, the thyroid dose is the only organ considered in this analysis.~~

The dose to the critical organ (or tissue) is the sum of the committed dose equivalent to the critical organ or tissue from inhalation and the dose equivalent to the organ or tissue from submersion in the plume. The postulated doses as a result of exposure to soil with ground surface contamination and soil contaminated to a depth of 15 cm were also determined. The resultant doses were negligible compared to the those resulting from submersion in the plume and are therefore not reported.

The committed dose equivalent to the organ or tissue from inhalation is the product of radionuclide release rate, the atmospheric dispersion factor, the occupancy time, the breathing rate, and the organ/tissue dose conversion factor. The dose equivalent to the organ or tissue from submersion in the plume is the product of the nuclide release rate, the atmospheric dispersion factor, the occupancy time, and the organ/tissue dose conversion factor.

The dose to the lens of the eye as a result of submersion in the plume was estimated using guidance from Dr. James Turner in his book, Atoms, Radiation, and Radiation Protection [7.3.10]. Dr. Turner states that alpha particles and low-energy beta particles, such as those from tritium, cannot penetrate to the lens of the eye (at a depth of 3 mm). The discussion continues that many noble gases emit photons and energetic beta particles, which in turn must be considered in the dose estimate. Dr. Turner states that the dose-equivalent rate to tissues near the surface of the body (e.g., lens of the eye) is more than 130 times the dose-equivalent rate in the lung from gases contained in the lung. Using the accident condition of storage for the MPC-68 (which is the highest dose to the lung), the estimated dose to the lung from gases in the lung is 5.34×10^{-4} mrem. Conservatively multiplying this value by 150, the estimated dose to the lens of the eye is 8.01×10^{-2} mrem. This estimated dose to the lens of the eye, 8.01×10^{-2} mrem, is a small fraction of the 15 rem limit imposed by 10 CFR 72.106(b).

7.3.5 Site Boundary

~~As can be seen from Table 7.3.2, the resultant doses for a non-mechanistic accident at the regulatory minimum site boundary distance of 100 meters are less than the accident limit of 5 rem specified in 10CFR72.106(b) [7.0.1] for the whole body or any organ. Thus, the minimum site boundary distance required by of the HI-STAR 100 System to comply with 10CFR72.106(b) [7.0.1] for this non-mechanistic postulated accident is 100 meters.~~

~~The annual dose limit in effluents and direct radiation from an ISFSI specified in 10CFR72.104(a) [7.0.1] is discussed in Chapter 10. 10CFR20 Subparts C and D specify additional requirements for occupational dose limits and radiation dose limits for individual members of the public. Chapter 10 specifically addresses these regulations.~~

The estimated accident doses at the controlled area boundary are highest for the accident condition of storage for the MPC-68. The estimated TEDE (44.1 mrem) is a small fraction of the 5 rem whole body limit imposed by 10 CFR 72.106(b). The estimated bone surface dose which is the highest *critical organ dose (468 mrem) is a small fraction of the 50 rem critical organ limit imposed by 10 CFR 72.106(b). Additionally, the shallow dose estimate to skin (0.17 mrem) is a small fraction of the 50 rem shallow dose equivalent to skin or other extremity limit imposed by 10 CFR 72.106(b).*

7.3.6 Assumptions

The following presents a summary of assumptions for the accident condition confinement analysis of the HI-STAR 100 System.

- The distance from the cask to the site boundary is 100 meters.
- 100% of the fuel rods have ruptured. This assumption is conservative because it results in the greatest potential release of radioactive material.
- Unchoked flow correlations were used as the unchoked flow correlations better approximate the true measured flowrate for the leakage rates associated with transportation packages.
- For conservatism, the upstream pressure at test conditions (inside of the MPC) is assumed to be 2 atm and the down stream pressure (outside of the MPC) is assumed to be 1 atm.
- The temperature at test conditions is assumed to be equal to an ambient reference temperature, 212° F based on the maximum temperature achievable by the water in the MPC during performance of the leak test. This is conservative because the leak hole diameter computed from test conditions is larger.
- Bounding accident conditions (i.e., MPC cavity at design pressure (125 psig) at peak cladding temperature limit (570° C)) are postulated for this analysis.
- ~~The capillary length required for Equation 7-3 was conservatively chosen to be the MPC lid closure weld which is 1.9cm.~~ *The capillary length required for Equation 2-3 was conservatively chosen to be smaller ofthe MPC lid closure weld sizes (MPC-24 and MPC-68, a=1.9 cm and MPC-68, a=3.2 cm) which is 1.9 cm. The shorter leak path assumption conservatively over estimates the leak rate in the thicker (MPC-68F) weld.*
- The majority of the activity associated with crud is due to ^{60}Co. This assumption follows from the discussion provided in NUREG/CR-6487 [7.3.2].
- The accident condition leakage rate persists for 30 days without a decrease in the rate or nuclide concentration.
- The individual at the site boundary is exposed for 720 hours (30 days). This conservatively assumes that the individual is exposed 24 hours per day for 30 days.

- A breathing rate of 3.3 x 10^{-4} m^3/sec for a worker is used for the analysis [7.0.2]. This assumption is in accordance with the guidance provided in NUREG-1536 for a worker.

- All fuel stored in the MPC is of the design basis type with a bounding burnup and cooling time.

- In accordance with the International Commission on Radiological Protection (ICRP) Publication 30 [7.3.7 *"for exposure in radioisotopes of the noble gases, external irraditaion will be of such overridding importance that it alone need be considered."* Therefore, the contribution to the committed effective dose equivalent from ^{85}Kr is neglected.

- *Exposure to dose conversion factors for inhalation reported in EPA Federal Guidance Report No. 11, Table 2.1 [7.3.5] were selected by lung clearance class which reports the most conservative values.*

- ~~The only organ to receive an appreciable dose is the thyroid. Therefore, the thyroid is the only organ considered. This is because the solubility of the noble gases in body tissue is very low, while inhaled radioiodine tends to concentrate in the thyroid.~~

- ~~Only ^{129}I contributes significantly to the dose recieved by the thyroid.~~

Table 7.3.1

Isotope Inventory and Release Fraction

Nuclide	MPC-24 Ci/Assembly	MPC-68 Ci/Assembly	MPC-68F Ci/Assembly	Release Fraction [7.3.2]
Gases				
^{3}H	2.21E+02	8.72E+01	*1.76E+01*	0.30
^{129}I	1.93E-02	7.72E-03	--	0.30
^{85}Kr	3.75E+03	1.43E+03	*2.54E+02*	0.30
Crud				
^{60}Co	2.18E+01	6.50E+01	*1.18E+01*	0.15 normal/off-normal 1.0 accident
Volatiles				
^{90}Sr	3.91E+04	1.52E+04	*4.64E+03*	2.0E-04
^{106}Ru	1.18E+04	4.16E+03	--	2.0E-04
^{134}Cs	1.90E+04	7.20E+03	*2.96E+01*	2.0E-04
^{137}Cs	5.77E+04	2.29E+04	*7.21E+03*	2.0E-04
Fines				
^{241}Pu	6.33E+04	2.10E+04	*4.99E+03*	3.0 E-05
^{90}Y	3.91E+04	1.52E+04	*4.64E+03*	3.0 E-05
^{147}Pm	2.48E+04	8.88E+03	*1.24E+02*	3.0 E-05
^{144}Ce	7.97E+03	2.46E+03	--	3.0 E-05
^{144}Pr	7.97E+03	2.46E+03	--	3.0 E-05
^{154}Eu	2.89E+03	1.07E+03	*1.37E+02*	3.0 E-05
^{244}Cm	2.06E+03	9.30E+02	*1.50E+02*	3.0 E-05
^{238}Pu	1.98E+03	7.49E+02	*2.41E+02*	3.0 E-05
^{125}Sb	1.57E+03	6.40E+02	--	3.0 E-05
^{155}Eu	8.53E+02	3.51E+02	*2.01E+01*	3.0 E-05

Table 7.3.1
(continued)

Isotope Inventory and Release Fractions

Nuclide	MPC-24 Ci/Assembly	MPC-68 Ci/Assembly	MPC-68F Ci/Assembly	Release Fraction [7.3.2]
^{241}Am	6.46E+02	2.20E+02	*2.45E+02*	3.0 E-05
^{125m}Te	3.84E+02	1.56E+02	--	3.0 E-05
^{240}Pu	3.06E+02	1.26E+02	*6.42E+01*	3.0 E-05
^{151}Sm	2.37E+02	--	*2.67E+01*	3.0 E-05
^{239}Pu	1.86E+02	6.16E+01	*3.05E+01*	3.0 E-05
^{137m}Ba	5.44E+04	2.16E+04	*6.81E+03*	3.0 E-05
^{106}Rh	1.18E+04	4.16E+03	--	3.0 E-05
^{144m}Pr	1.12E+02	--	--	3.0 E-05
^{243}Am	1.73E+01	7.39E+00	*2.55E+00*	3.0 E-05
^{242}Cm	1.54E+01	6.10E+00	*7.91E-01*	3.0 E-05
^{243}Cm	1.14E+01	4.81E+00	*1.30E+00*	3.0 E-05
^{239}Np	1.73E+01	7.39E+00	--	3.0 E-05
^{237}Np	2.02E-01	7.05E-02	*2.72E-02*	3.0 E-05
^{242}Pu	1.38E+00	5.95E-01	*2.51E-01*	3.0 E-05
^{242}Am	4.69E+00	1.69E+00	*9.55E-01*	3.0 E-05
^{242m}Am	4.72E+00	1.70E+00	*9.59E-01*	3.0 E-05

Note: The isotopes which contribute greater than 0.1% to the total curie inventory for the fuel assembly are considered in the evaluation as fines. *The analysis also includes actinides as the dose conversion factors for these isotopes are in general, orders of magnitude greater than other isotopes (e.g., isotopes of plutonium, americium, curium, and neptunium were included regardless of their contribution to the inventory).*

Table 7.3.2

MPC-24
Postulated Doses
To An Individual at the Controlled Area Boundary (100 meters)
As a Result of an Assumed Effluent Release

	Normal Conditions of Storage			*Off-Normal Conditions of Storage*			*Accident Conditions of Storage*		
Organ or Tissue	*Dose from Inhalation [mrem/yr]*	*Dose from Submersion [mrem/yr]*	*Total [mrem/yr]*	*Dose from Inhalation [mrem/yr]*	*Dose from Submersion [mrem/yr]*	*Total [mrem/yr]*	*Dose from Inhalation [mrem*]*	*Dose from Submersion [mrem*]*	*Total [mrem*]*
Gonad	*1.35E-02*	*2.45E-04*	*1.37E-02*	*1.07E-01*	*2.71E-04*	*1.07E-01*	*6.22E+00*	*1.11E-02*	*6.23E+00*
Breast	*1.22E-02*	*2.77E-04*	*1.25E-02*	*1.48E-02*	*3.06E-04*	*1.51E-02*	*6.32E-01*	*1.26E-02*	*6.45E-01*
Lung	*2.80E-01*	*2.47E-04*	*2.80E-01*	*7.82E-01*	*2.72E-04*	*7.82E-01*	*4.15E+01*	*1.12E-02*	*4.15E+01*
Red Marrow	*6.62E-02*	*2.45E-04*	*6.64E-02*	*5.62E-01*	*2.69E-04*	*5.62E-01*	*3.27E+01*	*1.11E-02*	*3.27E+01*
Bone Surface	*6.87E-01*	*3.55E-04*	*6.87E-01*	*6.79E+00*	*3.99E-04*	*6.79E+00*	*3.98E+02*	*1.65E-02*	*3.98E+02*
Thyroid	*1.08E-02*	*2.53E-04*	*1.11E-02*	*1.35E-02*	*2.79E-04*	*1.38E-02*	*5.88E-01*	*1.15E-02*	*6.00E-01*
Skin	*N/A*	*3.80E-04*	*3.80E-04*	*N/A*	*1.23E-03*	*1.23E-03*	*N/A*	*6.62E-02*	*6.62E-02*
Effective	*8.23E-02*	*2.51E-04*	***8.26E-02***	*4.77E-01*	*2.77E-04*	***4.77E-01***	*2.72E+01*	*1.14E-02*	***2.72E+01***

**The accident duration is 30 days.*

Table 7.3.3

MPC-68
Postulated Doses
To An Individual at the Controlled Area Boundary (100 meters)
As a Result of an Assumed Effluent Release

	Normal Conditions of Storage			Off-Normal Conditions of Storage			Accident Conditions of Storage		
Organ or Tissue	Dose from Inhalation [mrem/yr]	Dose from Submersion [mrem/yr]	Total [mrem/yr]	Dose from Inhalation [mrem/yr]	Dose from Submersion [mrem/yr]	Total [mrem/yr]	Dose from Inhalation [mrem*]	Dose from Submersion [mrem*]	Total [mrem*]
Gonad	4.06E-02	2.24E-03	4.28E-02	1.50E-01	2.27E-03	1.52E-01	8.21E+00	8.92E-02	8.29E+00
Breast	1.11E-01	2.53E-03	1.14E-01	1.14E-01	2.56E-03	1.17E-01	4.51E+00	1.01E-01	4.61E+00
Lung	2.13E+00	2.26E-03	2.13E+00	2.73E+00	2.29E-03	2.73E+00	1.20E+02	8.99E-02	1.20E+02
Red Marrow	1.67E-01	2.24E-03	1.70E-01	7.47E-01	2.27E-03	7.49E-01	4.18E+01	8.91E-02	4.18E+01
Bone Surface	8.75E-01	3.24E-03	8.77E-01	8.02E+00	3.29E-03	8.02E+00	4.68E+02	1.30E-01	4.68E+02
Thyroid	9.75E-02	2.31E-03	9.98E-02	1.01E-01	2.34E-03	1.03E-01	4.01E+00	9.21E-02	4.10E+00
Skin	N/A	2.74E-03	2.74E-03	N/A	3.74E-03	3.74E-03	N/A	1.68E-01	1.68E-01
Effective	4.06E-01	2.29E-03	**4.08E-01**	8.70E-01	2.32E-03	**8.72E-01**	4.41E+01	9.14E-02	**4.41E+01**

*The accident duration is 30 days.

Table 7.3.4

MPC-68F
Postulated Doses
To An Individual at the Controlled Area Boundary (100 meters)
As a Result of an Assumed Effluent Release

	Normal Conditions of Storage			Off-Normal Conditions of Storage			Accident Conditions of Storage		
Organ or Tissue	Dose from Inhalation [mrem/yr]	Dose from Submersion [mrem/yr]	Total [mrem/yr]	Dose from Inhalation [mrem/yr]	Dose from Submersion [mrem/yr]	Total [mrem/yr]	Dose from Inhalation [mrem*]	Dose from Submersion [mrem*]	Total [mrem*]
Gonad	9.62E-03	4.06E-04	1.00E-02	4.33E-02	4.08E-04	4.37E-02	2.80E+00	1.60E-02	2.82E+00
Breast	2.01E-02	4.59E-04	2.06E-02	2.07E-02	4.62E-04	2.12E-02	8.22E-01	1.80E-02	8.40E-01
Lung	3.94E-01	4.09E-04	3.94E-01	5.65E-01	4.12E-04	5.65E-01	2.57E+01	1.61E-02	2.57E+01
Red Marrow	4.24E-02	4.06E-04	4.28E-02	2.25E-01	4.08E-04	2.25E-01	1.46E+01	1.59E-02	1.46E+01
Bone Surface	3.07E-01	5.87E-04	3.08E-01	2.56E+00	5.92E-04	2.56E+00	1.72E+02	2.31E-02	1.72E+02
Thyroid	1.77E-02	4.19E-04	1.81E-02	1.84E-02	4.22E-04	1.88E-02	7.29E-01	1.65E-02	7.45E-01
Skin	N/A	4.98E-04	4.98E-04	N/A	6.73E-04	6.73E-04	N/A	3.00E-02	3.00E-02
Effective	8.26E-02	4.16E-04	**8.30E-02**	2.26E-01	4.18E-04	**2.26E-01**	1.32E+01	1.63E-02	**1.32E+01**

*The accident duration is 30 days.

Table 7.3.5 ~~Table 7.3.3~~
χ/Q Parameters

Parameter	Value	Reference
U	1 m/s	NUREG-1536 [7.0.2]
σ_y	4.0 m	Figure 1, Reg Guide 1.145 [7.3.4]
σ_z	2.5 m	Figure 2, Reg Guide 1.145 [7.3.4]
$\Sigma_y = M\ \sigma_y$	16	M is determined from Figure 3, Reg Guide 1.145 [7.3.4]
A	8.41 m^2	Chapter 1, Section 1.5

Table 7.3.6 ~~Table 7.3.4~~

Parameters for Test and Hypothetical Accident Conditions

Parameter	Test	Normal/*Off-Normal*	Hypothetical Accident
P_u	2 ATM (min)	4.99 ATM	9.5 ATM
P_d	1 ATM	1 ATM	1 ATM
T	373 K	499.2 K	843 K
M	4 g/mol	4 g/mol	4 g/mol
u (helium)	0.0231 cP	0.0287 cP	0.0397 cP
a	1.9 cm	1.9 cm	1.9 cm

7.4 REGULATORY COMPLIANCE

Chapter 7 of this TSAR has been prepared to summarize the confinement features and capabilities of the HI-STAR 100 System. The confinement boundary of the HI-STAR 100 System is designed to provide confinement of radionuclides under normal, off-normal, and accident conditions. The evaluations presented in Chapter 7 provides detailed analyses of the confinement system to show that the radiological releases to the environment during normal storage conditions and from a non-mechanistic accident will be within the limits established by the regulations. The inert atmosphere in the MPC and the passive heat removal capabilities of the HI-STAR 100 assure that the SNF assemblies remain protected from degradation, which might otherwise lead to gross cladding ruptures during storage.

The confinement features and capabilities of the HI-STAR 100 System can be summarized in the following evaluation statements:

1. Section 2 of this TSAR describes confinement structures, systems, and components (SSCs) important to safety in sufficient detail to permit evaluation of their effectiveness.

2. The design of the HI-STAR 100 System adequately protects the spent fuel cladding against degradation that might otherwise lead to gross cladding ruptures. The spent fuel rods are protected from degradation by maintaining an inert gas atmosphere (helium) inside the MPC and keeping the fuel cladding temperatures below the design basis values specified in Chapter 2. Chapter 4 of the TSAR discusses the relevant temperature analyses.

3. The design of the HI-STAR 100 System provides redundant sealing of the confinement system closure joints by the combination of the welded MPC lid, vent and drain port cover plates, and MPC closure ring. The MPC lid has a recess around the perimeter for installation of the closure ring. The MPC closure ring is welded to the MPC lid on the inner diameter of the ring and to the MPC shell on the outer diameter, thereby covering the vent and drain port cover plates, and the MPC lid-to-shell weld.

4. The confinement system is not required to be monitored.

5. The quantity of radionuclides postulated to be released to the environment is discussed in Section 7.2.6, 7.3.1 and 7.3.2 and is summarized in Table 7.3.1. Chapter 7 demonstrates that the incremental dose at the minimum controlled area boundary due to an atmospheric release resulting from leakage from the confinement boundary results in a minor contribution to the annual dose limit in effluents and direct radiation during normal operations or anticipated occurrences which meets the requirements in 10CFR72.104(a) [7.0.1]. The annual dose from normal and *off-normal* storage operations is provided in Table 7.3.2, *7.3.3 and 7.3.4* and reported in Chapter 10. The potential dose to an individual located at the minimum controlled area boundary (100 meters) from a non-mechanistic accident event is determined for each

type of MPC and is summarized in Tables 7.3.2, *7.3.3 and 7.3.4*. The licensee is required to perform a site-specific dose evaluation as part of the ISFSI design as dictated in 10CFR72.212 and Chapter 12 to demonstrate compliance with 10CFR72.104. The licensee's evaluation will account for the location of the controlled area boundary, ISFSI size and configuration, fuel assembly specifics, and the effects of radiation from other on-site operations. Chapter 11 presents the results of the evaluations performed to demonstrate that the HI-STAR 100 System can withstand the effects of all credible accident conditions and natural phenomena with minimal contribution to the site boundary dose. Chapter 5 demonstrates that the direct radiation doses that result from the loss of the neutron shield are far below the requirements of 10CFR72.106. These doses combined with the doses presented in Chapter 7, satisfy the regulatory requirement of 10CFR72.106. The licensee is responsible for demonstrating site-specific compliance with 10CFR72.106.

6. The HI-STAR 100 System confinement boundary is designed and fabricated in accordance with the ASME Code, Section III, Subsection NB to the maximum extent practicable. Chapter 2 provides design criteria for the confinement design. Table 2.2.7 provides applicable Code requirements. Exceptions to specific Code requirements with complete justifications are presented in Table 2.2.15. The structural adequacy of the MPC is demonstrated by the analyses documented in Chapter 3. The HI-STAR 100 System confinement boundary is adequately designed to maintain confinement of all radionuclides under normal, off-normal and accident conditions.

7. The design of the confinement system of the HI-STAR 100 is in compliance with 10CFR72 and the applicable design and acceptance criteria are satisfied. The evaluation of the confinement system design provides reasonable assurance that the HI-STAR 100 System will allow the long term, safe storage of spent fuel.

7.5 REFERENCES

[7.0.1] 10CFR72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste.

[7.0.2] NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems", January, 1997.

[7.1.1] American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB, Class 1 Components, 1995 Edition.

[7.1.2] HI-STAR 100 Safety Analysis Report, Holte International Report No. HI-951251, most current revision.

[7.3.1] Deleted.

[7.3.2] Anderson, B.L. et al. *Containment Analysis for Type B Packages Used to Transport Various Contents.* NUREG/CR-6487, UCRL-ID-124822. Lawrence Livermore National Laboratory, November 1996.

[7.3.3] Shleien, B, *The Health Physics and Radiological Health Handbook,* Scinta, Inc. Silver Spring, MD, 1992.

[7.3.4] U.S. Nuclear Regulatory Commission, "Atmospheric Dispersement Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Regulatory Guide 1.145, February 1989.

[7.3.5] U.S. EPA, Federal Guidance Report No. 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,* DE89-011065, 1988.

[7.3.6] U.S. EPA, Federal Guidance Report No. 12, *External Exposure to Radionuclides in Air, Water, and Soil,* EPA 402-R-93-081, 1993.

[7.3.7] International Commission on Radiological Protection, Limits for Intakes of Radionuclides by Workers, ICRP Publication 30, Part 1; Pergamon Press; Oxford; 1978.

[7.3.8] ANSI N14.5-1997. "American National Standard for Radioactive Material Leakage Tests on Packages for Shipment."

[7.3.9] Rosenhow, W.M.. and Hartnett, J.P., *Handbook of Heat Transfer*, McGraw Hill Book Company, New York, 1973.

[7.3.10] Turner, James E. *Atoms, Radiation , and Radiation Protection*, McGraw Hill Book Company, New York, 1992.

APPENDIX 7.A

EXAMPLE DOSE CALCULATIONS FOR NORMAL, OFF-NORMAL, AND ACCIDENT CONDITIONS OF STORAGE

MPC-68, Normal Conditions of Storage, Dose from Inhalation: 7 pages
MPC-68, Off-Normal Conditions of Storage, Dose from Inhalation: 7 pages
MPC-68, Accident Conditions of Storage, Dose from Inhalation: 7 pages

MPC-68, Normal Conditions of Storage, Dose from Submersion: 8 pages
MPC-68, Off-Normal Conditions of Storage, Dose from Submersion: 8 pages
MPC-68, Accident Conditions of Storage, Dose from Submersion: 8 pages

MPC-68														
Normal Conditions														
Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-06
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	3.30E-04	8.69E-11	3.22E-01	3.15E+07	1.24E-09
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	4.76E-09	1.76E+01	3.15E+07	2.85E-02
								Volatiles						
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	3.30E-04	2.69E-10	9.95E-01	3.15E+07	5.03E-06
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	3.30E-04	1.30E-09	4.81E+00	3.15E+07	6.65E-06
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	3.30E-04	1.30E-08	4.81E+01	3.15E+07	1.15E-04
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	3.30E-04	8.76E-09	3.24E+01	3.15E+07	2.47E-04
								Fines						
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	3.30E-04	6.82E-07	2.52E+03	3.15E+07	2.64E-03
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	3.30E-04	9.52E-12	3.52E-02	3.15E+07	2.67E-08
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	3.30E-04	8.25E-15	3.05E-05	3.15E+07	1.35E-11
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	1.93E-09	7.14E+00	3.15E+07	8.76E-07
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	2.41E-15	8.92E-06	3.15E+07	1.09E-12
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	3.30E-04	1.17E-08	4.33E+01	3.15E+07	2.31E-06
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	3.30E-04	1.59E-05	5.88E+04	3.15E+07	2.73E-03
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	3.30E-04	2.80E-05	1.04E+05	3.15E+07	3.87E-03
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	3.30E-04	3.60E-10	1.33E+00	3.15E+07	4.25E-08
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	3.30E-04	3.56E-10	1.32E+00	3.15E+07	2.30E-08
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	3.30E-04	3.25E-05	1.20E+05	3.15E+07	1.32E-03
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	3.30E-04	1.24E-10	4.59E-01	3.15E+07	3.57E-09
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	3.30E-04	3.18E-05	1.18E+05	3.15E+07	7.39E-04
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	4.03E-14	1.49E-04	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	3.30E-04	3.18E-05	1.18E+05	3.15E+07	3.61E-04
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	3.26E-05	1.21E+05	3.15E+07	4.44E-05
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	3.30E-04	5.70E-07	2.11E+03	3.15E+07	6.41E-07
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	3.30E-04	2.07E-05	7.66E+04	3.15E+07	1.84E-05
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	7.45E-11	2.76E-01	3.15E+07	1.02E-10
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	3.30E-04	2.96E-05	1.10E+05	3.15E+07	3.85E-07
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	3.30E-04	3.02E-05	1.12E+05	3.15E+07	3.31E-06
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	3.30E-04	1.94E-09	7.18E+00	3.15E+07	6.05E-10
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	3.30E-04	3.21E-05	1.19E+05	3.15E+07	1.01E-05
													Total	4.06E-02

MPC-68														
Normal Conditions														
Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-06
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	3.30E-04	2.09E-10	7.73E-01	3.15E+07	2.98E-09
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	1.84E-08	6.81E+01	3.15E+07	1.10E-01
								Volatiles						
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	3.30E-04	2.69E-10	9.95E-01	3.15E+07	5.03E-06
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	3.30E-04	1.78E-09	6.59E+00	3.15E+07	9.10E-06
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	3.30E-04	1.08E-08	4.00E+01	3.15E+07	9.56E-05
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	3.30E-04	7.84E-09	2.90E+01	3.15E+07	2.21E-04
								Fines						
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	3.30E-04	3.06E-11	1.13E-01	3.15E+07	1.19E-07
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	3.30E-04	9.52E-12	3.52E-02	3.15E+07	2.67E-08
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	3.30E-04	3.60E-14	1.33E-04	3.15E+07	5.90E-11
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	1.97E-09	7.29E+00	3.15E+07	8.94E-07
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	1.05E-14	3.89E-05	3.15E+07	4.76E-12
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	3.30E-04	1.55E-08	5.74E+01	3.15E+07	3.06E-06
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	3.30E-04	1.04E-09	3.85E+00	3.15E+07	1.78E-07
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	3.30E-04	1.00E-09	3.70E+00	3.15E+07	1.38E-07
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	3.30E-04	4.16E-10	1.54E+00	3.15E+07	4.91E-08
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	3.30E-04	6.14E-10	2.27E+00	3.15E+07	3.97E-08
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	3.30E-04	2.67E-09	9.88E+00	3.15E+07	1.08E-07
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	3.30E-04	1.07E-10	3.96E-01	3.15E+07	3.08E-09
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	3.30E-04	9.51E-10	3.52E+00	3.15E+07	2.21E-08
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	1.49E-13	5.51E-04	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	3.30E-04	9.22E-10	3.41E+00	3.15E+07	1.05E-08
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	1.52E-08	5.62E+01	3.15E+07	2.07E-08
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	3.30E-04	9.44E-10	3.49E+00	3.15E+07	1.06E-09
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	3.30E-04	6.29E-09	2.33E+01	3.15E+07	5.58E-09
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	1.63E-11	6.03E-02	3.15E+07	2.22E-11
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	3.30E-04	1.69E-08	6.25E+01	3.15E+07	2.20E-10
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	3.30E-04	9.45E-10	3.50E+00	3.15E+07	1.04E-10
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	3.30E-04	2.49E-12	9.21E-03	3.15E+07	7.76E-13
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	3.30E-04	1.38E-09	5.11E+00	3.15E+07	4.33E-10
													Total	1.11E-01

MPC-68														
Normal Conditions														
Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-06
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	3.30E-04	3.14E-10	1.16E+00	3.15E+07	4.47E-09
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	3.45E-07	1.28E+03	3.15E+07	2.07E+00
								Volatiles						
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	3.30E-04	2.86E-06	1.06E+04	3.15E+07	5.35E-02
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	3.30E-04	1.04E-06	3.85E+03	3.15E+07	5.32E-03
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	3.30E-04	1.18E-08	4.37E+01	3.15E+07	1.04E-04
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	3.30E-04	8.82E-09	3.26E+01	3.15E+07	2.48E-04
								Fines						
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	3.30E-04	7.42E-09	2.75E+01	3.15E+07	2.87E-05
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	3.30E-04	8.89E-09	3.29E+01	3.15E+07	2.49E-05
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	3.30E-04	7.74E-08	2.86E+02	3.15E+07	1.27E-04
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	1.83E-07	6.77E+02	3.15E+07	8.30E-05
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	9.40E-11	3.48E-01	3.15E+07	4.26E-08
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	3.30E-04	7.92E-08	2.93E+02	3.15E+07	1.56E-05
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	3.30E-04	1.93E-05	7.14E+04	3.15E+07	3.31E-03
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	3.30E-04	1.84E-05	6.81E+04	3.15E+07	2.54E-03
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	3.30E-04	2.17E-08	8.03E+01	3.15E+07	2.56E-06
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	3.30E-04	1.19E-08	4.40E+01	3.15E+07	7.70E-07
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	3.30E-04	1.84E-05	6.81E+04	3.15E+07	7.47E-04
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	3.30E-04	4.66E-10	1.72E+00	3.15E+07	1.34E-08
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	3.30E-04	1.73E-05	6.40E+04	3.15E+07	4.02E-04
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	3.26E-09	1.21E+01	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	3.30E-04	1.73E-05	6.40E+04	3.15E+07	1.97E-04
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	1.78E-05	6.59E+04	3.15E+07	0.00E+00
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	3.30E-04	1.55E-05	5.74E+04	3.15E+07	2.43E-05
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	3.30E-04	1.94E-05	7.18E+04	3.15E+07	1.74E-05
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	2.36E-09	8.73E+00	3.15E+07	1.72E-05
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	3.30E-04	1.61E-05	5.96E+04	3.15E+07	3.22E-09
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	3.30E-04	1.64E-05	6.07E+04	3.15E+07	2.09E-07
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	3.30E-04	5.20E-08	1.92E+02	3.15E+07	1.80E-06
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	3.30E-04	4.20E-06	1.55E+04	3.15E+07	1.62E-08
														1.32E-06
													Total	2.13E+00

MPC-68														
Normal Conditions														
Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-06
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	3.30E-04	1.40E-10	5.18E-01	3.15E+07	1.99E-09
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	1.72E-08	6.36E+01	3.15E+07	1.03E-01
								Volatiles						
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	3.30E-04	3.28E-08	1.21E+02	3.15E+07	6.13E-04
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	3.30E-04	1.76E-09	6.51E+00	3.15E+07	9.00E-06
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	3.30E-04	1.18E-08	4.37E+01	3.15E+07	1.04E-04
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	3.30E-04	8.30E-09	3.07E+01	3.15E+07	2.34E-04
								Fines						
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	3.30E-04	3.36E-06	1.24E+04	3.15E+07	1.30E-02
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	3.30E-04	2.79E-10	1.03E+00	3.15E+07	7.82E-07
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	3.30E-04	1.61E-09	5.96E+00	3.15E+07	2.64E-06
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	2.67E-08	9.88E+01	3.15E+07	1.21E-05
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	1.38E-14	5.11E-05	3.15E+07	6.26E-12
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	3.30E-04	1.06E-07	3.92E+02	3.15E+07	2.09E-05
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	3.30E-04	9.38E-05	3.47E+05	3.15E+07	1.61E-02
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	3.30E-04	1.52E-04	5.62E+05	3.15E+07	2.10E-02
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	3.30E-04	5.35E-10	1.98E+00	3.15E+07	6.31E-08
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	3.30E-04	1.43E-08	5.29E+01	3.15E+07	9.26E-07
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	3.30E-04	1.74E-04	6.44E+05	3.15E+07	7.06E-03
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	3.30E-04	3.01E-09	1.11E+01	3.15E+07	8.66E-08
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	3.30E-04	1.69E-04	6.25E+05	3.15E+07	3.93E-03
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	1.10E-08	4.07E+01	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	3.30E-04	1.69E-04	6.25E+05	3.15E+07	1.92E-03
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	1.73E-04	6.40E+05	3.15E+07	2.36E-04
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	3.30E-04	3.90E-06	1.44E+04	3.15E+07	4.39E-06
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	3.30E-04	1.18E-04	4.37E+05	3.15E+07	1.05E-04
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	2.08E-10	7.70E-01	3.15E+07	2.83E-10
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	3.30E-04	2.62E-04	9.69E+05	3.15E+07	3.41E-06
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	3.30E-04	1.61E-04	5.96E+05	3.15E+07	1.77E-05
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	3.30E-04	1.32E-08	4.88E+01	3.15E+07	4.11E-09
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	3.30E-04	1.69E-04	6.25E+05	3.15E+07	5.30E-05
													Total	1.68E-01

MPC-68														
Normal Conditions														
Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-06
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	3.30E-04	1.38E-10	5.11E-01	3.15E+07	1.96E-09
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	1.35E-08	5.00E+01	3.15E+07	8.09E-02
								Volatiles						
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	3.30E-04	7.09E-08	2.62E+02	3.15E+07	1.33E-03
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	3.30E-04	1.61E-09	5.96E+00	3.15E+07	8.23E-06
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	3.30E-04	1.10E-08	4.07E+01	3.15E+07	9.74E-05
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	3.30E-04	7.94E-09	2.94E+01	3.15E+07	2.24E-04
								Fines						
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	3.30E-04	4.20E-05	1.55E+05	3.15E+07	1.63E-01
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	3.30E-04	2.78E-10	1.03E+00	3.15E+07	7.79E-07
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	3.30E-04	2.01E-08	7.44E+01	3.15E+07	3.29E-05
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	4.54E-08	1.68E+02	3.15E+07	2.06E-05
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	1.47E-14	5.44E-05	3.15E+07	6.67E-12
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	3.30E-04	5.23E-07	1.94E+03	3.15E+07	1.03E-04
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	3.30E-04	1.17E-03	4.33E+06	3.15E+07	2.01E-01
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	3.30E-04	1.90E-03	7.03E+06	3.15E+07	2.62E-01
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	3.30E-04	9.78E-10	3.62E+00	3.15E+07	1.15E-07
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	3.30E-04	1.52E-07	5.62E+02	3.15E+07	9.84E-06
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	3.30E-04	2.17E-03	8.03E+06	3.15E+07	8.80E-02
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	3.30E-04	3.21E-08	1.19E+02	3.15E+07	9.24E-07
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	3.30E-04	2.11E-03	7.81E+06	3.15E+07	4.90E-02
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	1.38E-07	5.11E+02	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	3.30E-04	2.11E-03	7.81E+06	3.15E+07	2.40E-02
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	2.17E-03	8.03E+06	3.15E+07	2.96E-03
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	3.30E-04	4.87E-05	1.80E+05	3.15E+07	5.48E-05
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	3.30E-04	1.47E-03	5.44E+06	3.15E+07	1.30E-03
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	2.03E-09	7.51E+00	3.15E+07	2.77E-09
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	3.30E-04	3.27E-03	1.21E+07	3.15E+07	4.25E-05
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	3.30E-04	2.01E-03	7.44E+06	3.15E+07	2.21E-04
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	3.30E-04	1.65E-07	6.11E+02	3.15E+07	5.14E-08
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	3.30E-04	2.12E-03	7.84E+06	3.15E+07	6.65E-04
													Total	8.75E-01

MPC-68														
Normal Conditions														
Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-06
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	3.30E-04	1.56E-06	5.77E+03	3.15E+07	2.22E-05
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	1.62E-08	5.99E+01	3.15E+07	9.71E-02
								Volatiles						
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	3.30E-04	2.69E-10	9.95E-01	3.15E+07	5.03E-06
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	3.30E-04	1.72E-09	6.36E+00	3.15E+07	8.80E-06
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	3.30E-04	1.11E-08	4.11E+01	3.15E+07	9.83E-05
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	3.30E-04	7.93E-09	2.93E+01	3.15E+07	2.23E-04
								Fines						
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	3.30E-04	1.24E-11	4.59E-02	3.15E+07	4.80E-08
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	3.30E-04	9.52E-12	3.52E-02	3.15E+07	2.67E-08
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	3.30E-04	1.98E-14	7.33E-05	3.15E+07	3.24E-11
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	1.88E-09	6.96E+00	3.15E+07	8.53E-07
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	8.47E-15	3.13E-05	3.15E+07	3.84E-12
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	3.30E-04	7.14E-09	2.64E+01	3.15E+07	1.41E-06
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	3.30E-04	1.01E-09	3.74E+00	3.15E+07	1.73E-07
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	3.30E-04	9.62E-10	3.56E+00	3.15E+07	1.33E-07
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	3.30E-04	3.24E-10	1.20E+00	3.15E+07	3.82E-08
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	3.30E-04	2.40E-10	8.88E-01	3.15E+07	1.55E-08
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	3.30E-04	1.60E-09	5.92E+00	3.15E+07	6.49E-08
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	3.30E-04	9.93E-11	3.67E-01	3.15E+07	2.86E-09
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	3.30E-04	9.05E-10	3.35E+00	3.15E+07	2.10E-08
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	1.32E-14	4.88E-05	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	3.30E-04	9.03E-10	3.34E+00	3.15E+07	1.03E-08
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	8.29E-09	3.07E+01	3.15E+07	1.13E-08
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	3.30E-04	9.41E-10	3.48E+00	3.15E+07	1.06E-09
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	3.30E-04	3.83E-09	1.42E+01	3.15E+07	3.40E-09
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	7.62E-12	2.82E-02	3.15E+07	1.04E-11
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	3.30E-04	1.34E-08	4.96E+01	3.15E+07	1.74E-10
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	3.30E-04	8.79E-10	3.25E+00	3.15E+07	9.65E-11
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	3.30E-04	2.52E-12	9.32E-03	3.15E+07	7.85E-13
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	3.30E-04	5.64E-10	2.09E+00	3.15E+07	1.77E-10
													Total	9.75E-02

MPC-68														
Normal Conditions														
Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-06
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	3.30E-04	4.69E-08	1.74E+02	3.15E+07	6.68E-07
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud		3.30E-04				
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	5.91E-08	2.19E+02	3.15E+07	3.54E-01
								Volatiles		3.30E-04				
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	3.30E-04	3.51E-07	1.30E+03	3.15E+07	6.56E-03
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	3.30E-04	1.29E-07	4.77E+02	3.15E+07	6.60E-04
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	3.30E-04	1.25E-08	4.63E+01	3.15E+07	1.11E-04
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	3.30E-04	8.63E-09	3.19E+01	3.15E+07	2.43E-04
								Fines		3.30E-04				
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	3.30E-04	2.23E-06	8.25E+03	3.15E+07	8.64E-03
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	3.30E-04	2.13E-09	7.88E+00	3.15E+07	5.97E-06
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	3.30E-04	1.06E-08	3.92E+01	3.15E+07	1.74E-05
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	5.84E-08	2.16E+02	3.15E+07	2.65E-05
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	3.30E-04	1.17E-11	4.33E-02	3.15E+07	5.31E-09
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	3.30E-04	7.73E-08	2.86E+02	3.15E+07	1.53E-05
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	3.30E-04	6.70E-05	2.48E+05	3.15E+07	1.15E-02
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	3.30E-04	1.06E-04	3.92E+05	3.15E+07	1.46E-02
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	3.30E-04	3.30E-09	1.22E+01	3.15E+07	3.90E-07
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	3.30E-04	1.12E-08	4.14E+01	3.15E+07	7.25E-07
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	3.30E-04	1.20E-04	4.44E+05	3.15E+07	4.87E-03
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	3.30E-04	1.52E-09	5.62E+00	3.15E+07	4.37E-08
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	3.30E-04	1.16E-04	4.29E+05	3.15E+07	2.70E-03
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	8.10E-09	3.00E+01	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	3.30E-04	1.16E-04	4.29E+05	3.15E+07	1.32E-03
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	1.19E-04	4.40E+05	3.15E+07	1.62E-04
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	3.30E-04	4.67E-06	1.73E+04	3.15E+07	5.25E-06
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	3.30E-04	8.30E-05	3.07E+05	3.15E+07	7.36E-05
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	3.30E-04	6.78E-10	2.51E+00	3.15E+07	9.24E-10
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	3.30E-04	1.46E-04	5.40E+05	3.15E+07	1.90E-06
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	3.30E-04	1.11E-04	4.11E+05	3.15E+07	1.22E-05
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	3.30E-04	1.58E-08	5.85E+01	3.15E+07	4.92E-09
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	3.30E-04	1.15E-04	4.26E+05	3.15E+07	3.61E-05
													Total	4.06E-01

MPC-68 Off-Normal Conditions Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	$L_{off\ nor}$ Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-05
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	3.30E-04	8.69E-11	3.22E-01	3.15E+07	1.24E-08
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	4.76E-09	1.76E+01	3.15E+07	2.85E-02
								Volatiles						
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	3.30E-04	2.69E-10	9.95E-01	3.15E+07	5.03E-05
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	3.30E-04	1.30E-09	4.81E+00	3.15E+07	6.65E-05
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	3.30E-04	1.30E-08	4.81E+01	3.15E+07	1.15E-03
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	3.30E-04	8.76E-09	3.24E+01	3.15E+07	2.47E-03
								Fines						
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	3.30E-04	6.82E-07	2.52E+03	3.15E+07	2.64E-02
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	3.30E-04	9.52E-12	3.52E-02	3.15E+07	2.67E-07
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	3.30E-04	8.25E-15	3.05E-05	3.15E+07	1.35E-10
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	1.93E-09	7.14E+00	3.15E+07	8.76E-06
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	2.41E-15	8.92E-06	3.15E+07	1.09E-11
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	3.30E-04	1.17E-08	4.33E+01	3.15E+07	2.31E-05
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	3.30E-04	1.59E-05	5.88E+04	3.15E+07	2.73E-02
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	3.30E-04	2.80E-05	1.04E+05	3.15E+07	3.87E-02
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	3.30E-04	3.60E-10	1.33E+00	3.15E+07	4.25E-07
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	3.30E-04	3.56E-10	1.32E+00	3.15E+07	2.30E-07
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	3.30E-04	3.25E-05	1.20E+05	3.15E+07	1.32E-02
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	3.30E-04	1.24E-10	4.59E-01	3.15E+07	3.57E-08
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	3.30E-04	3.18E-05	1.18E+05	3.15E+07	7.39E-03
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	4.03E-14	1.49E-04	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	3.30E-04	3.18E-05	1.18E+05	3.15E+07	3.61E-03
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	3.26E-05	1.21E+05	3.15E+07	4.44E-04
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	3.30E-04	5.70E-07	2.11E+03	3.15E+07	6.41E-06
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	3.30E-04	2.07E-05	7.66E+04	3.15E+07	1.84E-04
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	7.45E-11	2.76E-01	3.15E+07	1.02E-09
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	3.30E-04	2.96E-05	1.10E+05	3.15E+07	3.85E-06
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	3.30E-04	3.02E-05	1.12E+05	3.15E+07	3.31E-05
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	3.30E-04	1.94E-09	7.18E+00	3.15E+07	6.05E-09
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	3.30E-04	3.21E-05	1.19E+05	3.15E+07	1.01E-04
													Total	1.50E-01

MPC-68															
Off-Normal Conditions															
Committed Effective Dose Equivalent From Inhalation															
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	$L_{off\ nor}$ Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-05
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	3.30E-04	2.09E-10	7.73E-01	3.15E+07	2.98E-08
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	1.84E-08	6.81E+01	3.15E+07	1.10E-01
								Volatiles						
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	3.30E-04	2.69E-10	9.95E-01	3.15E+07	5.03E-05
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	3.30E-04	1.78E-09	6.59E+00	3.15E+07	9.10E-05
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	3.30E-04	1.08E-08	4.00E+01	3.15E+07	9.56E-04
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	3.30E-04	7.84E-09	2.90E+01	3.15E+07	2.21E-03
								Fines						
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	3.30E-04	3.06E-11	1.13E-01	3.15E+07	1.19E-06
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	3.30E-04	9.52E-12	3.52E-02	3.15E+07	2.67E-07
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	3.30E-04	3.60E-14	1.33E-04	3.15E+07	5.90E-10
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	1.97E-09	7.29E+00	3.15E+07	8.94E-06
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	1.05E-14	3.89E-05	3.15E+07	4.76E-11
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	3.30E-04	1.55E-08	5.74E+01	3.15E+07	3.06E-05
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	3.30E-04	1.04E-09	3.85E+00	3.15E+07	1.78E-06
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	3.30E-04	1.00E-09	3.70E+00	3.15E+07	1.38E-06
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	3.30E-04	4.16E-10	1.54E+00	3.15E+07	4.91E-07
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	3.30E-04	6.14E-10	2.27E+00	3.15E+07	3.97E-07
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	3.30E-04	2.67E-09	9.88E+00	3.15E+07	1.08E-06
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	3.30E-04	1.07E-10	3.96E-01	3.15E+07	3.08E-08
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	3.30E-04	9.51E-10	3.52E+00	3.15E+07	2.21E-07
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	1.49E-13	5.51E-04	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	3.30E-04	9.22E-10	3.41E+00	3.15E+07	1.05E-07
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	1.52E-08	5.62E+01	3.15E+07	2.07E-07
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	3.30E-04	9.44E-10	3.49E+00	3.15E+07	1.06E-08
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	3.30E-04	6.29E-09	2.33E+01	3.15E+07	5.58E-08
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	1.63E-11	6.03E-02	3.15E+07	2.22E-10
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	3.30E-04	1.69E-08	6.25E+01	3.15E+07	2.20E-09
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	3.30E-04	9.45E-10	3.50E+00	3.15E+07	1.04E-09
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	3.30E-04	2.49E-12	9.21E-03	3.15E+07	7.76E-12
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	3.30E-04	1.38E-09	5.11E+00	3.15E+07	4.33E-09
													Total	1.14E-01

MPC-68														
Off-Normal Conditions														
Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	$L_{off\ nor}$ Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-05
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	3.30E-04	3.14E-10	1.16E+00	3.15E+07	4.47E-08
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	3.45E-07	1.28E+03	3.15E+07	2.07E+00
								Volatiles						
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	3.30E-04	2.86E-06	1.06E+04	3.15E+07	5.35E-01
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	3.30E-04	1.04E-06	3.85E+03	3.15E+07	5.32E-02
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	3.30E-04	1.18E-08	4.37E+01	3.15E+07	1.04E-03
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	3.30E-04	8.82E-09	3.26E+01	3.15E+07	2.48E-03
								Fines						
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	3.30E-04	7.42E-09	2.75E+01	3.15E+07	2.87E-04
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	3.30E-04	8.89E-09	3.29E+01	3.15E+07	2.49E-04
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	3.30E-04	7.74E-08	2.86E+02	3.15E+07	1.27E-03
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	1.83E-07	6.77E+02	3.15E+07	8.30E-04
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	9.40E-11	3.48E-01	3.15E+07	4.26E-07
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	3.30E-04	7.92E-08	2.93E+02	3.15E+07	1.56E-04
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	3.30E-04	1.93E-05	7.14E+04	3.15E+07	3.31E-02
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	3.30E-04	1.84E-05	6.81E+04	3.15E+07	2.54E-02
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	3.30E-04	2.17E-08	8.03E+01	3.15E+07	2.56E-05
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	3.30E-04	1.19E-08	4.40E+01	3.15E+07	7.70E-06
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	3.30E-04	1.84E-05	6.81E+04	3.15E+07	7.47E-03
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	3.30E-04	4.66E-10	1.72E+00	3.15E+07	1.34E-07
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	3.30E-04	1.73E-05	6.40E+04	3.15E+07	4.02E-03
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	3.26E-09	1.21E+01	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	3.30E-04	1.73E-05	6.40E+04	3.15E+07	1.97E-03
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	1.78E-05	6.59E+04	3.15E+07	2.43E-04
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	3.30E-04	1.55E-05	5.74E+04	3.15E+07	1.74E-04
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	3.30E-04	1.94E-05	7.18E+04	3.15E+07	1.72E-04
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	2.36E-09	8.73E+00	3.15E+07	3.22E-08
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	3.30E-04	1.61E-05	5.96E+04	3.15E+07	2.09E-06
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	3.30E-04	1.64E-05	6.07E+04	3.15E+07	1.80E-05
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	3.30E-04	5.20E-08	1.92E+02	3.15E+07	1.62E-07
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	3.30E-04	4.20E-06	1.55E+04	3.15E+07	1.32E-05
													Total	2.73E+00

MPC-68														
Off-Normal Conditions														
Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	$L_{off\ nor}$ Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-05
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	3.30E-04	1.40E-10	5.18E-01	3.15E+07	1.99E-08
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	1.72E-08	6.36E+01	3.15E+07	1.03E-01
								Volatiles						
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	3.30E-04	3.28E-08	1.21E+02	3.15E+07	6.13E-03
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	3.30E-04	1.76E-09	6.51E+00	3.15E+07	9.00E-05
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	3.30E-04	1.18E-08	4.37E+01	3.15E+07	1.04E-03
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	3.30E-04	8.30E-09	3.07E+01	3.15E+07	2.34E-03
								Fines						
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	3.30E-04	3.36E-06	1.24E+04	3.15E+07	1.30E-01
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	3.30E-04	2.79E-10	1.03E+00	3.15E+07	7.82E-06
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	3.30E-04	1.61E-09	5.96E+00	3.15E+07	2.64E-05
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	2.67E-08	9.88E+01	3.15E+07	1.21E-04
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	1.38E-14	5.11E-05	3.15E+07	6.26E-11
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	3.30E-04	1.06E-07	3.92E+02	3.15E+07	2.09E-04
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	3.30E-04	9.38E-05	3.47E+05	3.15E+07	1.61E-01
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	3.30E-04	1.52E-04	5.62E+05	3.15E+07	2.10E-01
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	3.30E-04	5.35E-10	1.98E+00	3.15E+07	6.31E-07
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	3.30E-04	1.43E-08	5.29E+01	3.15E+07	9.26E-06
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	3.30E-04	1.74E-04	6.44E+05	3.15E+07	7.06E-02
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	3.30E-04	3.01E-09	1.11E+01	3.15E+07	8.66E-07
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	3.30E-04	1.69E-04	6.25E+05	3.15E+07	3.93E-02
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	1.10E-08	4.07E+01	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	3.30E-04	1.69E-04	6.25E+05	3.15E+07	1.92E-02
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	1.73E-04	6.40E+05	3.15E+07	2.36E-03
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	3.30E-04	3.90E-06	1.44E+04	3.15E+07	4.39E-05
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	3.30E-04	1.18E-04	4.37E+05	3.15E+07	1.05E-03
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	2.08E-10	7.70E-01	3.15E+07	2.83E-09
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	3.30E-04	2.62E-04	9.69E+05	3.15E+07	3.41E-05
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	3.30E-04	1.61E-04	5.96E+05	3.15E+07	1.77E-04
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	3.30E-04	1.32E-08	4.88E+01	3.15E+07	4.11E-08
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	3.30E-04	1.69E-04	6.25E+05	3.15E+07	5.30E-04
													Total	7.47E-01

MPC-68														
Off-Normal Conditions														
Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	$L_{off\ nor}$ Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-05
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	3.30E-04	1.38E-10	5.11E-01	3.15E+07	1.96E-08
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	1.35E-08	5.00E+01	3.15E+07	8.09E-02
								Volatiles						
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	3.30E-04	7.09E-08	2.62E+02	3.15E+07	1.33E-02
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	3.30E-04	1.61E-09	5.96E+00	3.15E+07	8.23E-05
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	3.30E-04	1.10E-08	4.07E+01	3.15E+07	9.74E-04
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	3.30E-04	7.94E-09	2.94E+01	3.15E+07	2.24E-03
								Fines						
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	3.30E-04	4.20E-05	1.55E+05	3.15E+07	1.63E+00
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	3.30E-04	2.78E-10	1.03E+00	3.15E+07	7.79E-06
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	3.30E-04	2.01E-08	7.44E+01	3.15E+07	3.29E-04
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	4.54E-08	1.68E+02	3.15E+07	2.06E-04
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	1.47E-14	5.44E-05	3.15E+07	6.67E-11
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	3.30E-04	5.23E-07	1.94E+03	3.15E+07	1.03E-03
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	3.30E-04	1.17E-03	4.33E+06	3.15E+07	2.01E+00
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	3.30E-04	1.90E-03	7.03E+06	3.15E+07	2.62E+00
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	3.30E-04	9.78E-10	3.62E+00	3.15E+07	1.15E-06
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	3.30E-04	1.52E-07	5.62E+02	3.15E+07	9.84E-05
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	3.30E-04	2.17E-03	8.03E+06	3.15E+07	8.80E-01
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	3.30E-04	3.21E-08	1.19E+02	3.15E+07	9.24E-06
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	3.30E-04	2.11E-03	7.81E+06	3.15E+07	4.90E-01
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	1.38E-07	5.11E+02	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	3.30E-04	2.11E-03	7.81E+06	3.15E+07	2.40E-01
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	2.17E-03	8.03E+06	3.15E+07	2.96E-02
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	3.30E-04	4.87E-05	1.80E+05	3.15E+07	5.48E-04
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	3.30E-04	1.47E-03	5.44E+06	3.15E+07	1.30E-02
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	2.03E-09	7.51E+00	3.15E+07	2.77E-08
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	3.30E-04	3.27E-03	1.21E+07	3.15E+07	4.25E-04
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	3.30E-04	2.01E-03	7.44E+06	3.15E+07	2.21E-03
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	3.30E-04	1.65E-07	6.11E+02	3.15E+07	5.14E-07
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	3.30E-04	2.12E-03	7.84E+06	3.15E+07	6.65E-03
													Total	8.02E+00

MPC-68														
Off-Normal Conditions														
Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	$L_{off\ nor}$ Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-05
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	3.30E-04	1.56E-06	5.77E+03	3.15E+07	2.22E-04
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	1.62E-08	5.99E+01	3.15E+07	9.71E-02
								Volatiles						
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	3.30E-04	2.69E-10	9.95E-01	3.15E+07	5.03E-05
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	3.30E-04	1.72E-09	6.36E+00	3.15E+07	8.80E-05
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	3.30E-04	1.11E-08	4.11E+01	3.15E+07	9.83E-04
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	3.30E-04	7.93E-09	2.93E+01	3.15E+07	2.23E-03
								Fines						
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	3.30E-04	1.24E-11	4.59E-02	3.15E+07	4.80E-07
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	3.30E-04	9.52E-12	3.52E-02	3.15E+07	2.67E-07
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	3.30E-04	1.98E-14	7.33E-05	3.15E+07	3.24E-10
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	1.88E-09	6.96E+00	3.15E+07	8.53E-06
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	8.47E-15	3.13E-05	3.15E+07	3.84E-11
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	3.30E-04	7.14E-09	2.64E+01	3.15E+07	1.41E-05
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	3.30E-04	1.01E-09	3.74E+00	3.15E+07	1.73E-06
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	3.30E-04	9.62E-10	3.56E+00	3.15E+07	1.33E-06
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	3.30E-04	3.24E-10	1.20E+00	3.15E+07	3.82E-07
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	3.30E-04	2.40E-10	8.88E-01	3.15E+07	1.55E-07
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	3.30E-04	1.60E-09	5.92E+00	3.15E+07	6.49E-07
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	3.30E-04	9.93E-11	3.67E-01	3.15E+07	2.86E-08
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	3.30E-04	9.05E-10	3.35E+00	3.15E+07	2.10E-07
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	1.32E-14	4.88E-05	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	3.30E-04	9.03E-10	3.34E+00	3.15E+07	1.03E-07
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	8.29E-09	3.07E+01	3.15E+07	1.13E-07
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	3.30E-04	9.41E-10	3.48E+00	3.15E+07	1.06E-08
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	3.30E-04	3.83E-09	1.42E+01	3.15E+07	3.40E-08
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	7.62E-12	2.82E-02	3.15E+07	1.04E-10
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	3.30E-04	1.34E-08	4.96E+01	3.15E+07	1.74E-09
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	3.30E-04	8.79E-10	3.25E+00	3.15E+07	9.65E-10
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	3.30E-04	2.52E-12	9.32E-03	3.15E+07	7.85E-12
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	3.30E-04	5.64E-10	2.09E+00	3.15E+07	1.77E-09
													Total	1.01E-01

MPC-68														
Off-Normal Conditions														
Committed Effective Dose Equivalent From Inhalation														
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	$L_{off\ nor}$ Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
								Gases						
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	3.30E-04	1.73E-11	6.40E-02	3.15E+07	2.78E-05
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	3.30E-04	4.69E-08	1.74E+02	3.15E+07	6.68E-06
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
								Crud						
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	3.30E-04	5.91E-08	2.19E+02	3.15E+07	3.54E-01
								Volatiles						
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	3.30E-04	3.51E-07	1.30E+03	3.15E+07	6.56E-02
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	3.30E-04	1.29E-07	4.77E+02	3.15E+07	6.60E-03
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	3.30E-04	1.25E-08	4.63E+01	3.15E+07	1.11E-03
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	3.30E-04	8.63E-09	3.19E+01	3.15E+07	2.43E-03
								Fines						
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	3.30E-04	2.23E-06	8.25E+03	3.15E+07	8.64E-02
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	3.30E-04	2.13E-09	7.88E+00	3.15E+07	5.97E-05
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	3.30E-04	1.06E-08	3.92E+01	3.15E+07	1.74E-04
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	5.84E-08	2.16E+02	3.15E+07	2.65E-04
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	3.30E-04	1.17E-11	4.33E-02	3.15E+07	5.31E-08
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	3.30E-04	7.73E-08	2.86E+02	3.15E+07	1.53E-04
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	3.30E-04	6.70E-05	2.48E+05	3.15E+07	1.15E-01
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	3.30E-04	1.06E-04	3.92E+05	3.15E+07	1.46E-01
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	3.30E-04	3.30E-09	1.22E+01	3.15E+07	3.90E-06
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	3.30E-04	1.12E-08	4.14E+01	3.15E+07	7.25E-06
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	3.30E-04	1.20E-04	4.44E+05	3.15E+07	4.87E-02
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	3.30E-04	1.52E-09	5.62E+00	3.15E+07	4.37E-07
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	3.30E-04	1.16E-04	4.29E+05	3.15E+07	2.70E-02
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	8.10E-09	3.00E+01	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	3.30E-04	1.16E-04	4.29E+05	3.15E+07	1.32E-02
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.30E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	1.19E-04	4.40E+05	3.15E+07	1.62E-03
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	3.30E-04	4.67E-06	1.73E+04	3.15E+07	5.25E-05
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	3.30E-04	8.30E-05	3.07E+05	3.15E+07	7.36E-04
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	3.30E-04	6.78E-10	2.51E+00	3.15E+07	9.24E-09
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	3.30E-04	1.46E-04	5.40E+05	3.15E+07	1.90E-05
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	3.30E-04	1.11E-04	4.11E+05	3.15E+07	1.22E-04
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	3.30E-04	1.58E-08	5.85E+01	3.15E+07	4.92E-08
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	3.30E-04	1.15E-04	4.26E+05	3.15E+07	3.61E-04
													Total	8.70E-01

MPC-68													
Accident Conditions													
Committed Effective Dose Equivalent From Inhalation													
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
							Gases						
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	3.30E-04	1.73E-11	6.40E-02	2.59E+06	1.63E-03
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	3.30E-04	8.69E-11	3.22E-01	2.59E+06	7.25E-07
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
							Crud						
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	3.30E-04	4.76E-09	1.76E+01	2.59E+06	1.11E+00
							Volatiles						
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	3.30E-04	2.69E-10	9.95E-01	2.59E+06	2.95E-03
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	3.30E-04	1.30E-09	4.81E+00	2.59E+06	3.90E-03
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	3.30E-04	1.30E-08	4.81E+01	2.59E+06	6.74E-02
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	3.30E-04	8.76E-09	3.24E+01	2.59E+06	1.44E-01
							Fines						
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	3.30E-04	6.82E-07	2.52E+03	2.59E+06	1.55E+00
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	3.30E-04	9.52E-12	3.52E-02	2.59E+06	1.56E-05
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	3.30E-04	8.25E-15	3.05E-05	2.59E+06	7.92E-09
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	1.93E-09	7.14E+00	2.59E+06	5.13E-04
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	2.41E-15	8.92E-06	2.59E+06	6.41E-10
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	3.30E-04	1.17E-08	4.33E+01	2.59E+06	1.35E-03
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	3.30E-04	1.59E-05	5.88E+04	2.59E+06	1.60E+00
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	3.30E-04	2.80E-05	1.04E+05	2.59E+06	2.27E+00
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	3.30E-04	3.60E-10	1.33E+00	2.59E+06	2.49E-05
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	3.30E-04	3.56E-10	1.32E+00	2.59E+06	1.35E-05
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	3.30E-04	3.25E-05	1.20E+05	2.59E+06	7.73E-01
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	3.30E-04	1.24E-10	4.59E-01	2.59E+06	2.09E-06
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	3.30E-04	3.18E-05	1.18E+05	2.59E+06	4.33E-01
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	4.03E-14	1.49E-04	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	3.30E-04	3.18E-05	1.18E+05	2.59E+06	2.12E-01
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	3.26E-05	1.21E+05	2.59E+06	2.60E-02
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	3.30E-04	5.70E-07	2.11E+03	2.59E+06	3.76E-04
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	3.30E-04	2.07E-05	7.66E+04	2.59E+06	1.08E-02
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	7.45E-11	2.76E-01	2.59E+06	5.95E-08
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	3.30E-04	2.96E-05	1.10E+05	2.59E+06	2.25E-04
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	3.30E-04	3.02E-05	1.12E+05	2.59E+06	1.94E-03
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	3.30E-04	1.94E-09	7.18E+00	2.59E+06	3.54E-07
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	3.30E-04	3.21E-05	1.19E+05	2.59E+06	5.90E-03
												Total	8.21E+00

MPC-68													
Accident Conditions													
Committed Effective Dose Equivalent From Inhalation													
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
							Gases						
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	3.30E-04	1.73E-11	6.40E-02	2.59E+06	1.63E-03
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	3.30E-04	2.09E-10	7.73E-01	2.59E+06	1.74E-06
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
							Crud						
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	3.30E-04	1.84E-08	6.81E+01	2.59E+06	4.31E+00
							Volatiles						
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	3.30E-04	2.69E-10	9.95E-01	2.59E+06	2.95E-03
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	3.30E-04	1.78E-09	6.59E+00	2.59E+06	5.33E-03
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	3.30E-04	1.08E-08	4.00E+01	2.59E+06	5.60E-02
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	3.30E-04	7.84E-09	2.90E+01	2.59E+06	1.29E-01
							Fines						
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	3.30E-04	3.06E-11	1.13E-01	2.59E+06	6.94E-05
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	3.30E-04	9.52E-12	3.52E-02	2.59E+06	1.56E-05
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	3.30E-04	3.60E-14	1.33E-04	2.59E+06	3.45E-08
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	1.97E-09	7.29E+00	2.59E+06	5.24E-04
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	1.05E-14	3.89E-05	2.59E+06	2.79E-09
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	3.30E-04	1.55E-08	5.74E+01	2.59E+06	1.79E-03
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	3.30E-04	1.04E-09	3.85E+00	2.59E+06	1.05E-04
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	3.30E-04	1.00E-09	3.70E+00	2.59E+06	8.09E-05
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	3.30E-04	4.16E-10	1.54E+00	2.59E+06	2.88E-05
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	3.30E-04	6.14E-10	2.27E+00	2.59E+06	2.33E-05
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	3.30E-04	2.67E-09	9.88E+00	2.59E+06	6.35E-05
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	3.30E-04	1.07E-10	3.96E-01	2.59E+06	1.80E-06
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	3.30E-04	9.51E-10	3.52E+00	2.59E+06	1.29E-05
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	1.49E-13	5.51E-04	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	3.30E-04	9.22E-10	3.41E+00	2.59E+06	6.14E-06
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	1.52E-08	5.62E+01	2.59E+06	1.21E-05
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	3.30E-04	9.44E-10	3.49E+00	2.59E+06	6.22E-07
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	3.30E-04	6.29E-09	2.33E+01	2.59E+06	3.27E-06
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	1.63E-11	6.03E-02	2.59E+06	1.30E-08
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	3.30E-04	1.69E-08	6.25E+01	2.59E+06	1.29E-07
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	3.30E-04	9.45E-10	3.50E+00	2.59E+06	6.08E-08
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	3.30E-04	2.49E-12	9.21E-03	2.59E+06	4.55E-10
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	3.30E-04	1.38E-09	5.11E+00	2.59E+06	2.53E-07
												Total	4.51E+00

MPC-68													
Accident Conditions													
Committed Effective Dose Equivalent From Inhalation													
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
							Gases						
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	3.30E-04	1.73E-11	6.40E-02	2.59E+06	1.63E-03
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	3.30E-04	3.14E-10	1.16E+00	2.59E+06	2.62E-06
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
							Crud						
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	3.30E-04	3.45E-07	1.28E+03	2.59E+06	8.08E+01
							Volatiles						
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	3.30E-04	2.86E-06	1.06E+04	2.59E+06	3.13E+01
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	3.30E-04	1.04E-06	3.85E+03	2.59E+06	3.12E+00
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	3.30E-04	1.18E-08	4.37E+01	2.59E+06	6.12E-02
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	3.30E-04	8.82E-09	3.26E+01	2.59E+06	1.45E-01
							Fines						
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	3.30E-04	7.42E-09	2.75E+01	2.59E+06	1.68E-02
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	3.30E-04	8.89E-09	3.29E+01	2.59E+06	1.46E-02
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	3.30E-04	7.74E-08	2.86E+02	2.59E+06	7.43E-02
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	1.83E-07	6.77E+02	2.59E+06	4.86E-02
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	9.40E-11	3.48E-01	2.59E+06	2.50E-05
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	3.30E-04	7.92E-08	2.93E+02	2.59E+06	9.16E-03
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	3.30E-04	1.93E-05	7.14E+04	2.59E+06	1.94E+00
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	3.30E-04	1.84E-05	6.81E+04	2.59E+06	1.49E+00
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	3.30E-04	2.17E-08	8.03E+01	2.59E+06	1.50E-03
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	3.30E-04	1.19E-08	4.40E+01	2.59E+06	4.51E-04
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	3.30E-04	1.84E-05	6.81E+04	2.59E+06	4.37E-01
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	3.30E-04	4.66E-10	1.72E+00	2.59E+06	7.85E-06
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	3.30E-04	1.73E-05	6.40E+04	2.59E+06	2.36E-01
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	3.26E-09	1.21E+01	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	3.30E-04	1.73E-05	6.40E+04	2.59E+06	1.15E-01
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	1.78E-05	6.59E+04	2.59E+06	1.42E-02
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	3.30E-04	1.55E-05	5.74E+04	2.59E+06	1.02E-02
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	3.30E-04	1.94E-05	7.18E+04	2.59E+06	1.01E-02
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	2.36E-09	8.73E+00	2.59E+06	1.88E-06
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	3.30E-04	1.61E-05	5.96E+04	2.59E+06	1.23E-04
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	3.30E-04	1.64E-05	6.07E+04	2.59E+06	1.05E-03
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	3.30E-04	5.20E-08	1.92E+02	2.59E+06	9.50E-06
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	3.30E-04	4.20E-06	1.55E+04	2.59E+06	7.71E-04
												Total	1.20E+02

MPC-68 Accident Conditions Committed Effective Dose Equivalent From Inhalation													
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
							Gases						
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	3.30E-04	1.73E-11	6.40E-02	2.59E+06	1.63E-03
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	3.30E-04	1.40E-10	5.18E-01	2.59E+06	1.17E-06
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
							Crud						
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	3.30E-04	1.72E-08	6.36E+01	2.59E+06	4.03E+00
							Volatiles						
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	3.30E-04	3.28E-08	1.21E+02	2.59E+06	3.59E-01
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	3.30E-04	1.76E-09	6.51E+00	2.59E+06	5.27E-03
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	3.30E-04	1.18E-08	4.37E+01	2.59E+06	6.12E-02
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	3.30E-04	8.30E-09	3.07E+01	2.59E+06	1.37E-01
							Fines						
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	3.30E-04	3.36E-06	1.24E+04	2.59E+06	7.62E+00
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03.	3.30E-04	2.79E-10	1.03E+00	2.59E+06	4.58E-04
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	3.30E-04	1.61E-09	5.96E+00	2.59E+06	1.54E-03
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	2.67E-08	9.88E+01	2.59E+06	7.10E-03
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	1.38E-14	5.11E-05	2.59E+06	3.67E-09
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	3.30E-04	1.06E-07	3.92E+02	2.59E+06	1.23E-02
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	3.30E-04	9.38E-05	3.47E+05	2.59E+06	9.43E+00
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	3.30E-04	1.52E-04	5.62E+05	2.59E+06	1.23E+01
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	3.30E-04	5.35E-10	1.98E+00	2.59E+06	3.70E-05
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	3.30E-04	1.43E-08	5.29E+01	2.59E+06	5.42E-04
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	3.30E-04	1.74E-04	6.44E+05	2.59E+06	4.14E+00
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	3.30E-04	3.01E-09	1.11E+01	2.59E+06	5.07E-05
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	3.30E-04	1.69E-04	6.25E+05	2.59E+06	2.30E+00
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	1.10E-08	4.07E+01	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	3.30E-04	1.69E-04	6.25E+05	2.59E+06	1.12E+00
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	1.73E-04	6.40E+05	2.59E+06	1.38E-01
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	3.30E-04	3.90E-06	1.44E+04	2.59E+06	2.57E-03
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	3.30E-04	1.18E-04	4.37E+05	2.59E+06	6.13E-02
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	2.08E-10	7.70E-01	2.59E+06	1.66E-07
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	3.30E-04	2.62E-04	9.69E+05	2.59E+06	2.00E-03
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	3.30E-04	1.61E-04	5.96E+05	2.59E+06	1.04E-02
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	3.30E-04	1.32E-08	4.88E+01	2.59E+06	2.41E-06
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	3.30E-04	1.69E-04	6.25E+05	2.59E+06	3.10E-02
												Total	4.18E+01

MPC-68													
Accident Conditions													
Committed Effective Dose Equivalent From Inhalation													
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
							Gases						
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	3.30E-04	1.73E-11	6.40E-02	2.59E+06	1.63E-03
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	3.30E-04	1.38E-10	5.11E-01	2.59E+06	1.15E-06
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
							Crud						
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	3.30E-04	1.35E-08	5.00E+01	2.59E+06	3.16E+00
							Volatiles						
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	3.30E-04	7.09E-08	2.62E+02	2.59E+06	7.76E-01
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	3.30E-04	1.61E-09	5.96E+00	2.59E+06	4.82E-03
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	3.30E-04	1.10E-08	4.07E+01	2.59E+06	5.70E-02
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	3.30E-04	7.94E-09	2.94E+01	2.59E+06	1.31E-01
							Fines						
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	3.30E-04	4.20E-05	1.55E+05	2.59E+06	9.53E+01
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	3.30E-04	2.78E-10	1.03E+00	2.59E+06	4.57E-04
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	3.30E-04	2.01E-08	7.44E+01	2.59E+06	1.93E-02
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	4.54E-08	1.68E+02	2.59E+06	1.21E-02
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	1.47E-14	5.44E-05	2.59E+06	3.91E-09
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	3.30E-04	5.23E-07	1.94E+03	2.59E+06	6.05E-02
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	3.30E-04	1.17E-03	4.33E+06	2.59E+06	1.18E+02
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	3.30E-04	1.90E-03	7.03E+06	2.59E+06	1.54E+02
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	3.30E-04	9.78E-10	3.62E+00	2.59E+06	6.76E-05
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	3.30E-04	1.52E-07	5.62E+02	2.59E+06	5.76E-03
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	3.30E-04	2.17E-03	8.03E+06	2.59E+06	5.16E+01
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	3.30E-04	3.21E-08	1.19E+02	2.59E+06	5.41E-04
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	3.30E-04	2.11E-03	7.81E+06	2.59E+06	2.87E+01
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	1.38E-07	5.11E+02	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	3.30E-04	2.11E-03	7.81E+06	2.59E+06	1.40E+01
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	2.17E-03	8.03E+06	2.59E+06	1.73E+00
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	3.30E-04	4.87E-05	1.80E+05	2.59E+06	3.21E-02
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	3.30E-04	1.47E-03	5.44E+06	2.59E+06	7.64E-01
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	2.03E-09	7.51E+00	2.59E+06	1.62E-06
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	3.30E-04	3.27E-03	1.21E+07	2.59E+06	2.49E-02
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	3.30E-04	2.01E-03	7.44E+06	2.59E+06	1.29E-01
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	3.30E-04	1.65E-07	6.11E+02	2.59E+06	3.01E-05
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	3.30E-04	2.12E-03	7.84E+06	2.59E+06	3.89E-01
												Total	4.68E+02

MPC-68													
Accident Conditions													
Committed Effective Dose Equivalent From Inhalation													
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
							Gases						
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	3.30E-04	1.73E-11	6.40E-02	2.59E+06	1.63E-03
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	3.30E-04	1.56E-06	5.77E+03	2.59E+06	1.30E-02
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
							Crud						
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	3.30E-04	1.62E-08	5.99E+01	2.59E+06	3.79E+00
							Volatiles						
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	3.30E-04	2.69E-10	9.95E-01	2.59E+06	2.95E-03
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	3.30E-04	1.72E-09	6.36E+00	2.59E+06	5.15E-03
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	3.30E-04	1.11E-08	4.11E+01	2.59E+06	5.76E-02
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	3.30E-04	7.93E-09	2.93E+01	2.59E+06	1.31E-01
							Fines						
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	3.30E-04	1.24E-11	4.59E-02	2.59E+06	2.81E-05
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	3.30E-04	9.52E-12	3.52E-02	2.59E+06	1.56E-05
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	3.30E-04	1.98E-14	7.33E-05	2.59E+06	1.90E-08
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	1.88E-09	6.96E+00	2.59E+06	5.00E-04
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	8.47E-15	3.13E-05	2.59E+06	2.25E-09
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	3.30E-04	7.14E-09	2.64E+01	2.59E+06	8.25E-04
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	3.30E-04	1.01E-09	3.74E+00	2.59E+06	1.01E-04
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	3.30E-04	9.62E-10	3.56E+00	2.59E+06	7.79E-05
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	3.30E-04	3.24E-10	1.20E+00	2.59E+06	2.24E-05
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	3.30E-04	2.40E-10	8.88E-01	2.59E+06	9.10E-06
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	3.30E-04	1.60E-09	5.92E+00	2.59E+06	3.80E-05
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	3.30E-04	9.93E-11	3.67E-01	2.59E+06	1.67E-06
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	3.30E-04	9.05E-10	3.35E+00	2.59E+06	1.23E-05
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	1.32E-14	4.88E-05	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	3.30E-04	9.03E-10	3.34E+00	2.59E+06	6.01E-06
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	8.29E-09	3.07E+01	2.59E+06	6.62E-06
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	3.30E-04	9.41E-10	3.48E+00	2.59E+06	6.20E-07
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	3.30E-04	3.83E-09	1.42E+01	2.59E+06	1.99E-06
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	7.62E-12	2.82E-02	2.59E+06	6.08E-09
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	3.30E-04	1.34E-08	4.96E+01	2.59E+06	1.02E-07
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	3.30E-04	8.79E-10	3.25E+00	2.59E+06	5.65E-08
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	3.30E-04	2.52E-12	9.32E-03	2.59E+06	4.60E-10
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	3.30E-04	5.64E-10	2.09E+00	2.59E+06	1.04E-07
												Total	4.01E+00

MPC-68													
Accident Conditions													
Committed Effective Dose Equivalent From Inhalation													
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	Breathing Rate (m3/sec)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	CEDE (mRem)
							Gases						
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	3.30E-04	1.73E-11	6.40E-02	2.59E+06	1.63E-03
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	3.30E-04	4.69E-08	1.74E+02	2.59E+06	3.91E-04
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
							Crud						
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	3.30E-04	5.91E-08	2.19E+02	2.59E+06	1.38E+01
							Volatiles						
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	3.30E-04	3.51E-07	1.30E+03	2.59E+06	3.84E+00
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	3.30E-04	1.29E-07	4.77E+02	2.59E+06	3.87E-01
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	3.30E-04	1.25E-08	4.63E+01	2.59E+06	6.48E-02
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	3.30E-04	8.63E-09	3.19E+01	2.59E+06	1.42E-01
							Fines						
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	3.30E-04	2.23E-06	8.25E+03	2.59E+06	5.06E+00
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	3.30E-04	2.13E-09	7.88E+00	2.59E+06	3.50E-03
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	3.30E-04	1.06E-08	3.92E+01	2.59E+06	1.02E-02
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	5.84E-08	2.16E+02	2.59E+06	1.55E-02
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	3.30E-04	1.17E-11	4.33E-02	2.59E+06	3.11E-06
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	3.30E-04	7.73E-08	2.86E+02	2.59E+06	8.94E-03
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	3.30E-04	6.70E-05	2.48E+05	2.59E+06	6.73E+00
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	3.30E-04	1.06E-04	3.92E+05	2.59E+06	8.58E+00
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	3.30E-04	3.30E-09	1.22E+01	2.59E+06	2.28E-04
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	3.30E-04	1.12E-08	4.14E+01	2.59E+06	4.25E-04
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	3.30E-04	1.20E-04	4.44E+05	2.59E+06	2.85E+00
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	3.30E-04	1.52E-09	5.62E+00	2.59E+06	2.56E-05
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	3.30E-04	1.16E-04	4.29E+05	2.59E+06	1.58E+00
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	8.10E-09	3.00E+01	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	3.30E-04	1.16E-04	4.29E+05	2.59E+06	7.72E-01
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.30E-04	0.00E+00	0.00E+00	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	1.19E-04	4.40E+05	2.59E+06	9.50E-02
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	3.30E-04	4.67E-06	1.73E+04	2.59E+06	3.08E-03
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	3.30E-04	8.30E-05	3.07E+05	2.59E+06	4.31E-02
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	3.30E-04	6.78E-10	2.51E+00	2.59E+06	5.41E-07
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	3.30E-04	1.46E-04	5.40E+05	2.59E+06	1.11E-03
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	3.30E-04	1.11E-04	4.11E+05	2.59E+06	7.14E-03
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	3.30E-04	1.58E-08	5.85E+01	2.59E+06	2.89E-06
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	3.30E-04	1.15E-04	4.26E+05	2.59E+06	2.11E-02
												Total	4.41E+01

Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
MPC-68													
Normal Conditions													
Effective Dose Equivalent From Submersion													
								Gases					
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	4.83E-16	1.79E-06	3.15E+07	2.08E-11
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	1.17E-16	4.33E-07	3.15E+07	9.35E-07
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.23E-13	4.55E-04	3.15E+07	2.23E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	7.78E-18	2.88E-08	3.15E+07	4.41E-10
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	7.40E-14	2.74E-04	3.15E+07	1.99E-06
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	7.96E-18	2.95E-08	3.15E+07	6.79E-10
								Fines					
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	7.19E-20	2.66E-10	3.15E+07	8.44E-13
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	1.89E-16	6.99E-07	3.15E+07	1.61E-09
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	7.48E-19	2.77E-09	3.15E+07	3.71E-12
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	8.53E-16	3.16E-06	3.15E+07	1.17E-09
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	1.90E-15	7.03E-06	3.15E+07	2.61E-09
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	6.00E-14	2.22E-04	3.15E+07	3.59E-08
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	6.90E-18	2.55E-08	3.15E+07	3.59E-12
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	6.56E-18	2.43E-08	3.15E+07	2.75E-12
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	1.98E-14	7.33E-05	3.15E+07	7.08E-09
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	2.49E-15	9.21E-06	3.15E+07	4.88E-10
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	8.58E-16	3.17E-06	3.15E+07	1.05E-10
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	5.96E-16	2.21E-06	3.15E+07	5.20E-11
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	6.36E-18	2.35E-08	3.15E+07	4.48E-13
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	5.20E-20	1.92E-10	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	4.84E-18	1.79E-08	3.15E+07	1.67E-13
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	2.82E-14	1.04E-04	3.15E+07	3.40E-07
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	1.01E-14	3.74E-05	3.15E+07	2.35E-08
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.25E-16	1.20E-06	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	2.19E-15	8.10E-06	3.15E+07	9.04E-12
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	7.83E-18	2.90E-08	3.15E+07	2.67E-14
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	5.77E-15	2.13E-05	3.15E+07	1.55E-11
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	7.53E-15	2.79E-05	3.15E+07	3.11E-11
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	1.04E-15	3.85E-06	3.15E+07	4.10E-14
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	5.34E-18	1.98E-08	3.15E+07	1.78E-15
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	6.09E-16	2.25E-06	3.15E+07	5.75E-13
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	3.80E-17	1.41E-07	3.15E+07	3.61E-14
												Total	2.24E-03

MPC-68													
Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	6.66E-16	2.46E-06	3.15E+07	2.87E-11
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	1.34E-16	4.96E-07	3.15E+07	1.07E-06
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.39E-13	5.14E-04	3.15E+07	2.52E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	9.49E-18	3.51E-08	3.15E+07	5.37E-10
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	8.43E-14	3.12E-04	3.15E+07	2.26E-06
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	9.67E-18	3.58E-08	3.15E+07	8.25E-10
								Fines					
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	8.67E-20	3.21E-10	3.15E+07	1.02E-12
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	2.20E-16	8.14E-07	3.15E+07	1.87E-09
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	9.56E-19	3.54E-09	3.15E+07	4.74E-12
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	1.01E-15	3.74E-06	3.15E+07	1.39E-09
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	2.15E-15	7.96E-06	3.15E+07	2.96E-09
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	6.81E-14	2.52E-04	3.15E+07	4.07E-08
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	1.33E-17	4.92E-08	3.15E+07	6.91E-12
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	1.27E-17	4.70E-08	3.15E+07	5.32E-12
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	2.27E-14	8.40E-05	3.15E+07	8.12E-09
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	2.95E-15	1.09E-05	3.15E+07	5.79E-10
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	1.07E-15	3.96E-06	3.15E+07	1.32E-10
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	8.48E-16	3.14E-06	3.15E+07	7.39E-11
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	1.23E-17	4.55E-08	3.15E+07	8.66E-13
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	8.80E-20	3.26E-10	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	7.55E-18	2.79E-08	3.15E+07	2.60E-13
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	3.22E-14	1.19E-04	3.15E+07	3.89E-07
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	1.16E-14	4.29E-05	3.15E+07	2.70E-08
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	4.20E-16	1.55E-06	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	2.61E-15	9.66E-06	3.15E+07	1.08E-11
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	1.48E-17	5.48E-08	3.15E+07	5.05E-14
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	6.68E-15	2.47E-05	3.15E+07	1.80E-11
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	8.73E-15	3.23E-05	3.15E+07	3.61E-11
237Np	7.05E-02	1.01E+00	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.13E-16	1.60E-04	1.26E-15	4.66E-06	3.15E+07	5.01E-12
242Pu	5.95E-01	2.01E+00	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.58E-15	1.60E-04	1.03E-17	3.81E-08	3.15E+07	6.88E-13
242Am	1.69E+00	3.01E+00	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.52E-14	1.60E-04	7.30E-16	2.70E-06	3.15E+07	2.08E-10
242mAm	1.70E+00	4.01E+00	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.04E-14	1.60E-04	6.01E-17	2.22E-07	3.15E+07	2.29E-11
												Total	2.53E-03

MPC-68													
Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	2.75E-18	1.02E-08	3.15E+07	1.34E-09
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	2.14E-16	7.92E-07	3.15E+07	9.23E-12
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	1.14E-16	4.22E-07	3.15E+07	9.11E-07
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.24E-13	4.59E-04	3.15E+07	2.25E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	6.44E-18	2.38E-08	3.15E+07	3.65E-10
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	7.37E-14	2.73E-04	3.15E+07	1.98E-06
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	6.68E-18	2.47E-08	3.15E+07	5.70E-10
								Fines					
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	6.48E-20	2.40E-10	3.15E+07	7.61E-13
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	1.77E-16	6.55E-07	3.15E+07	1.50E-09
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	5.45E-19	2.02E-09	3.15E+07	2.70E-12
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	7.69E-16	2.85E-06	3.15E+07	1.06E-09
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	1.90E-15	7.03E-06	3.15E+07	2.61E-09
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	5.99E-14	2.22E-04	3.15E+07	3.58E-08
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	7.08E-19	2.62E-09	3.15E+07	3.68E-13
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	1.06E-18	3.92E-09	3.15E+07	4.44E-13
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	1.95E-14	7.22E-05	3.15E+07	6.97E-09
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	2.22E-15	8.21E-06	3.15E+07	4.35E-10
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	6.74E-16	2.49E-06	3.15E+07	8.29E-11
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	2.23E-16	8.25E-07	3.15E+07	1.94E-11
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	1.09E-18	4.03E-09	3.15E+07	7.68E-14
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	7.08E-21	2.62E-11	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	2.65E-18	9.81E-09	3.15E+07	9.12E-14
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	2.80E-14	1.04E-04	3.15E+07	3.38E-07
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	1.01E-14	3.74E-05	3.15E+07	2.35E-08
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	2.00E-16	7.40E-07	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	1.92E-15	7.10E-06	3.15E+07	7.93E-12
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	1.13E-18	4.18E-09	3.15E+07	3.85E-15
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	5.50E-15	2.04E-05	3.15E+07	1.48E-11
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	7.18E-15	2.66E-05	3.15E+07	2.97E-11
237Np	7.05E-02	1.01E+00	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.13E-16	1.60E-04	9.02E-16	3.34E-06	3.15E+07	3.59E-12
242Pu	5.95E-01	2.01E+00	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.58E-15	1.60E-04	9.69E-19	3.59E-09	3.15E+07	6.48E-14
242Am	1.69E+00	3.01E+00	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.52E-14	1.60E-04	5.51E-15	2.04E-05	3.15E+07	1.57E-09
242mAm	1.70E+00	4.01E+00	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.04E-14	1.60E-04	1.72E-17	6.36E-08	3.15E+07	6.55E-12
												Total	2.26E-03

MPC-68													
Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	1.64E-16	6.07E-07	3.15E+07	7.08E-12
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	1.09E-16	4.03E-07	3.15E+07	8.71E-07
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.23E-13	4.55E-04	3.15E+07	2.23E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	5.44E-18	2.01E-08	3.15E+07	3.08E-10
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	7.19E-14	2.66E-04	3.15E+07	1.93E-06
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	5.70E-18	2.11E-08	3.15E+07	4.86E-10
								Fines					
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	5.63E-20	2.08E-10	3.15E+07	6.61E-13
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	1.62E-16	5.99E-07	3.15E+07	1.38E-09
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	4.46E-19	1.65E-09	3.15E+07	2.21E-12
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	6.68E-16	2.47E-06	3.15E+07	9.18E-10
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	1.87E-15	6.92E-06	3.15E+07	2.57E-09
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	5.87E-14	2.17E-04	3.15E+07	3.51E-08
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	1.46E-18	5.40E-09	3.15E+07	7.59E-13
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	1.68E-18	6.22E-09	3.15E+07	7.03E-13
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	1.87E-14	6.92E-05	3.15E+07	6.69E-09
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	1.85E-15	6.85E-06	3.15E+07	3.63E-10
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	5.21E-16	1.93E-06	3.15E+07	6.41E-11
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	1.86E-16	6.88E-07	3.15E+07	1.62E-11
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	1.65E-18	6.11E-09	3.15E+07	1.16E-13
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	1.13E-20	4.18E-11	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	2.67E-18	9.88E-09	3.15E+07	9.19E-14
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	2.73E-14	1.01E-04	3.15E+07	3.30E-07
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	9.75E-15	3.61E-05	3.15E+07	2.27E-08
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	1.56E-16	5.77E-07	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	1.55E-15	5.74E-06	3.15E+07	6.40E-12
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	1.89E-18	6.99E-09	3.15E+07	6.44E-15
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	5.00E-15	1.85E-05	3.15E+07	1.34E-11
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	6.50E-15	2.41E-05	3.15E+07	2.68E-11
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	7.69E-16	2.85E-06	3.15E+07	3.03E-14
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	1.43E-18	5.29E-09	3.15E+07	4.76E-16
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	4.77E-16	1.76E-06	3.15E+07	4.51E-13
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	1.72E-17	6.36E-08	3.15E+07	1.63E-14
												Total	2.24E-03

MPC-68													
Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	1.10E-15	4.07E-06	3.15E+07	4.75E-11
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	2.20E-16	8.14E-07	3.15E+07	1.76E-06
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.78E-13	6.59E-04	3.15E+07	3.23E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	2.28E-17	8.44E-08	3.15E+07	1.29E-09
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	1.20E-13	4.44E-04	3.15E+07	3.22E-06
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	2.29E-17	8.47E-08	3.15E+07	1.95E-09
								Fines					
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	2.19E-19	8.10E-10	3.15E+07	2.57E-12
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	4.44E-16	1.64E-06	3.15E+07	3.77E-09
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	2.18E-18	8.07E-09	3.15E+07	1.08E-11
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	2.49E-15	9.21E-06	3.15E+07	3.42E-09
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	2.99E-15	1.11E-05	3.15E+07	4.11E-09
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	9.43E-14	3.49E-04	3.15E+07	5.64E-08
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	8.82E-18	3.26E-08	3.15E+07	4.58E-12
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	9.30E-18	3.44E-08	3.15E+07	3.89E-12
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	3.53E-14	1.31E-04	3.15E+07	1.26E-08
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	8.09E-15	2.99E-05	3.15E+07	1.59E-09
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	2.87E-15	1.06E-05	3.15E+07	3.53E-10
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	1.22E-15	4.51E-06	3.15E+07	1.06E-10
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	9.26E-18	3.43E-08	3.15E+07	6.52E-13
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	7.09E-20	2.62E-10	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	9.47E-18	3.50E-08	3.15E+07	3.26E-13
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	4.63E-14	1.71E-04	3.15E+07	5.59E-07
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	1.72E-14	6.36E-05	3.15E+07	4.00E-08
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	8.16E-16	3.02E-06	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	7.47E-15	2.76E-05	3.15E+07	3.09E-11
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	1.06E-17	3.92E-08	3.15E+07	3.61E-14
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	1.50E-14	5.55E-05	3.15E+07	4.03E-11
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	2.00E-14	7.40E-05	3.15E+07	8.26E-11
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	3.20E-15	1.18E-05	3.15E+07	1.26E-13
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	7.90E-18	2.92E-08	3.15E+07	2.63E-15
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	1.88E-15	6.96E-06	3.15E+07	1.78E-12
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	7.94E-17	2.94E-07	3.15E+07	7.54E-14
												Total	3.24E-03

MPC-68													
Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	3.86E-16	1.43E-06	3.15E+07	1.67E-11
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	1.18E-16	4.37E-07	3.15E+07	9.43E-07
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.27E-13	4.70E-04	3.15E+07	2.31E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	7.33E-18	2.71E-08	3.15E+07	4.15E-10
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	7.57E-14	2.80E-04	3.15E+07	2.03E-06
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	7.55E-18	2.79E-08	3.15E+07	6.44E-10
								Fines					
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	6.98E-20	2.58E-10	3.15E+07	8.19E-13
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	1.87E-16	6.92E-07	3.15E+07	1.59E-09
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	6.75E-19	2.50E-09	3.15E+07	3.35E-12
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	8.33E-16	3.08E-06	3.15E+07	1.15E-09
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	1.95E-15	7.22E-06	3.15E+07	2.68E-09
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	6.15E-14	2.28E-04	3.15E+07	3.68E-08
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	4.19E-18	1.55E-08	3.15E+07	2.18E-12
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	4.01E-18	1.48E-08	3.15E+07	1.68E-12
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	2.01E-14	7.44E-05	3.15E+07	7.19E-09
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	2.41E-15	8.92E-06	3.15E+07	4.73E-10
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	7.83E-16	2.90E-06	3.15E+07	9.63E-11
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	4.64E-16	1.72E-06	3.15E+07	4.05E-11
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	3.92E-18	1.45E-08	3.15E+07	2.76E-13
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.58E-20	1.32E-10	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	3.88E-18	1.44E-08	3.15E+07	1.34E-13
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	2.88E-14	1.07E-04	3.15E+07	3.48E-07
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	1.03E-14	3.81E-05	3.15E+07	2.39E-08
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	2.81E-16	1.04E-06	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	2.09E-15	7.73E-06	3.15E+07	8.63E-12
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	4.91E-18	1.82E-08	3.15E+07	1.67E-14
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	5.76E-15	2.13E-05	3.15E+07	1.55E-11
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	7.52E-15	2.78E-05	3.15E+07	3.11E-11
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	9.94E-16	3.68E-06	3.15E+07	3.92E-14
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	3.32E-18	1.23E-08	3.15E+07	1.10E-15
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	5.94E-16	2.20E-06	3.15E+07	5.61E-13
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	2.95E-17	1.09E-07	3.15E+07	2.80E-14
												Total	2.31E-03

MPC-68													
Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	3.31E-19	1.22E-09	3.15E+07	1.61E-10
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	3.80E-16	1.41E-06	3.15E+07	1.64E-11
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	1.19E-16	4.40E-07	3.15E+07	9.51E-07
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.26E-13	4.66E-04	3.15E+07	2.29E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	7.53E-18	2.79E-08	3.15E+07	4.26E-10
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	7.57E-14	2.80E-04	3.15E+07	2.03E-06
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	7.74E-18	2.86E-08	3.15E+07	6.60E-10
								Fines					
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	7.25E-20	2.68E-10	3.15E+07	8.51E-13
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	1.90E-16	7.03E-07	3.15E+07	1.61E-09
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	6.93E-19	2.56E-09	3.15E+07	3.44E-12
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	8.53E-16	3.16E-06	3.15E+07	1.17E-09
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	1.95E-15	7.22E-06	3.15E+07	2.68E-09
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	6.14E-14	2.27E-04	3.15E+07	3.67E-08
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	4.91E-18	1.82E-08	3.15E+07	2.55E-12
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	4.88E-18	1.81E-08	3.15E+07	2.04E-12
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	2.02E-14	7.47E-05	3.15E+07	7.23E-09
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	2.49E-15	9.21E-06	3.15E+07	4.88E-10
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	8.18E-16	3.03E-06	3.15E+07	1.01E-10
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	4.53E-16	1.68E-06	3.15E+07	3.95E-11
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	4.75E-18	1.76E-08	3.15E+07	3.34E-13
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.61E-20	1.34E-10	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	4.24E-18	1.57E-08	3.15E+07	1.46E-13
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	2.88E-14	1.07E-04	3.15E+07	3.48E-07
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	1.04E-14	3.85E-05	3.15E+07	2.42E-08
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	2.79E-16	1.03E-06	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	2.18E-15	8.07E-06	3.15E+07	9.00E-12
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	5.69E-18	2.11E-08	3.15E+07	1.94E-14
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	5.88E-15	2.18E-05	3.15E+07	1.58E-11
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	7.69E-15	2.85E-05	3.15E+07	3.18E-11
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	1.03E-15	3.81E-06	3.15E+07	4.06E-14
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	4.01E-18	1.48E-08	3.15E+07	1.33E-15
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	6.15E-16	2.28E-06	3.15E+07	5.81E-13
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	3.17E-17	1.17E-07	3.15E+07	3.01E-14
												Total	2.29E-03

MPC-68 Normal Conditions Effective Dose Equivalent From Submersion														
Nuclide	Inventory (Ci/Assy)	1% for normal storage	No. Assy	MPC Vol (cm3)	L_{nor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-11	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
I-129	7.72E-03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-15	1.60E-04	1.10E-15	4.07E-06	3.15E+07	4.75E-11
Kr-85	1.43E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-10	1.60E-04	1.32E-14	4.88E-05	3.15E+07	1.05E-04
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.45E-13	5.37E-04	3.15E+07	2.63E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-12	1.60E-04	9.20E-15	3.40E-05	3.15E+07	5.21E-07
Ru-106	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-13	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-12	1.60E-04	9.45E-14	3.50E-04	3.15E+07	2.54E-06
Cs-137	2.29E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-12	1.60E-04	8.63E-15	3.19E-05	3.15E+07	7.36E-07
								Fines					
PU241	2.10E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-13	1.60E-04	1.17E-19	4.33E-10	3.15E+07	1.37E-12
Y 90	1.52E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-13	1.60E-04	6.24E-14	2.31E-04	3.15E+07	5.30E-07
PM147	8.88E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-13	1.60E-04	8.11E-16	3.00E-06	3.15E+07	4.02E-09
CE144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	2.93E-15	1.08E-05	3.15E+07	4.03E-09
PR144	2.46E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-14	1.60E-04	8.43E-14	3.12E-04	3.15E+07	1.16E-07
EU154	1.07E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-14	1.60E-04	8.29E-14	3.07E-04	3.15E+07	4.96E-08
CM244	9.30E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-14	1.60E-04	3.91E-17	1.45E-07	3.15E+07	2.03E-11
PU238	7.49E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-14	1.60E-04	4.09E-17	1.51E-07	3.15E+07	1.71E-11
SB125	6.40E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-14	1.60E-04	2.65E-14	9.81E-05	3.15E+07	9.48E-09
EU155	3.51E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-14	1.60E-04	3.39E-15	1.25E-05	3.15E+07	6.65E-10
AM241	2.20E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-15	1.60E-04	1.28E-15	4.74E-06	3.15E+07	1.57E-10
TE125M	1.56E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-15	1.60E-04	1.94E-15	7.18E-06	3.15E+07	1.69E-10
PU240	1.26E+02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-15	1.60E-04	3.92E-17	1.45E-07	3.15E+07	2.76E-12
151Sm	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	1.90E-20	7.03E-11	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-15	1.60E-04	1.86E-17	6.88E-08	3.15E+07	6.40E-13
137mBa	2.16E+04	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-13	1.60E-04	3.73E-14	1.38E-04	3.15E+07	4.50E-07
106Rh	4.16E+03	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-13	1.60E-04	1.09E-13	4.03E-04	3.15E+07	2.53E-07
144mPr	0.00E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	5.08E-16	1.88E-06	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	2.75E-15	1.02E-05	3.15E+07	1.14E-11
242Cm	6.10E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-16	1.60E-04	4.29E-17	1.59E-07	3.15E+07	1.46E-13
243Cm	4.81E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-16	1.60E-04	9.79E-15	3.62E-05	3.15E+07	2.63E-11
239Np	7.39E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-16	1.60E-04	1.60E-14	5.92E-05	3.15E+07	6.61E-11
237Np	7.05E-02	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-18	1.60E-04	1.54E-15	5.70E-06	3.15E+07	6.07E-14
242Pu	5.95E-01	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-17	1.60E-04	3.27E-17	1.21E-07	3.15E+07	1.09E-14
242Am	1.69E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-17	1.60E-04	8.20E-15	3.03E-05	3.15E+07	7.74E-12
242mAm	1.70E+00	1.00E-02	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-17	1.60E-04	1.36E-16	5.03E-07	3.15E+07	1.29E-13
												Total	2.74E-03

MPC-68													
Off-Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	L_{offnor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	4.83E-16	1.79E-06	3.15E+07	2.08E-10
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	1.17E-16	4.33E-07	3.15E+07	9.35E-06
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.23E-13	4.55E-04	3.15E+07	2.23E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	7.78E-18	2.88E-08	3.15E+07	4.41E-09
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	7.40E-14	2.74E-04	3.15E+07	1.99E-05
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	7.96E-18	2.95E-08	3.15E+07	6.79E-09
								Fines					
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	7.19E-20	2.66E-10	3.15E+07	8.44E-12
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	1.89E-16	6.99E-07	3.15E+07	1.61E-08
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	7.48E-19	2.77E-09	3.15E+07	3.71E-11
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	8.53E-16	3.16E-06	3.15E+07	1.17E-08
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	1.90E-15	7.03E-06	3.15E+07	2.61E-08
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	6.00E-14	2.22E-04	3.15E+07	3.59E-07
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	6.90E-18	2.55E-08	3.15E+07	3.59E-11
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	6.56E-18	2.43E-08	3.15E+07	2.75E-11
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	1.98E-14	7.33E-05	3.15E+07	7.08E-08
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	2.49E-15	9.21E-06	3.15E+07	4.88E-09
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	8.58E-16	3.17E-06	3.15E+07	1.05E-09
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	5.96E-16	2.21E-06	3.15E+07	5.20E-10
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	6.36E-18	2.35E-08	3.15E+07	4.48E-12
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	5.20E-20	1.92E-10	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	4.84E-18	1.79E-08	3.15E+07	1.67E-12
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	2.82E-14	1.04E-04	3.15E+07	3.40E-06
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	1.01E-14	3.74E-05	3.15E+07	2.35E-07
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.25E-16	1.20E-06	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	2.19E-15	8.10E-06	3.15E+07	9.04E-11
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	7.83E-18	2.90E-08	3.15E+07	2.67E-13
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	5.77E-15	2.13E-05	3.15E+07	1.55E-10
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	7.53E-15	2.79E-05	3.15E+07	3.11E-10
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	1.04E-15	3.85E-06	3.15E+07	4.10E-13
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	5.34E-18	1.98E-08	3.15E+07	1.78E-14
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	6.09E-16	2.25E-06	3.15E+07	5.75E-12
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	3.80E-17	1.41E-07	3.15E+07	3.61E-13
												Total	2.27E-03

MPC-68													
Off-Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	L_{offnor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	6.66E-16	2.46E-06	3.15E+07	2.87E-10
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	1.34E-16	4.96E-07	3.15E+07	1.07E-05
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.39E-13	5.14E-04	3.15E+07	2.52E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	9.49E-18	3.51E-08	3.15E+07	5.37E-09
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	8.43E-14	3.12E-04	3.15E+07	2.26E-05
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	9.67E-18	3.58E-08	3.15E+07	8.25E-09
								Fines					
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	8.67E-20	3.21E-10	3.15E+07	1.02E-11
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	2.20E-16	8.14E-07	3.15E+07	1.87E-08
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	9.56E-19	3.54E-09	3.15E+07	4.74E-11
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	1.01E-15	3.74E-06	3.15E+07	1.39E-08
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	2.15E-15	7.96E-06	3.15E+07	2.96E-08
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	6.81E-14	2.52E-04	3.15E+07	4.07E-07
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	1.33E-17	4.92E-08	3.15E+07	6.91E-11
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	1.27E-17	4.70E-08	3.15E+07	5.32E-11
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	2.27E-14	8.40E-05	3.15E+07	8.12E-08
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	2.95E-15	1.09E-05	3.15E+07	5.79E-09
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	1.07E-15	3.96E-06	3.15E+07	1.32E-09
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	8.48E-16	3.14E-06	3.15E+07	7.39E-10
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	1.23E-17	4.55E-08	3.15E+07	8.66E-12
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	8.80E-20	3.26E-10	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	7.55E-18	2.79E-08	3.15E+07	2.60E-12
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	3.22E-14	1.19E-04	3.15E+07	3.89E-06
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	1.16E-14	4.29E-05	3.15E+07	2.70E-07
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	4.20E-16	1.55E-06	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	2.61E-15	9.66E-06	3.15E+07	1.08E-10
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	1.48E-17	5.48E-08	3.15E+07	5.05E-13
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	6.68E-15	2.47E-05	3.15E+07	1.80E-10
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	8.73E-15	3.23E-05	3.15E+07	3.61E-10
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	1.26E-15	4.66E-06	3.15E+07	4.96E-13
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	1.03E-17	3.81E-08	3.15E+07	3.43E-14
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	7.30E-16	2.70E-06	3.15E+07	6.89E-12
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	6.01E-17	2.22E-07	3.15E+07	5.71E-13
												Total	2.56E-03

MPC-68													
Off-Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	L_{offnor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	2.75E-18	1.02E-08	3.15E+07	1.34E-08
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	2.14E-16	7.92E-07	3.15E+07	9.23E-11
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	1.14E-16	4.22E-07	3.15E+07	9.11E-06
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.24E-13	4.59E-04	3.15E+07	2.25E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	6.44E-18	2.38E-08	3.15E+07	3.65E-09
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	7.37E-14	2.73E-04	3.15E+07	1.98E-05
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	6.68E-18	2.47E-08	3.15E+07	5.70E-09
								Fines					
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	6.48E-20	2.40E-10	3.15E+07	7.61E-12
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	1.77E-16	6.55E-07	3.15E+07	1.50E-08
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	5.45E-19	2.02E-09	3.15E+07	2.70E-11
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	7.69E-16	2.85E-06	3.15E+07	1.06E-08
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	1.90E-15	7.03E-06	3.15E+07	2.61E-08
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	5.99E-14	2.22E-04	3.15E+07	3.58E-07
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	7.08E-19	2.62E-09	3.15E+07	3.68E-12
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	1.06E-18	3.92E-09	3.15E+07	4.44E-12
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	1.95E-14	7.22E-05	3.15E+07	6.97E-08
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	2.22E-15	8.21E-06	3.15E+07	4.35E-09
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	6.74E-16	2.49E-06	3.15E+07	8.29E-10
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	2.23E-16	8.25E-07	3.15E+07	1.94E-10
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	1.09E-18	4.03E-09	3.15E+07	7.68E-13
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	7.08E-21	2.62E-11	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	2.65E-18	9.81E-09	3.15E+07	9.12E-13
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	2.80E-14	1.04E-04	3.15E+07	3.38E-06
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	1.01E-14	3.74E-05	3.15E+07	2.35E-07
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	2.00E-16	7.40E-07	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	1.92E-15	7.10E-06	3.15E+07	7.93E-11
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	1.13E-18	4.18E-09	3.15E+07	3.85E-14
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	5.50E-15	2.04E-05	3.15E+07	1.48E-10
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	7.18E-15	2.66E-05	3.15E+07	2.97E-10
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	9.02E-16	3.34E-06	3.15E+07	3.55E-13
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	9.69E-19	3.59E-09	3.15E+07	3.22E-15
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	5.51E-15	2.04E-05	3.15E+07	5.20E-11
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	1.72E-17	6.36E-08	3.15E+07	1.63E-13
												Total	2.29E-03

MPC-68													
Off-Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	L_{offnor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	1.64E-16	6.07E-07	3.15E+07	7.08E-11
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	1.09E-16	4.03E-07	3.15E+07	8.71E-06
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.23E-13	4.55E-04	3.15E+07	2.23E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	5.44E-18	2.01E-08	3.15E+07	3.08E-09
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	7.19E-14	2.66E-04	3.15E+07	1.93E-05
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	5.70E-18	2.11E-08	3.15E+07	4.86E-09
								Fines					
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	5.63E-20	2.08E-10	3.15E+07	6.61E-12
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	1.62E-16	5.99E-07	3.15E+07	1.38E-08
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	4.46E-19	1.65E-09	3.15E+07	2.21E-11
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	6.68E-16	2.47E-06	3.15E+07	9.18E-09
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	1.87E-15	6.92E-06	3.15E+07	2.57E-08
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	5.87E-14	2.17E-04	3.15E+07	3.51E-07
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	1.46E-18	5.40E-09	3.15E+07	7.59E-12
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	1.68E-18	6.22E-09	3.15E+07	7.03E-12
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	1.87E-14	6.92E-05	3.15E+07	6.69E-08
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	1.85E-15	6.85E-06	3.15E+07	3.63E-09
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	5.21E-16	1.93E-06	3.15E+07	6.41E-10
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	1.86E-16	6.88E-07	3.15E+07	1.62E-10
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	1.65E-18	6.11E-09	3.15E+07	1.16E-12
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	1.13E-20	4.18E-11	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	2.67E-18	9.88E-09	3.15E+07	9.19E-13
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	2.73E-14	1.01E-04	3.15E+07	3.30E-06
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	9.75E-15	3.61E-05	3.15E+07	2.27E-07
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	1.56E-16	5.77E-07	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	1.55E-15	5.74E-06	3.15E+07	6.40E-11
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	1.89E-18	6.99E-09	3.15E+07	6.44E-14
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	5.00E-15	1.85E-05	3.15E+07	1.34E-10
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	6.50E-15	2.41E-05	3.15E+07	2.68E-10
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	7.69E-16	2.85E-06	3.15E+07	3.03E-13
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	1.43E-18	5.29E-09	3.15E+07	4.76E-15
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	4.77E-16	1.76E-06	3.15E+07	4.51E-12
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	1.72E-17	6.36E-08	3.15E+07	1.63E-13
												Total	2.27E-03

MPC-68													
Off-Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	L_{offnor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	1.10E-15	4.07E-06	3.15E+07	4.75E-10
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	2.20E-16	8.14E-07	3.15E+07	1.76E-05
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.78E-13	6.59E-04	3.15E+07	3.23E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	2.28E-17	8.44E-08	3.15E+07	1.29E-08
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	1.20E-13	4.44E-04	3.15E+07	3.22E-05
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	2.29E-17	8.47E-08	3.15E+07	1.95E-08
								Fines					
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	2.19E-19	8.10E-10	3.15E+07	2.57E-11
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	4.44E-16	1.64E-06	3.15E+07	3.77E-08
PM147	8.86E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	2.18E-18	8.07E-09	3.15E+07	1.08E-10
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	2.49E-15	9.21E-06	3.15E+07	3.42E-08
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	2.99E-15	1.11E-05	3.15E+07	4.11E-08
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	9.43E-14	3.49E-04	3.15E+07	5.64E-07
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	8.82E-18	3.26E-08	3.15E+07	4.58E-11
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	9.30E-18	3.44E-08	3.15E+07	3.89E-11
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	3.53E-14	1.31E-04	3.15E+07	1.26E-07
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	8.09E-15	2.99E-05	3.15E+07	1.59E-08
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	2.87E-15	1.06E-05	3.15E+07	3.53E-09
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	1.22E-15	4.51E-06	3.15E+07	1.06E-09
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	9.26E-18	3.43E-08	3.15E+07	6.52E-12
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	7.09E-20	2.62E-10	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	9.47E-18	3.50E-08	3.15E+07	3.26E-12
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	4.63E-14	1.71E-04	3.15E+07	5.59E-06
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	1.72E-14	6.36E-05	3.15E+07	4.00E-07
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	8.16E-16	3.02E-06	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	7.47E-15	2.76E-05	3.15E+07	3.09E-10
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	1.06E-17	3.92E-08	3.15E+07	3.61E-13
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	1.50E-14	5.55E-05	3.15E+07	4.03E-10
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	2.00E-14	7.40E-05	3.15E+07	8.26E-10
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	3.20E-15	1.18E-05	3.15E+07	1.26E-12
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	7.90E-18	2.92E-08	3.15E+07	2.63E-14
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	1.88E-15	6.96E-06	3.15E+07	1.78E-11
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	7.94E-17	2.94E-07	3.15E+07	7.54E-13
												Total	3.29E-03

MPC-68

Off-Normal Conditions

Effective Dose Equivalent From Submersion

Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	L_{offnor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
								Gases					
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	3.86E-16	1.43E-06	3.15E+07	1.67E-10
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	1.18E-16	4.37E-07	3.15E+07	9.43E-06
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.27E-13	4.70E-04	3.15E+07	2.31E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	7.33E-18	2.71E-08	3.15E+07	4.15E-09
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	7.57E-14	2.80E-04	3.15E+07	2.03E-05
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	7.55E-18	2.79E-08	3.15E+07	6.44E-09
								Fines					
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	6.98E-20	2.58E-10	3.15E+07	8.19E-12
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	1.87E-16	6.92E-07	3.15E+07	1.59E-08
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	6.75E-19	2.50E-09	3.15E+07	3.35E-11
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	8.33E-16	3.08E-06	3.15E+07	1.15E-08
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	1.95E-15	7.22E-06	3.15E+07	2.68E-08
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	6.15E-14	2.28E-04	3.15E+07	3.68E-07
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	4.19E-18	1.55E-08	3.15E+07	2.18E-11
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	4.01E-18	1.48E-08	3.15E+07	1.68E-11
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	2.01E-14	7.44E-05	3.15E+07	7.19E-08
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	2.41E-15	8.92E-06	3.15E+07	4.73E-09
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	7.83E-16	2.90E-06	3.15E+07	9.63E-10
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	4.64E-16	1.72E-06	3.15E+07	4.05E-10
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	3.92E-18	1.45E-08	3.15E+07	2.76E-12
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.58E-20	1.32E-10	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	3.88E-18	1.44E-08	3.15E+07	1.34E-12
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	2.88E-14	1.07E-04	3.15E+07	3.48E-06
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	1.03E-14	3.81E-05	3.15E+07	2.39E-07
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	2.81E-16	1.04E-06	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	2.09E-15	7.73E-06	3.15E+07	8.63E-11
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	4.91E-18	1.82E-08	3.15E+07	1.67E-13
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	5.76E-15	2.13E-05	3.15E+07	1.55E-10
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	7.52E-15	2.78E-05	3.15E+07	3.11E-10
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	9.94E-16	3.68E-06	3.15E+07	3.92E-13
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	3.32E-18	1.23E-08	3.15E+07	1.10E-14
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	5.94E-16	2.20E-06	3.15E+07	5.61E-12
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	2.95E-17	1.09E-07	3.15E+07	2.80E-13
												Total	2.34E-03

MPC-68													
Off-Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	L_{offnor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	Effective Dose (mRem)
								Gases					
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	3.31E-19	1.22E-09	3.15E+07	1.61E-09
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	3.80E-16	1.41E-06	3.15E+07	1.64E-10
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	1.19E-16	4.40E-07	3.15E+07	9.51E-06
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.26E-13	4.66E-04	3.15E+07	2.29E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	7.53E-18	2.79E-08	3.15E+07	4.26E-09
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	7.57E-14	2.80E-04	3.15E+07	2.03E-05
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	7.74E-18	2.86E-08	3.15E+07	6.60E-09
								Fines					
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	7.25E-20	2.68E-10	3.15E+07	8.51E-12
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	1.90E-16	7.03E-07	3.15E+07	1.61E-08
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	6.93E-19	2.56E-09	3.15E+07	3.44E-11
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	8.53E-16	3.16E-06	3.15E+07	1.17E-08
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	1.95E-15	7.22E-06	3.15E+07	2.68E-08
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	6.14E-14	2.27E-04	3.15E+07	3.67E-07
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	4.91E-18	1.82E-08	3.15E+07	2.55E-11
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	4.88E-18	1.81E-08	3.15E+07	2.04E-11
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	2.02E-14	7.47E-05	3.15E+07	7.23E-08
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	2.49E-15	9.21E-06	3.15E+07	4.88E-09
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	8.18E-16	3.03E-06	3.15E+07	1.01E-09
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	4.53E-16	1.68E-06	3.15E+07	3.95E-10
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	4.75E-18	1.76E-08	3.15E+07	3.34E-12
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	3.61E-20	1.34E-10	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	4.24E-18	1.57E-08	3.15E+07	1.46E-12
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	2.88E-14	1.07E-04	3.15E+07	3.48E-06
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	1.04E-14	3.85E-05	3.15E+07	2.42E-07
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	2.79E-16	1.03E-06	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	2.18E-15	8.07E-06	3.15E+07	9.00E-11
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	5.69E-18	2.11E-08	3.15E+07	1.94E-13
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	5.88E-15	2.18E-05	3.15E+07	1.58E-10
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	7.69E-15	2.85E-05	3.15E+07	3.18E-10
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	1.03E-15	3.81E-06	3.15E+07	4.06E-13
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	4.01E-18	1.48E-08	3.15E+07	1.33E-14
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	6.15E-16	2.28E-06	3.15E+07	5.81E-12
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	3.17E-17	1.17E-07	3.15E+07	3.01E-13
												Total	2.32E-03

MPC-68													
Off-Normal Conditions													
Effective Dose Equivalent From Submersion													
Nuclide	Inventory (Ci/Assy)	10% for off-normal storage	No. Assy	MPC Vol (cm3)	L_{offnor} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	Effective Dose (mRem)
								Gases					
H-3	8.72E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.61E-10	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
I-129	7.72E-03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	2.31E-14	1.60E-04	1.10E-15	4.07E-06	3.15E+07	4.75E-10
Kr-85	1.43E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	0.30	4.29E-09	1.60E-04	1.32E-14	4.88E-05	3.15E+07	1.05E-03
								Crud					
Co-60	6.50E+01	1.00E+00	68	5.99E+06	8.80E-06	1.47E-12	0.15	9.74E-10	1.60E-04	1.45E-13	5.37E-04	3.15E+07	2.63E-03
								Volatiles					
Sr-90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	3.04E-11	1.60E-04	9.20E-15	3.40E-05	3.15E+07	5.21E-06
Ru-106	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	8.31E-12	1.60E-04	0.00E+00	0.00E+00	3.15E+07	0.00E+00
Cs-134	7.20E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	1.44E-11	1.60E-04	9.45E-14	3.50E-04	3.15E+07	2.54E-05
Cs-137	2.29E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	2.00E-04	4.58E-11	1.60E-04	8.63E-15	3.19E-05	3.15E+07	7.36E-06
								Fines					
PU241	2.10E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.29E-12	1.60E-04	1.17E-19	4.33E-10	3.15E+07	1.37E-11
Y 90	1.52E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.56E-12	1.60E-04	6.24E-14	2.31E-04	3.15E+07	5.30E-06
PM147	8.88E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.66E-12	1.60E-04	8.11E-16	3.00E-06	3.15E+07	4.02E-08
CE144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	2.93E-15	1.08E-05	3.15E+07	4.03E-08
PR144	2.46E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	7.37E-13	1.60E-04	8.43E-14	3.12E-04	3.15E+07	1.16E-06
EU154	1.07E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.21E-13	1.60E-04	8.29E-14	3.07E-04	3.15E+07	4.96E-07
CM244	9.30E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.79E-13	1.60E-04	3.91E-17	1.45E-07	3.15E+07	2.03E-10
PU238	7.49E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.24E-13	1.60E-04	4.09E-17	1.51E-07	3.15E+07	1.71E-10
SB125	6.40E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.92E-13	1.60E-04	2.65E-14	9.81E-05	3.15E+07	9.48E-08
EU155	3.51E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.05E-13	1.60E-04	3.39E-15	1.25E-05	3.15E+07	6.65E-09
AM241	2.20E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.59E-14	1.60E-04	1.28E-15	4.74E-06	3.15E+07	1.57E-09
TE125M	1.56E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	4.68E-14	1.60E-04	1.94E-15	7.18E-06	3.15E+07	1.69E-09
PU240	1.26E+02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	3.78E-14	1.60E-04	3.92E-17	1.45E-07	3.15E+07	2.76E-11
151Sm	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	1.90E-20	7.03E-11	3.15E+07	0.00E+00
239Pu	6.16E+01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.85E-14	1.60E-04	1.86E-17	6.88E-08	3.15E+07	6.40E-12
137mBa	2.16E+04	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	6.47E-12	1.60E-04	3.73E-14	1.38E-04	3.15E+07	4.50E-06
106Rh	4.16E+03	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.25E-12	1.60E-04	1.09E-13	4.03E-04	3.15E+07	2.53E-06
144mPr	0.00E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	0.00E+00	1.60E-04	5.08E-16	1.88E-06	3.15E+07	0.00E+00
243Am	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	2.75E-15	1.02E-05	3.15E+07	1.14E-10
242Cm	6.10E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.83E-15	1.60E-04	4.29E-17	1.59E-07	3.15E+07	1.46E-12
243Cm	4.81E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.44E-15	1.60E-04	9.79E-15	3.62E-05	3.15E+07	2.63E-10
239Np	7.39E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.21E-15	1.60E-04	1.60E-14	5.92E-05	3.15E+07	6.61E-10
237Np	7.05E-02	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	2.11E-17	1.60E-04	1.54E-15	5.70E-06	3.15E+07	6.07E-13
242Pu	5.95E-01	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	1.78E-16	1.60E-04	3.27E-17	1.21E-07	3.15E+07	1.09E-13
242Am	1.69E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.06E-16	1.60E-04	8.20E-15	3.03E-05	3.15E+07	7.74E-11
242mAm	1.70E+00	1.00E-01	68	5.99E+06	8.80E-06	1.47E-12	3.00E-05	5.09E-16	1.60E-04	1.36E-16	5.03E-07	3.15E+07	1.29E-12
												Total	3.74E-03

MPC-68												
Accident Conditions												
Effective Dose Equivalent From Submersion												
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
							Gases					
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	4.83E-16	1.79E-06	2.59E+06	1.22E-08
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	1.17E-16	4.33E-07	2.59E+06	5.48E-04
							Crud					
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	1.23E-13	4.55E-04	2.59E+06	8.73E-02
							Volatiles					
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	7.78E-18	2.88E-08	2.59E+06	2.58E-07
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	7.40E-14	2.74E-04	2.59E+06	1.16E-03
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	7.96E-18	2.95E-08	2.59E+06	3.98E-07
							Fines					
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	7.19E-20	2.66E-10	2.59E+06	4.94E-10
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	1.89E-16	6.99E-07	2.59E+06	9.41E-07
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	7.48E-19	2.77E-09	2.59E+06	2.17E-09
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	8.53E-16	3.16E-06	2.59E+06	6.87E-07
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	1.90E-15	7.03E-06	2.59E+06	1.53E-06
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	6.00E-14	2.22E-04	2.59E+06	2.10E-05
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	6.90E-18	2.55E-08	2.59E+06	2.10E-09
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	6.56E-18	2.43E-08	2.59E+06	1.61E-09
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	1.98E-14	7.33E-05	2.59E+06	4.15E-06
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	2.49E-15	9.21E-06	2.59E+06	2.86E-07
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	8.58E-16	3.17E-06	2.59E+06	6.18E-08
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	5.96E-16	2.21E-06	2.59E+06	3.04E-08
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	6.36E-18	2.35E-08	2.59E+06	2.62E-10
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	5.20E-20	1.92E-10	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	4.84E-18	1.79E-08	2.59E+06	9.76E-11
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	2.82E-14	1.04E-04	2.59E+06	1.99E-04
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	1.01E-14	3.74E-05	2.59E+06	1.38E-05
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.25E-16	1.20E-06	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	2.19E-15	8.10E-06	2.59E+06	5.30E-09
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	7.83E-18	2.90E-08	2.59E+06	1.56E-11
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	5.77E-15	2.13E-05	2.59E+06	9.09E-09
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	7.53E-15	2.79E-05	2.59E+06	1.82E-08
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	1.04E-15	3.85E-06	2.59E+06	2.40E-11
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	5.34E-18	1.98E-08	2.59E+06	1.04E-12
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	6.09E-16	2.25E-06	2.59E+06	3.37E-10
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	3.80E-17	1.41E-07	2.59E+06	2.12E-11
											Total	8.92E-02

MPC-68												
Accident Conditions												
Effective Dose Equivalent From Submersion												
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
							Gases					
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	6.66E-16	2.46E-06	2.59E+06	1.68E-08
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	1.34E-16	4.96E-07	2.59E+06	6.27E-04
							Crud					
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	1.39E-13	5.14E-04	2.59E+06	9.86E-02
							Volatiles					
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	9.49E-18	3.51E-08	2.59E+06	3.15E-07
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	8.43E-14	3.12E-04	2.59E+06	1.32E-03
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	9.67E-18	3.58E-08	2.59E+06	4.83E-07
							Fines					
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	8.67E-20	3.21E-10	2.59E+06	5.96E-10
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	2.20E-16	8.14E-07	2.59E+06	1.09E-06
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	9.56E-19	3.54E-09	2.59E+06	2.78E-09
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	1.01E-15	3.74E-06	2.59E+06	8.13E-07
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	2.15E-15	7.96E-06	2.59E+06	1.73E-06
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	6.81E-14	2.52E-04	2.59E+06	2.39E-05
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	1.33E-17	4.92E-08	2.59E+06	4.05E-09
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	1.27E-17	4.70E-08	2.59E+06	3.11E-09
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	2.27E-14	8.40E-05	2.59E+06	4.76E-06
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	2.95E-15	1.09E-05	2.59E+06	3.39E-07
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	1.07E-15	3.96E-06	2.59E+06	7.71E-08
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	8.48E-16	3.14E-06	2.59E+06	4.33E-08
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	1.23E-17	4.55E-08	2.59E+06	5.07E-10
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	8.80E-20	3.26E-10	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	7.55E-18	2.79E-08	2.59E+06	1.52E-10
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	3.22E-14	1.19E-04	2.59E+06	2.28E-04
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	1.16E-14	4.29E-05	2.59E+06	1.58E-05
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	4.20E-16	1.55E-06	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	2.61E-15	9.66E-06	2.59E+06	6.32E-09
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	1.48E-17	5.48E-08	2.59E+06	2.96E-11
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	6.68E-15	2.47E-05	2.59E+06	1.05E-08
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	8.73E-15	3.23E-05	2.59E+06	2.11E-08
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	1.26E-15	4.66E-06	2.59E+06	2.91E-11
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	1.03E-17	3.81E-08	2.59E+06	2.01E-12
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	7.30E-16	2.70E-06	2.59E+06	4.04E-10
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	6.01E-17	2.22E-07	2.59E+06	3.35E-11
											Total	1.01E-01

MPC-68												
Accident Conditions												
Effective Dose Equivalent From Submersion												
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
							Gases					
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	2.75E-18	1.02E-08	2.59E+06	7.85E-07
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	2.14E-16	7.92E-07	2.59E+06	5.41E-09
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	1.14E-16	4.22E-07	2.59E+06	5.34E-04
							Crud					
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	1.24E-13	4.59E-04	2.59E+06	8.80E-02
							Volatiles					
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	6.44E-18	2.38E-08	2.59E+06	2.14E-07
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	7.37E-14	2.73E-04	2.59E+06	1.16E-03
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	6.68E-18	2.47E-08	2.59E+06	3.34E-07
							Fines					
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	6.48E-20	2.40E-10	2.59E+06	4.46E-10
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	1.77E-16	6.55E-07	2.59E+06	8.81E-07
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	5.45E-19	2.02E-09	2.59E+06	1.58E-09
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	7.69E-16	2.85E-06	2.59E+06	6.19E-07
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	1.90E-15	7.03E-06	2.59E+06	1.53E-06
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	5.99E-14	2.22E-04	2.59E+06	2.10E-05
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	7.08E-19	2.62E-09	2.59E+06	2.16E-10
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	1.06E-18	3.92E-09	2.59E+06	2.60E-10
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	1.95E-14	7.22E-05	2.59E+06	4.09E-06
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	2.22E-15	8.21E-06	2.59E+06	2.55E-07
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	6.74E-16	2.49E-06	2.59E+06	4.85E-08
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	2.23E-16	8.25E-07	2.59E+06	1.14E-08
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	1.09E-18	4.03E-09	2.59E+06	4.50E-11
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	7.08E-21	2.62E-11	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	2.65E-18	9.81E-09	2.59E+06	5.34E-11
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	2.80E-14	1.04E-04	2.59E+06	1.98E-04
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	1.01E-14	3.74E-05	2.59E+06	1.38E-05
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	2.00E-16	7.40E-07	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	1.92E-15	7.10E-06	2.59E+06	4.65E-09
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	1.13E-18	4.18E-09	2.59E+06	2.26E-12
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	5.50E-15	2.04E-05	2.59E+06	8.66E-09
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	7.18E-15	2.66E-05	2.59E+06	1.74E-08
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	9.02E-16	3.34E-06	2.59E+06	2.08E-11
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	9.69E-19	3.59E-09	2.59E+06	1.89E-13
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	5.51E-15	2.04E-05	2.59E+06	3.05E-09
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	1.72E-17	6.36E-08	2.59E+06	9.57E-12
											Total	8.99E-02

MPC-68												
Accident Conditions												
Effective Dose Equivalent From Submersion												
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
							Gases					
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	1.64E-16	6.07E-07	2.59E+06	4.15E-09
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	1.09E-16	4.03E-07	2.59E+06	5.10E-04
							Crud					
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	1.23E-13	4.55E-04	2.59E+06	8.73E-02
							Volatiles					
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	5.44E-18	2.01E-08	2.59E+06	1.80E-07
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	7.19E-14	2.66E-04	2.59E+06	1.13E-03
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	5.70E-18	2.11E-08	2.59E+06	2.85E-07
							Fines					
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	5.63E-20	2.08E-10	2.59E+06	3.87E-10
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	1.62E-16	5.99E-07	2.59E+06	8.06E-07
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	4.46E-19	1.65E-09	2.59E+06	1.30E-09
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	6.68E-16	2.47E-06	2.59E+06	5.38E-07
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	1.87E-15	6.92E-06	2.59E+06	1.51E-06
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	5.87E-14	2.17E-04	2.59E+06	2.06E-05
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	1.46E-18	5.40E-09	2.59E+06	4.45E-10
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	1.68E-18	6.22E-09	2.59E+06	4.12E-10
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	1.87E-14	6.92E-05	2.59E+06	3.92E-06
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	1.85E-15	6.85E-06	2.59E+06	2.13E-07
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	5.21E-16	1.93E-06	2.59E+06	3.75E-08
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	1.86E-16	6.88E-07	2.59E+06	9.50E-09
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	1.65E-18	6.11E-09	2.59E+06	6.81E-11
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	1.13E-20	4.18E-11	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	2.67E-18	9.88E-09	2.59E+06	5.38E-11
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	2.73E-14	1.01E-04	2.59E+06	1.93E-04
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	9.75E-15	3.61E-05	2.59E+06	1.33E-05
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	1.56E-16	5.77E-07	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	1.55E-15	5.74E-06	2.59E+06	3.75E-09
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	1.89E-18	6.99E-09	2.59E+06	3.77E-12
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	5.00E-15	1.85E-05	2.59E+06	7.87E-09
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	6.50E-15	2.41E-05	2.59E+06	1.57E-08
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	7.69E-16	2.85E-06	2.59E+06	1.78E-11
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	1.43E-18	5.29E-09	2.59E+06	2.79E-13
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	4.77E-16	1.76E-06	2.59E+06	2.64E-10
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	1.72E-17	6.36E-08	2.59E+06	9.57E-12
											Total	8.91E-02

MPC-68												
Accident Conditions												
Effective Dose Equivalent From Submersion												
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
							Gases					
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	1.10E-15	4.07E-06	2.59E+06	2.78E-08
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	2.20E-16	8.14E-07	2.59E+06	1.03E-03
							Crud					
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	1.78E-13	6.59E-04	2.59E+06	1.26E-01
							Volatiles					
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	2.28E-17	8.44E-08	2.59E+06	7.56E-07
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	1.20E-13	4.44E-04	2.59E+06	1.89E-03
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	2.29E-17	8.47E-08	2.59E+06	1.14E-06
							Fines					
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	2.19E-19	8.10E-10	2.59E+06	1.51E-09
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	4.44E-16	1.64E-06	2.59E+06	2.21E-06
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	2.18E-18	8.07E-09	2.59E+06	6.34E-09
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	2.49E-15	9.21E-06	2.59E+06	2.01E-06
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	2.99E-15	1.11E-05	2.59E+06	2.41E-06
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	9.43E-14	3.49E-04	2.59E+06	3.30E-05
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	8.82E-18	3.26E-08	2.59E+06	2.69E-09
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	9.30E-18	3.44E-08	2.59E+06	2.28E-09
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	3.53E-14	1.31E-04	2.59E+06	7.40E-06
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	8.09E-15	2.99E-05	2.59E+06	9.30E-07
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	2.87E-15	1.06E-05	2.59E+06	2.07E-07
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	1.22E-15	4.51E-06	2.59E+06	6.23E-08
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	9.26E-18	3.43E-08	2.59E+06	3.82E-10
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	7.09E-20	2.62E-10	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	9.47E-18	3.50E-08	2.59E+06	1.91E-10
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	4.63E-14	1.71E-04	2.59E+06	3.27E-04
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	1.72E-14	6.36E-05	2.59E+06	2.34E-05
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	8.16E-16	3.02E-06	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	7.47E-15	2.76E-05	2.59E+06	1.81E-08
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	1.06E-17	3.92E-08	2.59E+06	2.12E-11
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	1.50E-14	5.55E-05	2.59E+06	2.36E-08
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	2.00E-14	7.40E-05	2.59E+06	4.84E-08
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	3.20E-15	1.18E-05	2.59E+06	7.39E-11
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	7.90E-18	2.92E-08	2.59E+06	1.54E-12
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	1.88E-15	6.96E-06	2.59E+06	1.04E-09
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	7.94E-17	2.94E-07	2.59E+06	4.42E-11
											Total	1.30E-01

MPC-68												
Accident Conditions												
Effective Dose Equivalent From Submersion												
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
							Gases					
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	3.86E-16	1.43E-06	2.59E+06	9.76E-09
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	1.18E-16	4.37E-07	2.59E+06	5.52E-04
							Crud					
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	1.27E-13	4.70E-04	2.59E+06	9.01E-02
							Volatiles					
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	7.33E-18	2.71E-08	2.59E+06	2.43E-07
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	7.57E-14	2.80E-04	2.59E+06	1.19E-03
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	7.55E-18	2.79E-08	2.59E+06	3.77E-07
							Fines					
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	6.98E-20	2.58E-10	2.59E+06	4.80E-10
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	1.87E-16	6.92E-07	2.59E+06	9.31E-07
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	6.75E-19	2.50E-09	2.59E+06	1.96E-09
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	8.33E-16	3.08E-06	2.59E+06	6.71E-07
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	1.95E-15	7.22E-06	2.59E+C6	1.57E-06
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	6.15E-14	2.28E-04	2.59E+06	2.15E-05
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	4.19E-18	1.55E-08	2.59E+06	1.28E-09
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	4.01E-18	1.48E-08	2.59E+06	9.83E-10
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	2.01E-14	7.44E-05	2.59E+06	4.21E-06
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	2.41E-15	8.92E-06	2.59E+06	2.77E-07
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	7.83E-16	2.90E-06	2.59E+06	5.64E-08
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	4.64E-16	1.72E-06	2.59E+06	2.37E-08
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	3.92E-18	1.45E-08	2.59E+06	1.62E-10
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.58E-20	1.32E-10	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	3.88E-18	1.44E-08	2.59E+06	7.83E-11
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	2.88E-14	1.07E-04	2.59E+06	2.04E-04
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	1.03E-14	3.81E-05	2.59E+06	1.40E-05
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	2.81E-16	1.04E-06	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	2.09E-15	7.73E-06	2.59E+06	5.06E-09
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	4.91E-18	1.82E-08	2.59E+06	9.81E-12
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	5.76E-15	2.13E-05	2.59E+06	9.07E-09
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	7.52E-15	2.78E-05	2.59E+06	1.82E-08
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	9.94E-16	3.68E-06	2.59E+06	2.29E-11
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	3.32E-18	1.23E-08	2.59E+06	6.47E-13
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	5.94E-16	2.20E-06	2.59E+06	3.29E-10
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	2.95E-17	1.09E-07	2.59E+06	1.64E-11
											Total	9.21E-02

MPC-68												
Accident Conditions												
Effective Dose Equivalent From Submersion												
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
							Gases					
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	3.31E-19	1.22E-09	2.59E+06	9.45E-08
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	3.80E-16	1.41E-06	2.59E+06	9.60E-09
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	1.19E-16	4.40E-07	2.59E+06	5.57E-04
							Crud					
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	1.26E-13	4.66E-04	2.59E+06	8.94E-02
							Volatiles					
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	7.53E-18	2.79E-08	2.59E+06	2.50E-07
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	7.57E-14	2.80E-04	2.59E+06	1.19E-03
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	7.74E-18	2.86E-08	2.59E+06	3.87E-07
							Fines					
PU241	2.10E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	7.25E-20	2.68E-10	2.59E+06	4.98E-10
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	1.90E-16	7.03E-07	2.59E+06	9.46E-07
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	6.93E-19	2.56E-09	2.59E+06	2.01E-09
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	8.53E-16	3.16E-06	2.59E+06	6.87E-07
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	1.95E-15	7.22E-06	2.59E+06	1.57E-06
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	6.14E-14	2.27E-04	2.59E+06	2.15E-05
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	4.91E-18	1.82E-08	2.59E+06	1.50E-09
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	4.88E-18	1.81E-08	2.59E+06	1.20E-09
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	2.02E-14	7.47E-05	2.59E+06	4.23E-06
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	2.49E-15	9.21E-06	2.59E+06	2.86E-07
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	8.18E-16	3.03E-06	2.59E+06	5.89E-08
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	4.53E-16	1.68E-06	2.59E+06	2.31E-08
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	4.75E-18	1.76E-08	2.59E+06	1.96E-10
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	3.61E-20	1.34E-10	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	4.24E-18	1.57E-08	2.59E+06	8.55E-11
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	2.88E-14	1.07E-04	2.59E+06	2.04E-04
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	1.04E-14	3.85E-05	2.59E+06	1.42E-05
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	2.79E-16	1.03E-06	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	2.18E-15	8.07E-06	2.59E+06	5.27E-09
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	5.69E-18	2.11E-08	2.59E+06	1.14E-11
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	5.88E-15	2.18E-05	2.59E+06	9.26E-09
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	7.69E-15	2.85E-05	2.59E+06	1.86E-08
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	1.03E-15	3.81E-06	2.59E+06	2.38E-11
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	4.01E-18	1.48E-08	2.59E+06	7.81E-13
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	6.15E-16	2.28E-06	2.59E+06	3.40E-10
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	3.17E-17	1.17E-07	2.59E+06	1.76E-11
											Total	9.14E-02

MPC-68												
Accident Conditions												
Effective Dose Equivalent From Submersion												
Nuclide	Inventory (Ci/Assy)	No. Assy	MPC Vol (cm3)	L_{acc} Rate at Upstream (cm3/s)	Fraction Released per sec	Release Fraction	Release Rate (Ci/sec)	X/Q (sec/m3)	DCF (Sv/Bq)	DCF (mRem/uCi)	Occ Time (sec)	EDE (mRem)
							Gases					
H-3	8.72E+01	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.72E-09	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
I-129	7.72E-03	68	5.99E+06	1.25E-05	2.09E-12	0.30	3.30E-13	8.00E-03	1.10E-15	4.07E-06	2.59E+06	2.78E-08
Kr-85	1.43E+03	68	5.99E+06	1.25E-05	2.09E-12	0.30	6.11E-08	8.00E-03	1.32E-14	4.88E-05	2.59E+06	6.18E-02
							Crud					
Co-60	6.50E+01	68	5.99E+06	1.25E-05	2.09E-12	1.00	9.25E-09	8.00E-03	1.45E-13	5.37E-04	2.59E+06	1.03E-01
							Volatiles					
Sr-90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	4.33E-10	8.00E-03	9.20E-15	3.40E-05	2.59E+06	3.05E-04
Ru-106	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	1.18E-10	8.00E-03	0.00E+00	0.00E+00	2.59E+06	0.00E+00
Cs-134	7.20E+03	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	2.05E-10	8.00E-03	9.45E-14	3.50E-04	2.59E+06	1.49E-03
Cs-137	2.29E+04	68	5.99E+06	1.25E-05	2.09E-12	2.00E-04	6.52E-10	8.00E-03	8.63E-15	3.19E-05	2.59E+06	4.31E-04
							Fines					
PU241	2.1JE+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	8.97E-11	8.00E-03	1.17E-19	4.33E-10	2.59E+06	8.04E-10
Y 90	1.52E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.49E-11	8.00E-03	6.24E-14	2.31E-04	2.59E+06	3.11E-04
PM147	8.88E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.79E-11	8.00E-03	8.11E-16	3.00E-06	2.59E+06	2.36E-06
CE144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	2.93E-15	1.08E-05	2.59E+06	2.36E-06
PR144	2.46E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.05E-11	8.00E-03	8.43E-14	3.12E-04	2.59E+06	6.79E-05
EU154	1.07E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	4.57E-12	8.00E-03	8.29E-14	3.07E-04	2.59E+06	2.90E-05
CM244	9.30E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.97E-12	8.00E-03	3.91E-17	1.45E-07	2.59E+06	1.19E-08
PU238	7.49E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.20E-12	8.00E-03	4.09E-17	1.51E-07	2.59E+06	1.00E-08
SB125	6.40E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.73E-12	8.00E-03	2.65E-14	9.81E-05	2.59E+06	5.55E-06
EU155	3.51E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.50E-12	8.00E-03	3.39E-15	1.25E-05	2.59E+06	3.90E-07
AM241	2.20E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.40E-13	8.00E-03	1.28E-15	4.74E-06	2.59E+06	9.22E-08
TE125M	1.56E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	6.66E-13	8.00E-03	1.94E-15	7.18E-06	2.59E+06	9.91E-08
PU240	1.26E+02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	5.38E-13	8.00E-03	3.92E-17	1.45E-07	2.59E+06	1.62E-09
151Sm	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	1.90E-20	7.03E-11	2.59E+06	0.00E+00
239Pu	6.16E+01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.63E-13	8.00E-03	1.86E-17	6.88E-08	2.59E+06	3.75E-10
137mBa	2.16E+04	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	9.22E-11	8.00E-03	3.73E-14	1.38E-04	2.59E+06	2.64E-04
106Rh	4.16E+03	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	1.78E-11	8.00E-03	1.09E-13	4.03E-04	2.59E+06	1.48E-04
144mPr	0.00E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	0.00E+00	8.00E-03	5.08E-16	1.88E-06	2.59E+06	0.00E+00
243Am	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	2.75E-15	1.02E-05	2.59E+06	6.65E-09
242Cm	6.10E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.61E-14	8.00E-03	4.29E-17	1.59E-07	2.59E+06	8.57E-11
243Cm	4.81E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.05E-14	8.00E-03	9.79E-15	3.62E-05	2.59E+06	1.54E-08
239Np	7.39E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.16E-14	8.00E-03	1.60E-14	5.92E-05	2.59E+06	3.87E-08
237Np	7.05E-02	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	3.01E-16	8.00E-03	1.54E-15	5.70E-06	2.59E+06	3.55E-11
242Pu	5.95E-01	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	2.54E-15	8.00E-03	3.27E-17	1.21E-07	2.59E+06	6.37E-12
242Am	1.69E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.22E-15	8.00E-03	8.20E-15	3.03E-05	2.59E+06	4.54E-09
242mAm	1.70E+00	68	5.99E+06	1.25E-05	2.09E-12	3.00E-05	7.26E-15	8.00E-03	1.36E-16	5.03E-07	2.59E+06	7.57E-11
											Total	1.68E-01

CHAPTER 8: OPERATING PROCEDURES

8.0 INTRODUCTION:

This chapter outlines the loading, unloading, and recovery procedures for the HI-STAR 100 System for storage operations. The procedures provided in this chapter are prescriptive to the extent that they provide the basis and general guidance for plant personnel in preparing detailed written site-specific loading, handling, storage and unloading procedures. The information provided in this chapter meets all requirements of NUREG-1536 [8.0.1].

Section 8.1 provides the procedure for loading the HI-STAR 100 System in the spent fuel pool. Section 8.2 provides guidance for ISFSI operations and general guidance for responding to abnormal events. Responses to abnormal events that may occur during normal loading operations are provided with the procedure steps. Section 8.3 provides the procedure for unloading the HI-STAR 100 System in the spent fuel pool. Section 8.4 provides the procedures for placement of the HI-STAR 100 System into storage directly from transport. ~~The Technical Specifications in Appendix 12.A~~*Appendices A and B to the Certificate of Compliance (CoC) 1008, including the Technical Specifications* provide functional and Operating Limits, Limiting Conditions *for*~~of~~ Operation (LCO*s*), Surveillance Requirements (SR's) *and design features*, as well as administrative information, such as Use and Application. *TSAR* Appendix 12.A ~~also~~ includes Bases for the Functional and Operating Limits, and the LCOs. The Technical Specifications impose restrictions and requirements that must be applied throughout the loading and unloading process. Equipment specific operating details such as Vacuum Drying System valve manipulation and Transporter operation will be provided to users based on the specific equipment selected by the users and the configuration of the site.

Licensees (Users) will utilize the procedures provided in this chapter, the Technical Specifications, the conditions of the Certificate of Compliance, equipment-specific operating instructions, and plant working procedures and apply them to develop the site-specific written loading, handling, unloading and storage procedures. The procedures contained herein describe acceptable methods for performing HI-STAR 100 loading and unloading operations. Users may alter these procedures to allow operations to be performed in parallel or out of sequence as long as the general intent of the procedure is met. Users may add or delete steps in their site-specific implementation procedures provided the intent of these guidelines is met. In the figures following each section, acceptable configurations of rigging, piping, and instrumentation are shown. The equipment specified in this chapter is acceptable for use in performing the associated cask operations. Alternative equipment may be used provided the design and operation of the proposed alternate equipment is reviewed by the Certificate Holder. Any deviations to the rigging should be approved by the user's load handling authority.

The loading and unloading procedures in Section 8.1 and 8.3 can also be appropriately revised into written site-specific procedures to allow dry loading and unloading of the system in a hot cell or other remote handling facility. The Dry Transfer Facility (DTF) loading and unloading procedures are essentially the same with respect to loading, vacuum drying, inerting, and leakage testing of the MPC. The dry transfer facility shall develop the appropriate site-specific procedures as part of the DTF facility license.

Tables 8.1.1 and 8.1.2 provide the handling weights for each of the HI-STAR 100 System major components and the loads to be lifted during the operation of the HI-STAR 100 System. Table 8.1.3 provides the HI-STAR 100 System bolt torque and sequencing requirements. Table 8.1.4 provides an operational description of the HI-STAR 100 System ancillary equipment and its safety designation. Fuel assembly selection and verification shall be performed by the licensee in accordance with written, approved procedures which ensure that only SNF assemblies authorized in *Appendix B to* the Certificate of Compliance ~~and as defined in the Functional and Operating Limits of the Technical Specifications~~ are loaded into the HI-STAR 100 System.

In addition to the requirements set forth in the ~~Technical Specifications~~*CoC*, users will be required to develop or modify existing programs and procedures to account for the operation of an ISFSI. Written procedures will be required to be developed or modified to account for such things as nondestructive examination (NDE) of the MPC welds, handling and storage of items and components identified as Important to Safety, 10CFR72.48 [8.0.2] programs, specialized instrument calibration, special nuclear material accountability at the ISFSI, security modifications, fuel handling procedures, training and emergency response, equipment and process qualifications. Users shall implement controls to ensure that the lifted weights do not exceed the HI-STAR 100 trunnion design limits. Users shall implement controls to monitor the time limit from the removal of the HI-STAR 100 from the spent fuel pool to the commencement of MPC draining to prevent boiling. Chapter 4 of the TSAR provides *examples of* the time limits based on ~~the~~ *representative* spent fuel pool temperatures *and design basis heat loads*. Users shall also implement controls to ensure that the HI-STAR 100 overpack cannot be subjected to a fire in excess of design limits during both transport operations and storage operations.

Table 8.1.5 summarizes the instrumentation used to load and unload the HI-STAR 100 System. Tables 8.1.6 and 8.1.7 provide sample receipt inspection checklists for the HI-STAR 100 overpack and the MPC, respectively. Users shall develop site-specific receipt inspection checklists, as required. Fuel handling, including the handling of fuel assemblies in the Damaged Fuel Container (DFC) shall be performed in accordance with written site-specific procedures. *Damaged fuel and fuel debris, as defined in the Technical Specifications appended to CoC 1008 shall be loaded in* DFCs. ~~shall be loaded in the spent fuel pool racks prior to placement into the MPC.~~

8.0.1 Technical and Safety Basis for Loading and Unloading Procedures:

The procedures herein (Sections 8.1 through 8.4) are developed for the loading, storage, handling, and unloading of spent fuel in the HI-STAR 100 System. The activities involved in loading of spent fuel in a canister system, if not carefully performed, may present personnel hazards and radiological impact. The design of the HI-STAR 100 System, including these procedures, the ancillary equipment, and the Technical Specifications, serve to minimize risks and mitigate consequences of potential events. To summarize, consideration is given in the loading and unloading systems and procedures to the potential events listed in Table 8.0.1.

The primary objective is to reduce the risk of occurrence and/or to mitigate the consequences of the event. The procedures contain Notes, Warnings, and Cautions to notify the operators of upcoming situations and provide additional information as needed. The Notes, Warnings and Cautions are purposely bolded and boxed, and immediately precede the applicable steps.

In the event of an extreme abnormal condition (e.g., cask drop or tip-over event) the user shall have appropriate procedural guidance to respond to the situation. As a minimum, the procedures shall address establishing emergency action levels, implementation of emergency action program, establishment of personnel exclusion zones, monitoring of radiological conditions, actions to mitigate or prevent the release of radioactive materials, and recovery planning and execution.

Table 8.0.1
OPERATIONAL CONSIDERATIONS

Potential Event:	Breached MPC in HI-STAR 100 overpack as it related to unloading operations
Methods Used to Address:	Procedural guidance is given to sample the HI-STAR 100 overpack annulus gas prior to opening of the HI-STAR 100 overpack penetrations.
References:	See Section 8.3.2 Step 4.
Potential Event:	Cask drop during handling operations
Methods Used to Address:	~~Cask l~~*L*ifting and handling equipment *used to lift the cask higher than the lifting height limits* is designed to ANSI N14.6 [8.0.3] and ~~NUREG-0612 [8.0.4]~~ *incorporates redundant drop protection features*. Procedural guidance is given for cask handling, inspection of lifting equipment, and proper engagement to the trunnions. Technical Specifications provide lifting requirements.
References:	See Section 8.1.2. See LCO 2.1.3.
Potential Event:	Cask tip-over prior to welding of the MPC lid
Methods Used to Address:	The optional Lid Retention System is available to secure the MPC lid during movement between the spent fuel pool and the cask preparation area.
References:	See Section 8.1.5 Step 1. See Figure 8.1.14 and 8.1.16.
Potential Event:	Contamination of the MPC external shell
Methods Used to Address:	The annulus seal and Annulus Overpressure System minimize the potential for the MPC external shell to become contaminated from contact with the spent fuel pool water. Technical Specifications require surveys of the accessible portions of the MPC shell to monitor for removable contamination.
References:	See Figures 8.1.12 and 8.1.13. See LCO 2.2.2.
Potential Event:	Contamination spread from cask process system exhausts
Methods Used to Address:	All processing systems are equipped with exhausts that can be directed to the plant's processing systems or spent fuel pool.
References:	See Figures 8.1.19, 8.1.21, and 8.1.22.

Table 8.0.1
OPERATIONAL CONSIDERATIONS
(Continued)

Potential Event:	Damage to fuel assembly cladding from oxidation/thermal shock.
Methods Used to Address:	Fuel assemblies are never subjected to air or oxygen during loading and unloading operations. The Cool-Down System brings fuel assembly temperatures to below water boiling temperature using helium prior to reflooding with water during cask unloading operations.
References:	See Section 8.1.5 Step 24b and Section 8.3.2 Step 14.
Potential Event:	Damage to Vacuum Drying System vacuum gauges from positive pressure.
Methods Used to Address:	Vacuum Drying System is separate from pressurized gas and water systems.
References:	See Figure 8.1.22 and 8.1.23.
Potential Event:	Difficulty in installing the MPC lid.
Methods Used to Address:	The optional Lid Retention System has alignment pins to help guide the MPC lid into position during underwater installation.
References:	See Figure 8.1.14 and 8.1.16.
Potential Event:	Excess dose from grossly-damaged fuel assemblies
Methods Used to Address:	MPC gas sampling allows operators to determine the integrity of the fuel cladding prior to opening the MPC. This allows preparation and planning for handling of grossly-damaged fuel. The Removable Valve Operating Assemblies (RVOAs) allow the vent and drain ports to be operated like valves and prevent the need to hot tap into the penetrations during unloading operation.
References:	See Figure 8.1.15 and Section 8.3.2 Step 13.
Potential Event:	Excess dose to operators.
Methods Used to Address:	The procedures provide ALARA Notes and Warnings when radiological conditions may change.
References:	See ALARA Notes and Warnings throughout the procedures.

Table 8.0.1
OPERATIONAL CONSIDERATIONS
(Continued)

Potential Event:	Excess generation of radioactive waste
Methods Used to Address:	The HI-STAR 100 System uses process systems that minimize the amount of radioactive waste generated. Such features include smooth surfaces for ease of decontamination efforts, prevention of avoidable contamination, and procedural guidance to reduce decontamination requirements. Where possible, items are installed by hand and require no tools.
References:	Examples: HI-STAR 100 overpack bottom protective cover, bolt plugs in empty holes, pre-wetting of components.

8.1 PROCEDURE FOR LOADING THE HI-STAR 100 SYSTEM IN THE SPENT FUEL POOL

8.1.1 Overview of Loading Operations

The HI-STAR 100 System is used to load, unload, transfer and store spent fuel. Specific steps are performed to prepare the HI-STAR 100 System for fuel loading, to load the fuel, to prepare the system for storage and to place it in storage at an ISFSI. The HI-STAR 100 overpack may be transferred between the ISFSI and the fuel loading facility using a specially designed transporter, heavy haul transfer trailer, or any other load handling equipment designed for such applications as long as the lifting requirements described in LCO 2.1.3 are met. Users shall develop detailed written procedures to control on-site transport operations. Section 8.1.2 provides the general procedures for handling of the HI-STAR 100 overpack and MPC. Figure 8.1.1 shows a flow diagram of the HI-STAR 100 System loading operations. Figure 8.1.2 illustrates some of the major HI-STAR 100 System loading operations.

Note:
The procedures describe plant facilities, functions, and processes in general terms. Each site is different with regard to layout, organization and nomenclature. Users shall interpret the nomenclature used herein to suit their particular site, organization, and methods of operation.

Refer to the boxes of Figure 8.1.2 for the following description. At the start of loading operations, an empty MPC is upended (Box 1). The empty MPC is raised and inserted into the HI-STAR 100 overpack (Box 2). The annulus is filled with plant demineralized water and the MPC is filled with either spent fuel pool water or plant demineralized water (Box 3). An inflatable seal is installed in the annulus between the MPC and the HI-STAR 100 overpack to prevent spent fuel pool water from contaminating the exterior surface of the MPC. The HI-STAR 100 overpack and the MPC are then raised and lowered into the spent fuel pool for fuel loading using the lift yoke (Box 4). Pre-selected assemblies are loaded into the MPC and a visual verification of the assembly identification is performed (Box 5).

While still underwater, a thick shielded lid (the MPC lid) is installed using either slings attached to the lift yoke or the Lid Retention System (Box 6). The lift yoke remotely engages to the HI-STAR 100 overpack lifting trunnions to lift the HI-STAR 100 overpack and loaded MPC close to the spent fuel pool surface (Box 7). When radiation dose rate measurements confirm that it is safe to remove the HI-STAR 100 overpack from the spent fuel pool, the cask is removed from the spent fuel pool. If the Lid Retention System is being used, the HI-STAR 100 overpack closure plate bolts are installed to secure the MPC lid for the transfer to the cask preparation area. The lift yoke and HI-STAR 100 overpack are sprayed with demineralized water to help remove contamination as they are removed from the spent fuel pool.

The HI-STAR 100 overpack is placed in the designated preparation area and the lift yoke and Lid Retention System retention disk are removed. The next phase of decontamination is then performed. The top surfaces of the MPC lid and the upper flange of the HI-STAR 100 overpack are decontaminated. The Temporary Shield Ring (if utilized) is installed and filled with water. The inflatable annulus seal is removed, and the annulus shield is installed. The Temporary Shield

Ring provides additional personnel shielding around the top of the HI-STAR 100 overpack during MPC closure operations. The annulus shield provides additional personnel shielding at the top of the annulus and also prevents small items from being dropped into the annulus. Dose rates are measured at the MPC lid and around the mid-height circumference of the HI-STAR 100 overpack to ensure that the dose rates are within expected values. ~~in accordance with the Technical Specifications (LCO 2.2.1).~~

The MPC water level is lowered slightly, the MPC is vented, and the MPC lid is seal welded using the Automated Welding System (Box 8). Visual examinations are performed on the tack welds. Liquid penetrant examinations are performed on the root and final passes. An ultrasonic or multi-layer PT examination is performed on the MPC Lid-to-Shell weld to ensure that the weld is satisfactory. As an alternative to volumetric examination of the MPC lid-to-shell weld, a multi-layer PT is performed including one intermediate examination after approximately every three-eighth inch of weld depth. The water level is raised to the top of the MPC and a hydrostatic test is performed on the primary MPC confinement welds to verify structural integrity. A small amount of water is displaced with helium gas for leakage testing. A helium leakage rate test is performed on the MPC lid-to-shell weld to verify weld integrity and to ensure that required leakage rates are within Technical Specification acceptance criteria (LCO 2.1.1).

The water level is raised to the top of the MPC again and then the MPC water is displaced from the MPC by blowdown of the water using pressurized helium or nitrogen gas introduced into the vent port of the MPC thus displacing the water through the drain line. ~~The volume of water displaced from the MPC is measured to determine the free volume inside the MPC. This information is used later in the operation sequence to determine the helium backfill requirements for the MPC.~~

The Vacuum Drying System (VDS) is connected to the MPC and is used to remove all residual liquid water from the MPC in a stepped evacuation process (Box 9). A stepped evacuation process is used to preclude the formation of ice in the MPC and Vacuum Drying System lines. The internal pressure is reduced to below 3 torr and held for 30 minutes to ensure that all liquid water is removed (LCO 2.1.1).

Following the dryness test, the VDS is disconnected, the Helium Backfill System (HBS) is connected, and the MPC is backfilled with a predetermined ~~mass (density)~~*pressure* of helium gas (LCO 2.1.1). The helium backfill ensures adequate heat transfer during storage, provides an inert atmosphere for long-term fuel integrity, and provides the means of future leakage rate testing of the MPC confinement boundary welds. Cover plates are installed and seal welded over the MPC vent and drain ports and liquid penetrant examinations are performed on the root *(for multi-pass welds)* and final passes (Box 10). The cover plates are helium leakage tested to confirm that they meet the established leakage rate criteria (LCO 2.1.1).

The MPC closure ring is then placed on the MPC and dose rates are measured at the MPC lid to ensure that the dose rates are within expected values. The closure ring is aligned, tacked in place and seal welded providing redundant closure of the MPC confinement boundary closure welds. Tack welds are visually examined, and the root *(for multi-pass welds)* and final welds are inspected using the liquid penetrant examination technique to ensure weld integrity.

The annulus shield is removed and the remaining water in the annulus is drained. The MPC lid and accessible areas at the top of the MPC shell are smeared for removable contamination and the HI-STAR 100 overpack dose rates are measured (LCO 2.2.1). The HI-STAR 100 overpack closure plate is installed (Box 11) and the bolts are torqued. The HI-STAR 100 overpack annulus is vacuum dried and backfilled with helium gas (LCO 2.1.2). The HI-STAR 100 overpack mechanical seals are helium leakage tested to assure they will provide long-term retention of the annulus helium (LCO 2.1.2). The HI-STAR 100 overpack cover plates are installed. The Temporary Shield Ring is drained and removed. Dose rates are taken on the overpack to ensure that they are less than the Technical Specification limits (LCO 2.2.1).

The HI-STAR 100 overpack is moved to the ISFSI pad (Box 12). The HI-STAR 100 overpack may be moved using a number of methods as long as the lifting requirements of LCO 2.1.3 are met.

8.1.2 HI-STAR 100 System Receiving and Handling Operations:

> **Note:**
> The HI-STAR 100 overpack may be received and handled in several different configurations and may be transported on-site in a horizontal or vertical orientation. This section provides general guidance for the HI-STAR 100 overpack and MPC rigging and handling. Site-specific procedures shall specify the required operational sequences based on the cask handling configuration and limitations at the sites. Refer to LCO 2.1.3 for lifting requirements *for a loaded overpack.*

> **Note:**
> Steps 1 through 4 describe the handling operations using a lift yoke. Specialty rigging may be substituted if the lift complies with NUREG-0612 [8.0.4].

1. Vertical Handling of the HI-STAR 100 overpack:

> **Note:**
> Prior to performing any lifting operation, the removable shear ring segments under the two lifting trunnions must be removed.

a. Verify that the lift yoke load test certifications are current.

b. Visually inspect the lift yoke and the lifting trunnions for gouges, cracks, deformation or other indications of damage.

c. Engage the lift yoke to the lifting trunnions. See Figure 8.1.3.

d. Apply lifting tension to the lift yoke and verify proper engagement of the lift yoke.

Note:
Refer to the site's heavy load handling procedures for lift height, load path, floor loading and other applicable load handling requirements. Refer to LCO 2.1.3 for lifting requirements for a loaded HI-STAR 100 System.

e. Raise the HI-STAR 100 overpack and position it accordingly.

2. Upending of the HI-STAR 100 overpack in the transport frame:

Warning:
Personnel shall remain clear of the unshielded bottom of the loaded overpack. Users shall coordinate operations to keep the bottom cover installed to the maximum extent practicable whenever when the loaded overpack is downended.

a. If installed, remove the overpack bottom cover. Rigging points are provided. See Figure 8.1.4.

b. Position the HI-STAR 100 overpack under the lifting device. Refer to Step 1, above.

c. Verify that the lift yoke load test certifications are current.

d. Visually inspect the lift yoke and the lifting trunnions for gouges, cracks, deformation or other indications of damage.

e. Place a light layer of Fel-Pro Chemical Products, N-5000, Nuclear Grade Lubricant (or equivalent) on the cask trunnions and the palms of the lift yoke.

f. Engage the lift yoke to the lifting trunnions. See Figure 8.1.3.

g. Apply lifting tension to the lift yoke and verify proper engagement of the lift yoke.

h. Slowly rotate the HI-STAR 100 overpack to the vertical position keeping all rigging as close to vertical as practicable. See Figure 8.1.4.

i. Lift the pocket trunnions clear of the transport frame rotation trunnions.

j. Position the HI-STAR 100 overpack per site direction.

3. Downending of the HI-STAR 100 overpack in the transport frame:

a. Position the transport frame under the lifting device.

b. Verify that the lift yoke load test certifications are current.

c. Visually inspect the lift yoke and the lifting trunnions for gouges, cracks, deformation or other indications of damage.

d. Place a light layer of Fel-Pro Chemical Products, N-5000, Nuclear Grade Lubricant (or equivalent) on the cask trunnions and the palms of the lift yoke.

e. Place a light layer of Fel-Pro Chemical Products, N-5000, Nuclear Grade Lubricant (or equivalent) in the inside surfaces of the cask rotation trunnion pockets and the corresponding surfaces of the transport frame.

f. Engage the lift yoke to the lifting trunnions. See Figure 8.1.3.

g. Apply lifting tension to the lift yoke and verify proper lift yoke engagement.

h. Position the pocket trunnions to receive the transport frame rotation trunnions. See Figure 8.1.4.

i. Slowly rotate the HI-STAR 100 overpack to the horizontal position keeping all rigging as close to vertical as practicable.

j. Disengage the lift yoke.

Warning:
Personnel shall remain clear of the unshielded bottom of the loaded overpack. Users shall coordinate operations to keep the bottom cover installed to the maximum extent practicable whenever when the loaded overpack is downended.

k. If necessary for radiation shielding, install the overpack bottom cover. Rigging points are provided. See Figure 8.1.4.

4. Horizontal Handling of the HI-STAR 100 overpack in the transport frame:

   a. Secure the transport frame for HI-STAR 100 downending.

   b. Downend the HI-STAR 100 overpack on the transport frame per Step 3, if necessary.

   c. Inspect the transport frame lift rigging in accordance with site approved rigging procedures.

   d. Position the transport frame accordingly.

5. Empty MPC Installation in the HI-STAR 100 overpack:

Note:
To avoid side loading the MPC lift lugs, the MPC must be upended in the MPC Upending Frame *(or equivalent)*.. See Figure 8.1.5.

   a. If necessary, remove any MPC shipping covers and rinse off any road dirt with water. Be sure to remove any foreign objects from the MPC internals.

   b. Upend the MPC as follows:

1. Visually inspect the MPC Upending Frame for gouges, cracks, deformation or other indications of damage.

2. Install the MPC on the Upending Frame. Make sure that the banding straps are secure around the MPC shell. See Figure 8.1.5.

Warning:
The Upending Frame rigging bars are equipped with cleats that prevent the slings from sliding along the bar. The slings must be placed to the outside of the cleats to prevent an out-of-balance condition. The Upending Frame rigging points are labeled.

3. Inspect the Upending Frame slings in accordance with the site's lifting equipment inspection procedures. Rig the slings around the bar in a choker configuration to the outside of the cleats. See Figure 8.1.5.

4. Attach the MPC upper end slings of the Upending Frame to the main overhead lifting device. Attach the bottom-end slings to a secondary lifting device (or a chain fall attached to the primary lifting device).

5. Raise the MPC in the Upending Frame.

Warning:
The Upending Frame corner should be kept close to the ground during the upending process.

6. Slowly lift the upper end of the Upending Frame while lowering the bottom end of the Upending Frame.

7. When the MPC approaches the vertical orientation, release the tension on the lower slings.

8. Place the MPC in a vertical orientation on a level surface.

9. Disconnect the MPC straps and disconnect the rigging.

c. Install the MPC in the HI-STAR 100 overpack as follows:

1. Install the four point lift sling to the lift lugs inside the MPC. See Figure 8.1.6.

Caution:
Be careful not to damage the seal seating surface during MPC installation.

2. Raise and place the MPC inside the HI-STAR 100 overpack.

Note:
An alignment punch mark is provided on the HI-STAR 100 overpack and the top edge of the MPC. Similar marks are provided on the MPC lid and closure ring. See Figure 8.1.7.

3. Rotate the MPC so the alignment marks agree and seat the MPC inside the HI-STAR 100 overpack. Disconnect the MPC rigging or the MPC lift rig.

8.1.3 HI-STAR 100 Overpack and MPC Receipt Inspection and Loading Preparation

> **ALARA Note:**
> A bottom protective cover may be attached to the HI-STAR 100 overpack bottom or placed in the designated preparation area and spent fuel pool. This will help prevent embedding contaminated particles in the HI-STAR 100 overpack bottom surface and ease the decontamination effort.

1. Place the HI-STAR 100 overpack in the cask receiving area. Perform appropriate contamination and security surveillances, as required.

2. If necessary, remove the HI-STAR 100 overpack closure plate by removing the closure plate bolts. See Figure 8.1.8 for rigging example.

    a. Place the closure plate on cribbing that protects the seal seating surfaces and allows access for seal replacement.

    b. Install the seal surface protector on the HI-STAR 100 overpack seal seating surface. See Figure 8.1.12.

3. Rinse off any road dirt with water. Inspect all cavity locations for foreign objects. Remove any foreign objects.

4. Disconnect the rigging.

5. Store the closure plate and bolts in a site-approved location.

6. At the site's discretion, perform an MPC receipt inspection and cleanliness inspection in accordance with a site-specific inspection checklist.

7. Install the MPC inside the HI-STAR 100 overpack and place the HI-STAR 100 overpack in the designated preparation area. See Section 8.1.2.

> **Note:**
> *Fuel spacers are fuel-type specific. Not all fuel types require fuel spacers. Upper fuel spacers are threaded into the underside of the MPC lid. Fuel spacers may be loaded any time prior to insertion of the fuel assemblies in the MPC.*
> ~~Upper fuel spacers are fuel-type specific. Not all fuel types require fuel spacers.~~

8. Install the upper fuel spacers in the MPC lid as follows:

> **Warning:**
> Never work under a suspended load.

    a. Position the MPC lid on supports to allow access to the underside of the MPC lid.

b. Thread the fuel spacers into the holes provided on the underside of the MPC lid. See Figure 8.1.9 and Table 8.1.3 for torque requirements. See Figure 8.1.8.

c. Install threaded inserts in the MPC lid where and when spacers will not be installed, if necessary. See Table 8.1.3 for torque requirements.

9. Perform an MPC lid and closure ring fit test:

Note:
It will be necessary to perform the MPC installation and inspection in a location that has sufficient crane clearance to perform the operation.

a. Visually inspect the MPC lid rigging (See Figure 8.1.8).

b. Raise the MPC lid such that the drain line can be installed. Install the drain line to the underside of the MPC lid. See Figure 8.1.10.

c. Align the MPC lid and lift yoke so the drain line will be positioned in the MPC drain location. See Figure 8.1.11. Install the MPC lid. Verify that the MPC lid fit and weld prep are in accordance with the approved design drawings.

ALARA Note:
The closure ring is installed by hand. No tools are required.

d. Install the closure ring. See Figure 8.1.7.

e. Verify that closure ring fit and weld prep are in accordance with the approved design drawings.

f. Remove the closure ring and the MPC lid. Disconnect the drain line. Store these components in an approved plant storage location.

Note:
Fuel spacers are fuel-type specific. Not all fuel types require fuel spacers. Lower fuel spacers are set in the MPC cells manually. No restraining devices are used. *Fuel spacers may be loaded any time prior to insertion of the fuel assemblies in the MPC.*

10. Install lower fuel spacers in the MPC (if required for the fuel type). See Figure 8.1.9.

11. Fill the MPC and annulus as follows:

Caution:
Do not use any sharp tools or instruments to install the inflatable seal. Some air in the inflatable seal helps in the installation.

a. Remove the HI-STAR 100 overpack drain port cover and port plug and install the drain connector. Store the drain port cover plate and port plug in an approved storage location.

b. Fill the annulus with plant demineralized water to just below the inflatable seal seating surface.

c. Manually insert the inflatable annulus seal around the MPC. See Figure 8.1.12.

d. Ensure that the seal is uniformly positioned in the annulus area.

e. Inflate the seal to between 30 and 35 psig *or as directed by the manufacturer.*

f. Visually inspect the seal to ensure that it is properly seated in the annulus. Deflate, adjust and inflate the seal as necessary. Replace the seal as necessary.

ALARA Note:
Waterproof tape placed over empty bolt holes, and bolt plugs may reduce the time required for decontamination.

12. At the user's discretion, install the HI-STAR 100 overpack closure plate bolt plugs and/or apply waterproof tape over any empty bolt holes.

ALARA Note:
Keeping the water level below the top of the MPC prevents splashing during handling.

13. Fill the MPC with either demineralized water or spent fuel pool water to approximately 12 inches below the top of the MPC shell.

14. Place the HI-STAR 100 overpack in the spent fuel pool as follows:

ALARA Note:
The Annulus Overpressure System is used to provide further protection against MPC external shell contamination during in-pool operations. The Annulus Overpressure System is equipped with double-locking quick disconnects to prevent inadvertent draining. The reservoir valve must be closed to ensure that the annulus is not inadvertently drained through the Annulus Overpressure System when the cask is raised above the level of the annulus reservoir.

a. If used, fill the Annulus Overpressure System lines and reservoir with demineralized water and close the reservoir valve. Attach the Annulus Overpressure System to the HI-STAR 100 overpack via the quick disconnect. See Figure 8.1.13.

b. Engage the lift yoke to the HI-STAR 100 overpack lifting trunnions and position the HI-STAR 100 overpack over the cask loading area with the basket aligned to the orientation of the spent fuel racks.

ALARA Note:
Wetting the components that enter the spent fuel pool may reduce the amount of decontamination work to be performed later.

c. Wet the surfaces of the HI-STAR 100 overpack and lift yoke with plant demineralized water while slowly lowering the HI-STAR 100 overpack into the spent fuel pool.

d. When the top of the HI-STAR 100 overpack reaches the elevation of the reservoir, open the Annulus Overpressure System reservoir valve. Maintain the reservoir water level at approximately 3/4 full the entire time the cask is in the spent fuel pool.

e. Place the HI-STAR 100 overpack on the floor of the cask loading area and disengage the lift yoke. Visually verify that the lift yoke is fully disengaged. Remove the lift yoke from the spent fuel pool while spraying the crane cables and yoke with plant demineralized water.

8.1.4 MPC Fuel Loading

Note:
An underwater camera or other suitable viewing device may be used for monitoring underwater operations.

1. Perform a fuel assembly selection verification using plant fuel records to ensure that only fuel assemblies that meet all the conditions for loading as specified in Appendix B to Certificate of Compliance ~~72-~~1008 have been selected for loading into the MPC.

2. Load the pre-selected fuel assemblies into the MPC in accordance with the approved fuel loading pattern.

3. Perform a post-loading visual verification of the assembly identification to confirm that the serial numbers match the approved fuel loading pattern.

8.1.5 MPC Closure

Note:
The user may elect to use the optional Lid Retention System (See Figure 8.1.14) to assist in the installation of the MPC lid and attachment of the lift yoke, and to provide the means to secure the MPC lid in the event of a drop or tip-over accident during loaded cask handling operations outside of the spent fuel pool. The user is responsible for evaluating the additional weight imposed on the cask, lift yoke, crane and floor prior to use to ensure that its use does not exceed the crane capacity, heavy loads handling restrictions, or 250,000 pounds. See Tables 8.1.1 and 8.1.2.

1. Visually inspect the MPC lid rigging or Lid Retention System in accordance with site-approved rigging procedures. Attach the MPC lid to the lift yoke so that MPC lid, drain line and trunnions will be in relative alignment. Raise the MPC lid and adjust the rigging so the MPC lid hangs level as necessary.

2. Install the drain line to the underside of the MPC lid. See Figure 8.1.10.

3. Align the MPC lid and lift yoke so the drain line will be positioned in the MPC drain location and the cask trunnions will also engage. See Figure 8.1.11 and 8.1.16.

ALARA Note:
Wetting the components that enter the spent fuel pool may reduce the amount of decontamination work to be performed later.

4. Slowly lower the MPC lid into the pool and insert the drain line into the drain access location and visually verify that the drain line is correctly oriented. See Figure 8.1.11.

5. Lower the MPC lid while monitoring for any hang-up of the drain line. If the drain line becomes kinked or disfigured for any reason, remove the MPC lid and replace the drain line.

Note:
The upper surface of the MPC lid will seat approximately flush with the top edge of the MPC shell when properly installed. ~~The upper surface of the MPC lid will seat approximately 3/8 inch below the top edge of the MPC shell when properly installed.~~

6. Seat the MPC lid in the MPC and visually verify that the lid is properly installed.

7. Engage the lift yoke to the HI-STAR 100 overpack lifting trunnions.

8. Apply a slight tension to the lift yoke and visually verify proper engagement of the lift yoke to the lifting trunnions.

ALARA Note:
Activated debris may have settled on the top face of the HI-STAR 100 overpack and MPC during fuel loading. The cask top surface should be kept under water until a preliminary dose rate scan clears the cask for removal.

9. Raise the HI-STAR 100 overpack until the MPC lid is just below the surface of the spent fuel pool. Survey the area above the cask lid to check for hot particles. Raise and flush the upper surface of the HI-STAR 100 overpack and MPC with the plant demineralized water hoses as necessary to remove any activated particles from the HI-STAR 100 overpack or the MPC lid.

10. Visually verify that the MPC lid is properly seated. Lower the HI-STAR 100 overpack, reinstall the MPC lid, and repeat Step 9, as necessary.

11. If the Lid Retention System is used, inspect the closure plate bolts for general condition. Replace worn or damaged bolts with new bolts.

12. Install the Lid Retention System bolts if the Lid Retention System is used.

Warning:
Cask removal from the spent fuel pool is the heaviest lift that occurs during HI-STAR 100 loading operations. The HI-STAR 100 trunnions must not be subjected to lifted loads in excess of 250,000 lbs. Users may elect to pump a measured quantity of water from the MPC prior to removing the HI-STAR 100 from the spent fuel pool. See Table 8.1.1 and 8.1.2 for weight information.

13. If necessary for lifted weight conditions, pump a measured amount of water from the MPC. See Figure 8.1.18 and Tables 8.1.1 and 8.1.2.

14. Continue to raise the HI-STAR 100 overpack under the direction of the plant's radiological control personnel. Continue rinsing the surfaces with demineralized water. When the top of the HI-STAR 100 overpack reaches the approximate elevation as the reservoir, close the Annulus Overpressure System reservoir valve. See Figure 8.1.13.

Caution:
Users are required to take necessary actions to prevent boiling of the water in the MPC. This may be accomplished by performing a site-specific analysis to identify a time limitation to ensure that water boiling will not occur in the MPC prior to the initiation of draining operations. Chapter 4 of the TSAR provides some sample time limits for the time to initiation of draining for various spent fuel pool water temperatures using design basis heat loads. These time limits may be adopted if the user chooses not to perform a site-specific analysis. If time limitations are imposed, users shall have appropriate procedures and equipment to take action *if time limits are approached or exceeded.* One course of action involves initiating an MPC water flush for a certain duration and flow rate. Any site-specific analysis shall identify the methods to respond should it become likely that the imposed time limit could be exceeded.

ALARA Note:
To reduce decontamination time, the surfaces of the HI-STAR 100 overpack and lift yoke should be kept wet until decontamination begins.

15. Remove the HI-STAR 100 overpack from the spent fuel pool while spraying the surfaces with plant demineralized water. Record the time.

ALARA Note:
Decontamination of the HI-STAR 100 overpack bottom should be performed using pole-mounted cleaning devices.

16. Decontaminate the HI-STAR 100 overpack bottom and perform a contamination survey of the HI-STAR 100 overpack bottom. Remove the bottom protective cover, if used.

17. If used, disconnect the Annulus Overpressure System from the HI-STAR 100 overpack via the quick disconnect. See Figure 8.1.13.

18. Set the HI-STAR 100 overpack in the designated cask preparation area.

19. Disconnect the lifting slings or Lid Retention System (if used) from the MPC lid and disengage the lift yoke. Decontaminate and store these items in an approved storage location.

Warning:
MPC lid dose rates are measured to ensure that dose rates are within expected values. Dose rates exceeding the 429 mrem/hour could indicate that fuel assemblies not meeting the specifications of Appendix B to CoC ~~72~~-1008 have been loaded.

   a. Measure the dose rates at the MPC lid and verify that the combined gamma and neutron dose rate is below 429 mrem/hour.

20. Perform decontamination of the HI-STAR 100 overpack.

21. Prepare the MPC for MPC lid welding as follows:

ALARA Note:
The Temporary Shield Ring is installed by hand, no tools are required.

a. Decontaminate the area around the HI-STAR 100 overpack top flange and install the Temporary Shield Ring, (if used). See Figure 8.1.17.

b. Fill the Temporary Shield Ring with water (if used).

c. Carefully decontaminate the MPC lid top surface and the shell area above the inflatable annulus seal.

d. Deflate and remove the annulus seal.

ALARA Note:
The water in the HI-STAR 100 overpack-to-MPC annulus provides personnel shielding. The level should be checked periodically and refilled accordingly.

22. Attach the drain line to the HI-STAR 100 overpack drain port connector and lower the annulus water level approximately 6 inches.

ALARA Note:
The MPC exterior shell survey is performed to evaluate the performance of the inflatable annulus seal. Indications of contamination could require the MPC to be unloaded.

a. Survey the MPC lid top surfaces and the accessible areas of the top two inches of the MPC shell in accordance with the requirements of LCO 2.2.2.

ALARA Note:
The annulus shield is used to prevent objects from being dropped into the annulus and helps reduce dose rates directly above the annulus region. The annulus shield is hand installed and requires no tools.

23. Install the annulus shield. See Figure 8.1.12.

24. Prepare for MPC lid welding as follows:

Note:
The following steps use two identical Removable Valve Operating Assemblies (RVOAs) (See Figure 8.1.15) to engage the MPC vent and drain ports. The MPC vent and drain ports are equipped with metal-to-metal seals to minimize leakage during vacuum drying, and to withstand the long-term effects of temperature and radiation. The RVOAs allow the vent and drain ports to be operated like valves and prevent the need to hot tap into the penetrations during unloading operations. The RVOAs are purposely not installed until the cask is removed from the spent fuel pool to reduce the amount of decontamination.

Note:
The vent and drain ports are opened by pushing the RVOA handle down to engage the square nut on the cap and turning the handle fully in the counter-clockwise direction. The handle will not turn once the port is fully open. Similarly, the vent and drain ports are closed by turning the handle fully in the clockwise direction. The ports are closed when the handle cannot be turned further.

a. Clean the vent and drain ports to remove any dirt. Install the RVOAs (See Figure 8.1.15) to the vent and drain ports leaving caps open.

ALARA Warning:
Personnel should remain clear of the drain lines any time water is being pumped or purged from the MPC. Assembly crud, suspended in the water, may create a radiation hazard to workers. Controlling the amount of water pumped from the MPC prior to welding keeps the fuel assembly cladding covered with water yet still allows room for thermal expansion.

b. Attach the water pump to the drain port (See Figure 8.1.18) and pump ~~approximately 120 gallons~~*between 50 and 120 gallons of MPC water* to the spent fuel pool or liquid radwaste system. The water level is lowered to keep moisture away from the weld region.

c. Disconnect the water pump.

25. Weld the MPC lid as follows:

ALARA Warning:
Grinding of MPC welds may create the potential for contamination. All grinding activities shall be performed under the direction of radiation protection personnel.

Note:
The vacuum source *may* help~~s~~ improve the weld quality by keeping moist air from condensing on the MPC lid weld area. The vacuum source can be supplied from a wet/dry vacuum cleaner or small vacuum pump.

a. Attach a vacuum source *(if used)* to the vent port or inert the gas space under the MPC lid.

ALARA Warning:
It may be necessary to rotate or reposition the MPC lid slightly to achieve uniform weld gap and lid alignment. A punch mark is located on the outer edge of the MPC lid and shell. These marks are aligned with the alignment mark on the top edge of the HI-STAR 100 overpack (See Figure 8.1.7). If necessary, the MPC lid lift should be performed using a hand operated chain fall to closely control the lift to allow rotation and repositioning by hand. If the chain fall is hung from the crane hook, the crane should be tagged out of service to prevent inadvertent use during this operation. Continuous radiation monitoring is recommended.

b. If necessary center the lid in the MPC shell using a hand-operated chain fall.

Note:
The MPC is equipped with lid shims that serve to close the gap in the joint for MPC lid closure weld.

c. As necessary, install the MPC lid shims around the MPC lid to make the weld gap uniform.

ALARA Note:
The optional AWS Baseplate shield is used to further reduce the dose rates to the operators working around the top cask surfaces.

d. Install the Automated Welding System baseplate shield *(if used)*. See Figure 8.1.8 for rigging.

e. Install the Automated Welding System Robot *(if used)*. See Figure 8.1.8 for rigging.

f. Tack weld the MPC lid.

g. Visually inspect the tack welds.

h. Lay the root weld.

Note:
The MPC lid-to-shell (LTS) weld may be examined by either volumetric examination (UT) or multi-layer liquid penetrant (PT) examination. If volumetric examination is used, it shall be the ultrasonic method and shall include PT examination of the root and final weld layers. If PT alone is used, at a minimum, it must include the root and final layers and one intermediate PT after approximately every 3/8 *inch* of weld depth.

For all PT examinations in this procedure, the ASME Boiler and Pressure Vessel Code, Section V, Article 6 provides the liquid penetrant inspection methods. The acceptance criteria for liquid penetrant examination shall be in accordance with ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Article NB-5350 as specified on the Design Drawings. ASME Code, Section III, Subsection NB, Article NB-4450 provides acceptable requirements for weld repair. NDE personnel shall be qualified per the requirements of Section V of the Code or site-specific program.

Methods for UT examination of the LTS weld shall be in accordance with ASME Section V, Article 5 with acceptance criteria per ASM Section III, NB-5332. NDE personnel shall be qualified per the requirements of Section V of the Code or site-specific program.

i. Disconnect the vacuum source from the vent port (if used).

j. Perform a liquid penetrant examination on the MPC lid root weld.

k. Complete the MPC lid welding, performing at least one intermediate layer liquid penetrant examination after approximately *every* 3/8 inch weld depth.

l. Perform a liquid penetrant examination on the MPC lid final pass and UT examination, as required.

26. Perform hydrostatic and MPC leakage rate testing as follows:

> **ALARA Note:**
> The leakage rates are determined before the MPC is drained for ALARA reasons. A weld repair is a lower dose activity if water remains inside the MPC.

a. Attach the drain line to the vent port and route the drain line to the spent fuel pool or the plant liquid radwaste system. See Figure 8.1.19 for the hydrostatic test arrangement.

> **ALARA Warning:**
> Water flowing from the MPC may carry activated particles and fuel particles. Apply appropriate ALARA practices around the drain line.

b. Fill the MPC with either spent fuel pool water or plant demineralized water until water is observed flowing out of the vent port drain hose.

> **Note:**
> Section 9.1.2.2.2 of the TSAR provides additional details on performance of the hydrostatic test.

c. Perform a hydrostatic test of the MPC as follows:

1. Close the drain valve and pressurize the MPC to 125 +5/-0 psig.

2. Close the inlet valve and monitor the pressure for a minimum of 10 minutes.

3. Following the 10-minute hold period, visually examine the MPC lid-to-shell weld for leakage of water. The acceptance criteria is no observable water leakage.

d. Release the MPC internal pressure, disconnect the water fill line and drain line from the vent and drain port RVOAs leaving the vent and drain port caps open.

1. Repeat Step 25.l.

e. Attach a regulated helium supply (pressure set to 10+10/-0 psig) to the vent port and attach the drain line to the drain port as shown on Figure 8.1.21.

~~f.Reset the totalizer on the drain line.~~

~~g.~~*f.* Verify the correct pressure (pressure set to 10+10/-0 psig) on the helium supply and open the helium supply valve. Drain approximately *5 to 10* ~~twenty~~ gallons. ~~as measured by the totalizer.~~

~~h.~~*g.* Close the drain port valve and pressurize the MPC to 10+10/-0 psig helium.

~~i.~~*h.* Close the vent port.

> **Note:**
> The leakage detector may detect residual helium in the atmosphere. If the leakage tests detects a leak, the area should be flushed with nitrogen or compressed air and the location should be retested.

~~j.~~*i.* Perform a helium sniffer probe leakage rate test of the MPC lid-to shell weld in accordance with the Mass Spectrometer Leak Detector (MSLD) manufacturer's instructions and ANSI N14.5 [8.1.2]. The MPC helium leakage rate test acceptance criteria are specified in LCO 2.1.1.

~~k.~~*j.* Repair any weld defects in accordance with the site's approved weld repair procedures. Reperform the Ultrasonic, Hydrostatic and Helium Leakage tests if weld repair is performed.

27. Drain the MPC as follows:

> ~~**Note:**~~
> ~~It is necessary to completely fill the MPC with water to get an accurate measurement of the MPC internal free space.~~

~~a. Attach the drain line to the vent port and route the drain line to the spent fuel pool or the plant liquid radwaste system. See Figure 8.1.19.~~

> ~~**ALARA Warning:**~~
> ~~Water flowing from the MPC may carry activated particles and fuel particles. Apply appropriate ALARA practices around the drain line.~~

~~b. Attach the water fill line to the drain port (water pressure set to 15+5/-0 psig) and fill the MPC with either spent fuel pool water or plant demineralized water until water is observed flowing out of the drain line.~~

~~c. Disconnect the water fill and drain lines from the MPC leaving the vent port valve open to allow for thermal expansion of the MPC water.~~

> **ALARA Warning:**
> Dose rates will rise as water is drained from the MPC. Continuous dose rate monitoring is recommended.

~~d.~~*a.* Attach a regulated helium or nitrogen supply (pressure set to ~~1~~*25*+5/-0 psig) to the vent port.

~~e.~~*b.* Attach a drain line to the drain port shown on Figure 8.1.21.

~~f.Reset the totalizer on the drain line.~~

~~g.~~*c.* Verify the correct pressure (pressure set to ~~1~~25+5/-0) on the gas supply.

~~h.~~*d.* Open the gas supply valve and record the time at the start of MPC draindown.

Note:
An optional warming device may be placed under the HI-STAR 100 Overpack to replace the heat lost during the evaporation process of vacuum drying. This may be used at the user's discretion for older and colder fuel assemblies to reduce vacuum drying times.

~~i.~~*e.* Start the warming device, if used.

~~j.~~*f.* Blow the water out of the MPC until water ceases to flow out of the drain line. Shut the gas supply valve.

~~k.Record the volume of water (as measured on the totalizer) drained from the MPC.~~

~~l.~~*g.* Disconnect the gas supply line from the MPC.

~~m.~~*h.* Disconnect the drain line from the MPC.

28. Vacuum Dry the MPC as follows:

Note:
Vacuum drying is performed to remove moisture and oxidizing gasses from the MPC. This ensures a suitable environment for long-term storage of spent fuel assemblies and ensures that the MPC pressure remains within design limits. The vacuum drying process reduces the MPC internal pressure in stages. Dropping the internal pressure too quickly may cause the formation of ice in the fittings. Ice formation could result in incomplete removal of moisture from the MPC. *The vacuum stages are intermediate steps and should be considered approximate values.*

a. Attach the Vacuum Drying System (VDS) to the vent and drain port RVOAs. See Figure 8.1.22.

Note:
The Vacuum Drying System may be configured with an optional fore-line condenser to increase vacuum pump efficiency. Water may need to be periodically drained. The volume of condensed water should be measured and added to the water volume measured during MPC draining.

b. Reduce the MPC pressure to approximately 100 torr and throttle the VDS suction valve to maintain this pressure for approximately 15 minutes.

c. Reduce the MPC pressure to approximately 70 torr and throttle the VDS suction valve to maintain this pressure for approximately 15 minutes.

d. Reduce the MPC pressure to approximately 50 torr and throttle the VDS suction valve to maintain this pressure for approximately 15 minutes.

e. Reduce the MPC pressure to approximately 30 torr and throttle the VDS suction valve to maintain this pressure for approximately 15 minutes.

Note:
The Vacuum Drying System pressure will remain at about 30 torr until most of the liquid water has been removed from the MPC.

f. When the MPC pressure begins to drop (without any operator action), completely open the VDS suction valve and reduce the MPC pressure to below 3 torr.

g. Shut the VDS valves and verify a stable MPC pressure on the vacuum gage.

Note:
The MPC pressure may rise due to the presence of water in the MPC. The dryness test may need to be repeated several times until all the water has been removed. Leaks in the Vacuum Drying System, damage to the vacuum pump, and improper vacuum gauge calibration may cause repeated failure of the dryness verification test. These conditions should be checked as part of the corrective actions if repeated failure of the dryness verification test is occurring.

h. Perform the MPC dryness verification test in accordance with the acceptance criteria of LCO 2.1.1.

i. Close the vent and drain port valves.

j. Disconnect the VDS from the MPC.

k. Stop the warming device, if used.

l. Close the drain port RVOA cap and remove the drain port RVOA.

Note:
Helium backfill requires 99.995% (minimum) purity.

29. Backfill the MPC as follows:

~~a. Calculate and record the maximum and minimum Helium backfill loading M_{max} and M_{min} respectively (g-moles):~~

~~$M_{max} = V_W (L^*_{He} - e_L)$~~

~~$M_{min} = V_W (0.90 L^*_{He} + e_L)$~~

~~where:~~

~~M_{max} = maximum helium backfill (g-moles)~~
~~M_{min} = minimum helium backfill (g-moles)~~

~~V_W=~~	~~free volume of the MPC as measured during MPC draining and vacuum drying (liters)~~
~~L^*_{He}=~~	~~backfill loading per unit volume as listed in LCO 2.1.1 (g-moles/liter) for each MPC type~~
~~e_L=~~	~~absolute error in helium loading (g-moles/liter)~~

~~b.~~*a.* Set the helium bottle regulator pressure to 70+5/-0 psig.

~~c.~~*b.* Purge the Helium Backfill System to remove oxygen from the lines.

~~d.~~*c.* Attach the Helium Backfill System (HBS) to the vent port as shown on Figure 8.1.23 and open the vent port.

~~e.Reset the mass-flow meter on the helium supply line.~~

~~f.~~*d.* ~~Verify the correct pressure (pressure set to 70+5/-0 psig) and s~~*S*lowly open the helium supply valve while monitoring the *pressure rise in the MPC.*~~helium mass-flow meter.~~

~~g.~~*e.* ~~Throttle the helium supply to regulate the flow rate to between 40 and 50 standard liters per minute.~~

Note:
If helium bottles need to be replaced, the bottle valve needs to be closed and the entire regulator assembly transferred to the new bottle.

~~h.~~*f.* *Carefully b*~~B~~ackfill the MPC to *greater than 0 psig and less than the maximum pressure specified in LCO 2.1.1*~~between M_{max} and M_{min} as determined in Step 29.a~~.

~~i.~~*g.* Disconnect the HBS from the MPC.

~~j.~~*h.* Close the vent port RVOA and disconnect the vent port RVOA.

30. Weld the vent and drain port cover plates as follows:

a. Wipe the inside area of the vent and drain port recesses to dry and clean the surfaces.

b. Place the cover plate over the vent port recess.

c. Raise the edge of the cover plate and insert the nozzle of the helium supply into the vent port recess to displace the oxygen with helium.

Note:
Helium gas is required to be injected into the port recesses to ensure that the leakage test is valid.

d. Displace the air in the recess using the helium nozzle and immediately close the cover plate.

e. Tack weld the cover plate.

f. Visually inspect the tack welds.

g. Weld the root pass on the vent port cover plate.

Note:
ASME Boiler and Pressure Vessel Code, Section V, Article 6 provides the liquid penetrant inspection methods. The acceptance standards for liquid penetrant examination shall be in accordance with ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Article NB-5350 as specified on the Design Drawings. ASME Code, Section III, Subsection NB, Article NB-4450 provides acceptable requirements for weld repair. NDE personnel shall be qualified per the requirements of Section V of the Code or site-specific program.

h. Perform a liquid penetrant examination on the vent port cover plate root weld.

i. Complete the vent port cover plate welding.

Note:
ASME Boiler and Pressure Vessel Code, Section V, Article 6 provides the liquid penetrant inspection methods. The acceptance standards for liquid penetrant examination shall be in accordance with ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Article NB-5350 as specified on the Design Drawings. ASME Code, Section III, Subsection NB, Article NB-4450 provides acceptable requirements for weld repair. NDE personnel shall be qualified per the requirements of Section V of the Code or site-specific program.

j. Perform a liquid penetrant examination on the vent port cover weld.

k. Repeat Steps 30.a through 30.j for the drain port cover plate.

31. Perform a leakage test of the MPC vent and drain port cover plates as follows:

Note:
The leakage detector may detect residual helium in the atmosphere from the helium injection process. If the leakage tests detects a leak, the area should be blown clear with compressed air or nitrogen and the location should be retested.

a. Flush the area around the vent and drain cover plates with compressed air or nitrogen to remove any residual helium gas.

b. Perform a helium leakage rate test of vent and drain cover plate welds in accordance with the Mass Spectrometer Leak Detector (MSLD) manufacturer's instructions and ANSI N14.5 [8.1.2]. The MPC helium leakage rate test acceptance criteria are specified in LCO 2.1.1.

c. Repair any weld defects in accordance with the site's approved code weld repair procedures. Reperform the leakage test as required.

32. Weld the MPC closure ring as follows:

ALARA Note:
The closure ring is installed by hand. No tools are required.

a. Install and align the closure ring. See Figure 8.1.7.

b. Tack weld the closure ring to the MPC shell and the MPC lid.

c. Visually inspect the tack welds.

d. Lay the root weld between the closure ring and the MPC shell *(as applicable)*.

e. Lay the root weld between the closure ring and the MPC lid *(as applicable)*.

f. Lay the root weld connecting the two closure ring segments *(as applicable)*.

Note:
ASME Boiler and Pressure Vessel Code, Section V, Article 6 provides the liquid penetrant inspection methods. The acceptance standards for liquid penetrant examination shall be in accordance with ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Article NB-5350 as specified on the Design Drawings. ASME Code, Section III, Subsection NB, Article NB-4450 provides acceptable requirements for weld repair. NDE personnel shall be qualified per the requirements of Section V of the Code or site-specific program.

g. Perform a liquid penetrant examination on the closure ring root welds.

h. Complete the closure ring welding.

Note:
ASME Boiler and Pressure Vessel Code, Section V, Article 6 provides the liquid penetrant inspection methods. The acceptance standards for liquid penetrant examination are contained in the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Article NB-5350. ASME Code, Section III, Subsection NB, Article NB-4450 provides acceptable requirements for weld repair. NDE personnel shall be qualified per the requirements of Section V of the Code or site-specific program.

i. Perform a liquid penetrant examination on the closure ring final weld.

j. Remove the Automated Welding System *(if used)*.

k. If necessary, remove the AWS baseplate shield. See Figure 8.1.8 for rigging.

8.1.6 Preparation for Storage

1. Remove the annulus shield and seal surface protector and store it in an approved plant storage location

ALARA Warning:
Dose rates will rise around the top of the annulus as water is drained from the annulus. Apply appropriate ALARA practices.

2. Attach a drain line to the HI-STAR 100 overpack drain connector and drain the remaining water from the annulus to the spent fuel pool or the plant liquid radwaste system (See Figure 8.1.13).

3. Install the overpack closure plate as follows:

   a. Remove any waterproof tape or bolt plugs used for contamination mitigation.

   b. Clean the closure plate seal seating surface and the HI-STAR 100 overpack seal seating surface and install new overpack closure plate mechanical seals.

   c. Remove the test port plug and store it in a site-approved location. Discard any used metallic seals.

Note:
Care should be taken to protect the seal seating surface from scratches, nicks or dents.

   d. Install the closure plate (see Figure 8.1.8). Disconnect the closure plate lifting eyes and install the bolt hole plugs in the empty bolt holes (See Table 8.1.3 for torque requirements).

   e. Install and torque the closure plate bolts. See Table 8.1.3 for torque requirements.

   f. Remove the vent port cover plate and remove the port plug and seal. Discard any used mechanical seals.

4. Dry the overpack annulus as follows:

   a. Disconnect the drain connector from the overpack.

   b. Install the drain port plug with a new seal and torque the plug. See Table 8.1.3 for torque requirements. Discard any used metallic seals.

Note:
Preliminary annulus vacuum drying may be performed using the test cover to improve flow rates and reduce vacuum drying time. Dryness testing and helium backfill shall use the backfill tool.

c. Load the backfill tool with the HI-STAR 100 overpack vent port plug and the vent port with a new plug seal. Attach the backfill tool to the HI-STAR 100 overpack vent port with the plug removed. See Figure 8.1.24. See Table 8.1.3 for torque requirements.

d. Evacuate the HI-STAR 100 overpack pressure to approximately 100 torr.

e. Evacuate the HI-STAR 100 overpack pressure to approximately 50 torr.

f. Evacuate the HI-STAR 100 overpack pressure to approximately 30 torr.

g. Throttle the VDS suction valves to maintain about 30 torr.

Note:
The Vacuum Drying System pressure will remain at about 30 torr until most of the liquid water has been removed from the overpack.

h. Continue to operate the Vacuum Drying System at about 30 torr while monitoring the HI-STAR 100 overpack pressure.

i. When the HI-STAR 100 overpack pressure begins to drop (without any operator action), completely open the Vacuum Drying System suction valve and reduce the HI-STAR 100 overpack pressure to below 3 torr.

Note:
The annulus pressure may rise due to the presence of water in the HI-STAR 100 overpack. The dryness test may need to be repeated several times until all the water has been removed. Leaks in the Vacuum Drying System, damage to the vacuum pump, and improper vacuum gauge calibration may cause repeated failure of the dryness verification test. These conditions should be checked as part of the corrective actions if repeated failure of the dryness verification test is occurring.

j. Perform a HI-STAR 100 overpack Annulus Dryness Verification in accordance with LCO 2.1.2.

5. Backfill, and leakage test the overpack as follows:

a. Attach the helium supply to the backfill tool.

b. Verify the correct pressure on the helium supply (pressure set to10+4/-0 psig) and open the helium supply valve.

c. Backfill the HI-STAR 100 overpack annulus in accordance with LCO 2.1.2.

d. Install the overpack vent port plug and torque. See Table 8.1.3 for torque requirements.

e. Disconnect the overpack backfill tool from the vent port.

f. Flush the overpack vent port recess with compressed air to remove any standing helium gas.

g. Install the overpack test cover to the overpack vent port as shown on Figure 8.1.25. See Table 8.1.3 for torque requirements.

h. Evacuate the test cavity per the MSLD manufacturer's instructions and isolate the vacuum pump from the overpack test cover.

i. Perform a leakage rate test of overpack vent port plug per the MSLD manufacturer's instructions and ANSI N14.5 [8.1.2]. The helium leakage rate test acceptance criterion is specified in LCO 2.1.2.

j. Remove the overpack test cover and install a new metallic seal on the overpack vent port cover plate. Discard any used metallic seals.

k. Install the vent port cover plate and torque the bolts. See Table 8.1.3 for torque requirements.

l. Repeat Steps 5.f through 5.k for the overpack drain port.

6. Leak test the overpack closure plate inner mechanical seal as follows:

a. Attach the closure plate test tool to the closure plate test port with the and MSLD attached. See Figure 8.1.26. See Table 8.1.3 for torque requirements.

b. Evacuate the closure plate test port tool and closure plate inter-seal area per the MSLD manufacturer's instructions.

c. Perform a leakage rate test of overpack closure plate inner mechanical seal in accordance with the MSLD manufacturer's instructions and ANSI N14.5 [8.1.2]. The helium leakage rate test acceptance criterion is specified in LCO 2.1.2.

d. Remove the closure plate test tool from the test port and install the test port plug with a new mechanical seal. See Table 8.1.3 for torque requirements. Discard any used metallic seals.

7. Drain the Temporary Shield Ring (Figure 8.1.17), if used. Remove the ring segments and store them in an approved plant storage location.

ALARA Warning:
For ALARA reasons, decontamination of the overpack bottom shall be performed using pole-mounted cleaning tools or other remote leaning devices.

ALARA Warning:
If the overpack is to be downended on the transport frame, the bottom shield should be installed quickly. Personnel should remain clear of the bottom of the unshielded overpack.

a. Raise the HI-STAR 100 overpack and decontaminate the overpack bottom and perform a final survey and decontamination of the overpack. The acceptance criteria are the user's site requirements for transporting items out of the radiological controlled area or the LCO 2.2.2 (whichever is more restrictive).

8. Verify that the HI-STAR 100 overpack dose rates are within the requirements of LCO 2.2.1.

8.1.7 Placement of the HI-STAR 100 Overpack into Storage

1. Secure the HI-STAR 100 overpack to the transporter as necessary. See Figure 8.1.27 for several transporter options.

2. Verify lifting requirements of LCO 2.1.3 are met.

3. Remove the transporter wheel chocks (if necessary) and transfer the HI-STAR 100 overpack to the ISFSI along the site-approved transfer route.

Note:
The HI-STAR 100 minimum pitch shall be 12 feet (nominal).

4. Transfer the HI-STAR 100 overpack to its designated storage location at the appropriate pitch. See Figure 8.1.28.

5. Install the HI-STAR 100 overpack pocket trunnion plugs and shear ring segments, if necessary. See Table 8.1.3 for torque requirements. See Figure 8.1.29.

ALARA Note:
The optional overpack bottom ring is used to reduce dose rates around the base of the HI-STAR 100 overpack. The segments are slid into place under the HI-STAR 100 overpack neutron shield.

6. If used, install the Overpack Bottom Ring (Figure 8.1.30).

Table 8.1.1

HI-STAR 100 SYSTEM COMPONENT AND HANDLING WEIGHTS

Component	Weight (lbs)		Case† Applicability			
	MPC-24	MPC-68	1	2	3	4
Empty HI-STAR 100 overpack (without closure plate)	145,726	145,726	1	1	1	1
HI-STAR 100 overpack lid (closure plate without rigging)	7,984	7,984		1	1	1
Empty MPC (without lid or closure ring)	29,075	28,502	1	1	1	1
MPC lid (without fuel spacers or drain line)	9677	10,194	1	1	1	1
MPC Closure Ring	145	145		1	1	1
MPC Lower Fuel Spacers (variable)††	401	258	1	1	1	1
MPC Upper Fuel Spacers (variable)††	144	315	1	1	1	1
MPC Drain Line	50	50	1	1	1	1
Fuel (design basis without non-fuel bearing components)	36,360	42,092	1	1	1	1
Damaged Fuel Container (Dresden 1)	0	150				
Damaged Fuel Container (Humboldt Bay)	0	120				
MPC water (with fuel in MPC)†††	17,630	16,957	1			
Annulus Water	280	280	1			
HI-STAR 100 overpack Lift Yoke (with slings)	*3600*~~3200~~	*3600*~~3200~~	1	1		
Annulus Seal	50	50	1			
Lid Retention System (optional)	2300	2300				
Transport Frame	6700	6700				1
Overpack Bottom Cover (optional)	6400	6400				1
Temporary Shield Ring (optional)	2500	2500				
Automated Welding System Baseplate Shield (optional)	2000	2000				
Automated Welding System Robot	1900	1900				
Pocket Trunnion Plugs (optional)	60	60			1	
Overpack Bottom Ring (optional)	1300	1300			1	

† See Table 8.1.2.

†† The fuel spacers referenced in this table are for the heaviest fuel assembly for each MPC. This yields the maximum weight of fuel assemblies and spacers.

††† Varies by fuel type and loading configuration. Users may opt to pump some water from the MPC prior to removal from the spent fuel pool to reduce the overall lifted weight.

TABLE 8.1.2
MAXIMUM HANDLING WEIGHTS
HI-STAR 100 OVERPACK

Caution:
The maximum weight supported by the HI-STAR 100 overpack lifting trunnions (not including the lift yoke) cannot exceed 250,000 lbs. Users should determine their specific handling weights based on the MPC contents and the expected handling modes.

Note:
The weight of the fuel spacers and the damaged fuel container are less than the weight of the design basis fuel assembly for each MPC and are therefore not included in the maximum handling weight calculations.

Case No.	Load Handling Evolution	Weight (lbs)	
		MPC-24	MPC-68
1	Loaded HI-STAR 100 Overpack Removal from Spent Fuel Pool	*242,993*~~242,593~~	*248,024*~~247,624~~
2	Loaded HI-STAR 100 Overpack Movement to transport device	*233,162*~~232,762~~	*238,866*~~238,466~~
3	Loaded HI-STAR 100 Overpack in Storage	230,922	236,626
4	Loaded HI-STAR 100 on Transport Frame During On-Site Handling	242,662	248,366

Table 8.1.3
HI-STAR 100 SYSTEM TORQUE REQUIREMENTS

Fastener	Torque (ft-lbs)	Pattern
Overpack Closure Plate Bolts†, ††	First Pass – Hand Tight Second Pass – Wrench Tight Third Pass – 860+25/-25 Fourth Pass – 1725+50/-50 Final Pass - 2895+90/-90	Figure 8.1.31
Overpack Vent and Drain Port Cover Plate Bolts††	12+2/-0	X-pattern
Overpack Vent and Drain Port Plugs	~~22+2/-0~~ *45+5/-2*	None
Closure Plate Test Port Plug	22+2/-0	None
Backfill Tool Test Cover Bolts††	16+2/-0	X-pattern
Shear Ring Segment Bolts	22+2/-0	None
Overpack Bottom Cover Bolts	200+20/-0	None
Pocket Trunnion Plugs	Hand Tight	None
Upper Fuel Spacers	Hand Tight	None
Threaded Inserts (all)	Hand Tight	None

† Detorquing shall be performed by turning the bolts counter-clockwise in 1/3 turn +/- 30 degrees increments per pass according to Figure 8.1.31 for three passes. The bolts may then be removed.

†† Bolts shall be cleaned and inspected for damage or excessive wear (replaced if necessary) and coated with a light layer of Fel-Pro Chemical Products, N-5000, Nuclear Grade Lubricant (or equivalent).

Table 8.1.4
HI-STAR 100 SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION

Equipment	Important To Safety Classification	Reference Figure	Description
Annulus Overpressure System (optional)	Not Important To Safety	8.1.13	The Annulus Overpressure System is used for supplemental protection against spent fuel pool water contamination of the external MPC shell and baseplate surfaces by providing a slight annulus overpressure. The Annulus Overpressure System consists of the quick disconnects water reservoir, reservoir valve and annulus connector hoses. User is responsible for supplying demineralized water to the location of the Annulus Overpressure System.
Annulus Shield (optional)	Not Important To Safety	8.1.12	A segmented solid shield that is placed at the top of the annulus to provide supplemental shielding to the operators performing cask loading and closure operations. Shield segments are installed by hand, no crane or tools required.
Automated Welding System (optional)	Not Important To Safety	8.1.2b	Used for remote welding of the MPC lid, vent and drain port cover plates and the MPC closure ring. The AWS consists of the robot, wire feed system, torch system, weld power supply and gas lines.
AWS Baseplate Shield (optional)	Not Important To Safety	8.1.2b	The AWS baseplate shield provides supplemental shielding to the operators during the cask closure operations.
Backfill Tool	Not Important to Safety	8.1.24	Used to dry, backfill the HI-STAR 100 annulus and install the HI-STAR 100 overpack vent and drain port plugs. The backfill tool uses the same bolts as the HI-STAR 100 overpack vent and drain cover plates.
Blowdown Supply System	Not Important To Safety	8.1.21	Gas hose with pressure gauge, regulator used for blowdown of the MPC.
Cask Transporter	User designated	8.1.27	Used for handling of the HI-STAR 100 overpack cask around the site. The cask transporter may take the form of heavy haul transfer trailer, special transporter or other equipment specifically designed for such function.
Closure Plate Test Tool	Not Important to Safety	8.1.26	Used to helium leakage test the HI-STAR 100 overpack Closure Plate inner mechanical seal.

Table 8.1.4
HI-STAR 100 SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION
(continued)

Equipment	Important To Safety Classification	Reference Figure	Description
Cool-Down System	Not Important To Safety	8.3.5	The Cool-Down System is a closed-loop forced ventilation cooling system used to gas-cool the MPC fuel assemblies down to a temperature water can be introduced without the risk of thermally shocking the fuel assemblies or flashing the water, causing uncontrolled pressure transients. The Cool-Down System is attached between the MPC drain and vent ports The CDS consists of the piping, blower, heat exchanger, valves, instrumentation, and connectors. The CDS is used only for unloading operations.
Drain Connector	Not Important To Safety	8.1.13	Used for draining the annulus water following cask closure operations. The Drain Connector consists of the connector pipe valve, and quick disconnect for adapting to the Annulus Overpressure System.
Four Legged Sling and Lifting Rings	Not Important To Safety (controlled under the user's rigging equipment program)	8.1.8	Used for rigging the HI-STAR 100 overpack upper shield lid, MPC lid, AWS Baseplate shield, and Automated Welding System Baseplate Shield. Consists of a four legged sling, lifting rings, shackles and a main lift link.
Helium Backfill System	Not Important To Safety	8.1.23	Used for helium backfilling of the MPC. System consists of the gas lines, mass flow monitor, integrator, and valved quick disconnect.
Hydrostatic Test System	Not Important to Safety	8.1.19	Used to hydrostatically test the MPC primary welds. The hydrostatic test system consists of the gauges, piping, pressure protection system piping and connectors.
Inflatable Annulus Seal	Not Important To Safety	8.1.12	Used to prevent spent fuel pool water from contaminating the external MPC shell and baseplate surfaces during in-pool operations.
Lid Retention System (optional)	User designated	8.1.14	The Lid Retention System provides three functions; it guides the MPC lid into place during underwater installation, establishes lift yoke alignment with the HI-STAR 100 overpack trunnions, and locks the MPC lid in place during cask handling operations between the pool and decontamination pad. The device consists of the retention disk, alignment pins, lift yoke connector links and lift yoke attachment bolts.

Table 8.1.4
HI-STAR 100 SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION
(continued)

Equipment	Important To Safety Classification	Reference Figure	Description
Lift Yoke	User designated	8.1.3	Used for HI-STAR 100 overpack cask handling when used in conjunction with the overhead crane. The lift yoke consists of the lift yoke assembly and crane hook engagement pin(s). The lift yoke is a modular design that allows inspection, disassembly, maintenance and replacement of components.
MPC Fill Pump System (optional)	Not Important To Safety	Not shown	Large pump used for filling the MPC with spent fuel pool water prior to cask insertion into the spent fuel pool. Also used for emptying of the MPC for unloading operations.
MPC Upending Frame	Not Important to Safety	8.1.5	A welded steel frame used to evenly support the MPC during upending operations. The frame consists of the main frame, MPC support saddles, two rigging bars, wrap around-straps, and strap attachment lugs.
MSLD (Helium Leakage Detector)	Not Important To Safety	Not shown	Used for helium leakage testing of the MPC closure welds.
MSLD Calibration Sources.	Not Important To Safety	Not shown	Traceable leakage sources for periodic calibration of the MSLD.
Overpack Bottom Cover (optional)	Not Important to Safety	Not shown	A cup-shaped shield used to reduce dose rates around the HI-STAR 100 overpack bottom end when operated in the horizontal orientation.
Overpack Bottom Ring (optional)	Not Important to Safety	Figure 8.1.30	Segmented shield ring that fits under the HI-STAR 100 overpack neutron shield. Used to reduce dose rates around the HI-STAR 100 overpack bottom end.
Overpack Test Cover	Not Important to Safety	8.1.25	Used to helium leakage test the HI-STAR 100 overpack vent and drain port plug seals.
Seal Surface Protector (optional)	Not Important to Safety	8.1.12	Used to protect the HI-STAR 100 overpack mechanical seal seating surface during loading and MPC closure operations.
Small Water Pump (optional)	Not Important To Safety	8.1.18	Used for lowering the MPC water level prior to lid welding. The small water pump consists of the pump, hose and connector fittings.
Temporary Shield Ring (optional)	Not Important To Safety	8.1.17	A water-filled segmented tank that fits on the cask neutron shield around the upper forging and provides supplemental shielding to personnel performing cask loading and closure operations. Shield segments are installed by hand, no tools are required.

Table 8.1.4
HI-STAR 100 SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION
(continued)

Equipment	Important To Safety Classification	Reference Figure	Description
Threaded Inserts	Not Important To Safety	Not shown	Used to fill the empty threaded holes in the HI-STAR 100 overpack and MPC.
Transport Frame (optional)	Not Important To Safety	8.1.4	A frame used to support the HI-STAR 100 overpack during on-site movement and upending/downending operations. The frame consists of the rotation trunnions, main frame beams and front saddle and lift points.
Vacuum Drying System	Not Important To Safety	8.1.22	Used for removal of residual moisture from the MPC and HI-STAR 100 Overpack annulus following water draining. Used for evacuation of the MPC to support backfilling operations. Used to support test volume samples for MPC unloading operations. The VDS consists of the vacuum pump, piping, skid, gauges, valves, inlet filter, flexible hoses, connectors, control system.
Vacuum Drying System Fore-Line Condenser (optional)	Not Important to Safety	Not Shown	Optional item used to improve the Vacuum Drying System pump efficiency. The condenser removes water from the vacuum stream prior to the vacuum pump.
Vent and Drain RVOAs (optional)	Not Important To Safety	8.1.15	Used to drain, dry, inert and fill the MPC through the vent and drain ports. The vent and drain RVOAs allow the vent and drain ports to be operated like valves and prevent the need to hot tap into the penetrations during unloading operation.
Warming Device (optional)	Not Important to Safety	Not Shown	Used to improve vacuum drying time for older and colder fuel assemblies. The device typically consists of the heater pad, heater, circulation pump, expansion tank, hoses and fittings. Other configurations are acceptable.
Water Totalizers	Not Important To Safety	8.1.18 and 8.1.21	Used for water pump-down prior to lid welding operations *and water removal for MPC helium leakage testing*. ~~Used for determining the MPC free space volume which is the input for the calculation of the required helium backfill quantities.~~
Weld Removal System (optional)	Not Important To Safety	8.3.2b	Semi-automated weld removal system used for removal of the MPC to shell weld, MPC to closure ring weld and closure ring to MPC shell weld. The WRS mechanically removes the welds using a high-speed cutter.

Table 8.1.5
HI-STAR 100 SYSTEM INSTRUMENTATION SUMMARY FOR LOADING AND UNLOADING OPERATIONS†

Note:
The following list summarizes the instruments identified in the procedures for cask loading and unloading operations. Alternate instruments are acceptable as long as they can perform appropriate measurements.

Instrument	Function
Dose Rate Monitors/Survey Equipment	Monitors dose rate and contamination levels and ensures proper function of shielding. Ensures assembly debris is not inadvertently removed from the spent fuel pool during overpack removal.
Flow Rate Monitor	Monitors the air flow rate during assembly cool-down.
Helium Mass Flow Monitor (optional)	Determines the amount of helium introduced into the MPC during backfilling operations. Includes integrator.
Helium Mass Spectrometer Leak Detector (MSLD)	Ensures leakage rates of welds are within acceptance criteria.
Helium Pressure Gauges	Ensures correct helium backfill pressure during backfilling operation.
Volumetric Testing Rig	Used to assess the integrity of the MPC lid-to-shell weld.
Pressure Gauge	Ensures correct helium pressure during fuel cool-down operations.
Hydrostatic Test Pressure Gauge	Used for hydrostatic testing of MPC lid-to-shell weld.
Temperature Gauge	Monitors the state of fuel cool-down prior to MPC flooding.
Temperature Probe	For fuel cool-down operations
Vacuum Gauges	Used for vacuum drying operations and to prepare an MPC evacuated sample bottle for ~~MPC~~*MPC* gas sampling for unloading operations.
Water Pressure Gauge	Used for performance of the MPC Hydrostatic Test.
Water Totalizer	Used for water pump-down prior to lid welding operations *and water removal for MPC helium leakage testing.* ~~Used for determining the MPC free space volume which is the input for the calculation of the required helium backfill quantities.~~

† All instruments require calibration. See figures at the end of this section for additional instruments, controllers and piping diagrams.

Table 8.1.6
HI-STAR 100 OVERPACK INSPECTION CHECKLIST

Note:
This checklist provides the basis for establishing a site-specific inspection checklist for the HI-STAR 100 overpack. Specific findings shall be brought to the attention of the appropriate site organizations for assessment, evaluation and potential corrective action prior to use.

HI-STAR 100 Overpack Closure Plate:

1. Lifting rings shall be inspected for general condition and date of required load test certification.
2. The test port shall be inspected for dirt and debris, hole blockage, thread condition, presence or availability of the port plug and replacement mechanical seals.
3. The mechanical seal grooves shall be inspected for cleanliness, dents, scratches and gouges and the presence or availability of replacement mechanical seals.
4. The painted surfaces shall be inspected for corrosion and chipped, cracked or blistered paint.
5. All closure plate surfaces shall be relatively free of dents, scratches, gouges or other damage.
6. The vent port plug shall be inspected for thread condition, and sealing surface condition (scratches, gouges).
7. Overpack vent port shall be inspected for presence or availability of port plugs, hole blockage, plug seal seating surface condition.
8. Overpack vent port cover plate shall be inspected for cleanliness, scratches, dents, and gouges, availability of retention bolts, availability of replacement mechanical seals.

HI-STAR 100 Overpack Main Body:

1. The impact limiter attachment bolt holes shall be inspected for dirt and debris and thread condition.
2. The mechanical seal seating surface shall be inspected for cleanliness, scratches, and dents or gouges.
3. The drain port plug shall be inspected for thread condition, and sealing surface condition (scratches, gouges).
4. The closure plate bolt holes shall be inspected for dirt, debris and thread damage.
5. Painted surfaces shall be inspected for corrosion and chipped, cracked or blistered paint.
6. Trunnions shall be inspected for deformation, cracks, thread damage, end plate damage, corrosion, excessive galling, damage to the locking plate, presence or availability of locking plate and end plate retention bolts.

Table 8.1.6
HI-STAR 100 OVERPACK INSPECTION CHECKLIST
(continued)

~~1.~~*7.* Pocket trunnion recesses shall be inspected for indications of over stressing (i.e., cracks, deformation, excessive wear).

~~2.~~*8.* Overpack drain port cover plate shall be inspected for cleanliness, scratches, dents, and gouges, availability of retention bolts, availability of replacement mechanical seals.

~~3.~~*9.* Overpack drain port shall be inspected for presence or availability of port plug, availability of replacement mechanical seals, hole blockage, plug seal seating surface condition.

~~4.~~*10.* Annulus inflatable seal groove shall be inspected for cleanliness, scratches, dents, gouges, sharp corners, burrs or any other condition that may damage the inflatable seal.

~~5.~~*11.* The overpack rupture disks shall be inspected for presence or availability and the top surface of the disk shall be visually inspected for holes, cracks, tears or breakage.

~~6.~~*12.* The nameplate shall be inspected for presence and general condition.

~~7.~~*13.* The removable shear ring shall be inspected for fit and thread condition.

Table 8.1.7
MPC RECEIPT INSPECTION CHECKLIST

Note:
This checklist provides the basis for establishing a site-specific inspection checklist for MPC. Specific findings shall be brought to the attention of the appropriate site organizations for assessment, evaluation and potential corrective action prior to use.

MPC Lid and Closure Ring:
1. The MPC lid and closure ring surfaces shall be relatively free of dents, gouges or other shipping damage.
2. The drain line shall be inspected for straightness, thread condition, and blockage.
3. Upper fuel spacers (if used) shall be inspected for availability and general condition. Plugs shall be available for non-used spacer locations.
4. Lower fuel spacers (if used) shall be inspected for availability and general condition.
5. Drain and vent port cover plates shall be inspected for availability and general condition.
6. Serial numbers shall be inspected for readability.

MPC Main Body:
1. All visible MPC body surfaces shall be inspected for dents, gouges or other shipping damage.
2. Fuel cell openings shall be inspected for debris, dents and general condition.
3. Lift lugs shall be inspected for general condition.
4. Verify proper MPC basket type for contents.

8.3 PROCEDURE FOR UNLOADING THE HI-STAR 100 SYSTEM IN THE SPENT FUEL POOL

8.3.1 Overview of HI-STAR 100 System Unloading Operations

ALARA Note:
The procedure described below uses the Weld Removal System, a remotely operated system that mechanically removes the welds. Users may opt to remove some or all of the welds using hand operated equipment. The decision should be based on dose rates, accessibility, degree of weld removal, and available tooling and equipment.

The HI-STAR 100 System unloading procedures describe the general actions necessary to prepare the MPC for unloading, cool the stored fuel assemblies in the MPC, flood the MPC cavity, remove the lid welds, unload the spent fuel assemblies, and recover the HI-STAR 100 overpack and empty MPC. Special precautions are outlined to ensure personnel safety during the unloading operations, and to prevent the risk of MPC over-pressurization and thermal shock to the stored spent fuel assemblies. Figure 8.3.1 shows a flow diagram of the HI-STAR 100 overpack unloading operations. Figure 8.3.2 illustrates the major HI-STAR 100 overpack unloading operations.

Refer to the boxes of Figure 8.3.2 for the following description. The HI-STAR 100 overpack is returned to the fuel building using any of the methodologies as described in Section 8.1 (Box 1). The HI-STAR 100 overpack vent port cover plate is removed and a gas sample is drawn from the HI-STAR 100 overpack annulus to determine the condition of the MPC confinement boundary. The annulus is depressurized and the HI-STAR 100 overpack closure plate is removed (Box 2). The Temporary Shield Ring is installed on the HI-STAR 100 overpack upper section. The Temporary Shield Ring and annulus are filled with plant demineralized water. The annulus shield is installed to protect the annulus from debris produced from the lid removal process. The MPC closure ring weld is removed using the Weld Removal System. The closure ring *above the vent and drain ports and the vent and drain port cover plates are core-drilled and removed to access the vent and drain ports.*~~is removed. The vent port cover plate weld is removed and the cover plate is removed~~ (Box 3). The design of the vent and drain ports use metal-to-metal seals that prevent rapid decompression of the MPC and subsequent spread of contamination during unloading. The vent port RVOA is attached to the vent port and an evacuated sample bottle is connected. The vent port is opened slightly to allow the sample bottle to obtain a gas sample from inside the MPC. A gas sample is performed to assess the condition of the fuel assembly cladding.~~ A vent line is attached to the vent port and the MPC is vented to the fuel building ventilation system or spent fuel pool as determined by the site's radiation protection personnel. The drain port cover plate weld is removed and the cover plate is removed.~~

The MPC is cooled using a closed-loop heat exchanger to reduce the MPC internal temperature to allow water flooding (Box 4). The cool-down process gradually reduces the cladding temperature to a point where the MPC may be flooded with water without thermally shocking the fuel assemblies or causing uncontrolled pressure transients the MPC from the formation of steam. Following the fuel cool-down, the MPC is filled with water at a specified rate (Box 5). The Weld Removal System then removes *both the closure ring-to-MPC shell weld and* the MPC lid to MPC shell welds. The Weld Removal System is removed with the MPC lid left in place (Box 6).

The top surfaces of the HI-STAR 100 overpack and MPC are cleared of metal shavings. The annulus shield is removed and the inflatable annulus seal is installed and pressurized. The MPC lid is rigged to the lift yoke or Lid Retention System and the lift yoke is engaged to the HI-STAR 100 overpack lifting trunnions. The HI-STAR 100 overpack is placed in the spent fuel pool and the MPC lid is removed (Box 7). All fuel assemblies are returned to the spent fuel storage racks (Box 8) and the MPC fuel cells are vacuumed to remove any assembly debris and crud. The HI-STAR 100 overpack and MPC are returned to the designated preparation area (Box 9) where the MPC water is pumped back into the spent fuel pool or liquid radwaste facility. The annulus water is drained and the MPC and overpack are decontaminated (Box 10 and 11).

8.3.2 HI-STAR 100 Overpack Recovery from Storage

1. Transfer the HI-STAR 100 overpack to the fuel building. The same methods may be used as was performed in the original cask placement operations. See Section 8.1.

2. Position the HI-STAR 100 overpack under the lifting device.

3. Place the HI-STAR 100 overpack in the designated preparation area.

ALARA Warning:
Gas sampling is performed to assess the condition of the MPC confinement boundary. If a leak is discovered in the MPC boundary, the user's Radiation Control organization may require special actions to vent the HI-STAR 100.

4. Perform annulus gas sampling as follows:

   a. Remove the overpack vent port cover plate and attach the backfill tool with a sample bottle attached. See Figure 8.3.3. Store the cover plate in a site-approved location.

   b. Using a vacuum pump, evacuate the sample bottle and backfill tool.

   c. Slowly open the vent port plug and gather a gas sample from the annulus. Reinstall the HI-STAR 100 overpack vent port plug.

   d. Evaluate the gas sample and determine the condition of the MPC confinement boundary.

5. If the confinement boundary is intact (i.e., no radioactive gas is measured) then vent the overpack annulus by removing the overpack vent port seal plug (using the backfill tool). Otherwise vent the annulus gas in accordance with instructions from Radiation Protection.

6. Remove the closure plate bolts. See Table 8.1.3 for detorquing requirements. Store the closure plate bolts in a site-approved location.

7. Remove the overpack closure plate. See Figure 8.1.8 for rigging. Store the closure plate on cribbing to protect the seal seating surfaces.

8. Install the HI-STAR 100 overpack Seal Surface Protector (See Figure 8.1.12).

Warning:
Annulus fill water may flash to steam due to high MPC shell temperatures. Water addition should be performed in a slow and controlled manner.

9. Remove the HI-STAR 100 overpack drain port cover and port plug and install the drain connector. Store the drain port cover plate and port plug in an approved storage location.

10. Slowly fill the annulus area with plant demineralized water to approximately 4 inches below the top of the MPC shell and install the annulus shield. The annulus shield reduces the dose around the annulus area and prevents debris from entering the annulus during MPC lid weld removal operations. See Figure 8.1.12.

11. Remove the MPC closure *welds*~~ring~~ as follows:

ALARA Note:
The following procedures describe weld removal using the Weld Removal System. The Weld Removal System removes the welds with a high speed machine tool head. A vacuum head is attached to remove a majority of the metal shavings. Other methods of opening the MPC are acceptable.

ALARA Warning:
Weld removal may create an airborne radiation condition. Weld removal must be performed under the direction of the user's Radiation Protection organization.

a. Install bolt plugs and/or waterproof tape on the closure plate bolt holes.

b. Install the Weld Removal System on the MPC lid and *core drill through the closure ring and vent and drain port cover plate welds.*~~remove the closure ring inner and outer welds.~~

c. ~~Remove the closure ring.~~

12. Access the vent and drain ports.

~~12.Remove the vent port cover plate weld and remove the vent port cover plate.~~

ALARA Note:
The MPC vent and drain ports are equipped with metal-to-metal seals to minimize leakage and withstand the long-term effects of temperature and radiation. The vent and drain port design prevents the need to hot tap into the penetrations during unloading operation and eliminate the risk of a pressurized release of gas from the MPC.

13. Take an MPC gas sample as follows:

a. Attach the RVOA to the vent port (See Figure 8.1.15).

b. Attach a sample bottle to the vent port RVOA as shown on Figure 8.3.4.

c. Using the Vacuum Drying System, evacuate the RVOA and Sample Bottle.

d. Slowly open the vent port cap using the RVOA and gather a gas sample from the MPC internal atmosphere.

e. Close the vent port cap and disconnect the sample bottle.

ALARA Note:
The gas sample analysis is performed to determine the condition of the fuel cladding in the MPC. The gas sample may indicate that fuel with damaged cladding is present in the MPC. The results of the gas sample test may affect personnel protection and how the gas is processed during MPC depressurization.

f. Turn the sample bottle over to the site's Radiation Protection or Chemistry Department for analysis.

~~g. Remove the drain port cover plate weld and remove the cover plate.~~

~~h.~~*g.* Install the RVOA in the drain port.

14. Perform Fuel Assembly Cool-Down as follows:

a. Configure the Cool-Down System as shown on Figure 8.3.5.

b. Verify that the helium gas pressure regulator is set *to less than 100 psig.*~~to 85+3/-3 psig~~.

c. Open the helium gas supply valve to purge the gas lines of air.

Note:
The coolant flow direction is into the drain port and out of the vent port.

d. Confirm the heat exchanger coolant flow direction.

e. If necessary, slowly open the helium supply valve and increase the Cool-Down System pressure to *MPC pressure*~~100 +3/-3 psig~~. Close the helium supply valve.

f. Start the gas coolers.

g. Open the vent and drain port caps using the RVOAs.

h. Start the blower and monitor the gas exit temperature. Continue the fuel cool-down operations until the gas exit temperature meets the requirements of LCO *2.1.4*.

Note:
Water filling should commence immediately after the completion of fuel cool-down operations to minimize prevent fuel assembly heat-up. Prepare the water fill and vent lines in advance of water filling.

i. Prepare the MPC fill and vent lines as shown on Figure 8.1.19. Route the vent port line several feet below the spent fuel pool surface or to the radwaste gas facility. Turn off the blower and disconnect the gas lines to the vent and drain port RVOAs. Attach the vent line to the MPC vent port and slowly open the vent line valve to depressurize the MPC.

j. Attach the water fill line to the MPC drain port and slowly open the water supply valve and establish a ~~flow rate of between 12 to18 gallons per minute (gpm) and a~~ pressure less than 90 psi. Fill the MPC until bubbling from the vent line has terminated. Close the water supply valve on completion.

k. Disconnect both lines from the drain and vent ports leaving the drain port cap open to allow for thermal expansion of the water during MPC lid weld removal.

l. Remove the *closure ring-to-MPC shell weld and the* MPC lid-to-shell weld using the Weld Removal System and remove the Weld Removal System. See Figure 8.1.8 for rigging.

m. Vacuum the top surfaces of the MPC and the HI-STAR 100 overpack to remove any metal shavings.

15. Install the inflatable annulus seal as follows:

Caution:
Do not use any sharp tools or instruments to install the inflatable seal.

a. Remove the annulus shield.

b. Manually insert the inflatable seal around the MPC. See Figure 8.1.12.

c. Ensure that the seal is uniformly positioned in the annulus area.

d. Inflate the seal to between 30 and 35 psig or as directed by the manufacturer.

~~d.Inflate the seal between 30 and 35 psig.~~

e. Visually inspect the seal to ensure that it is properly seated in the annulus. Deflate, adjust and inflate the seal as necessary.

16. Place HI-STAR 100 overpack in the spent fuel pool as follows:

a. Engage the lift yoke to the HI-STAR 100 overpack lifting trunnions, remove the MPC lid lifting threaded inserts and attach the MPC lid slings or Lid Retention System to the MPC lid.

b. If the Lid Retention System is used, inspect the lid bolts for general condition. Replace worn or damaged bolts with new bolts.

c. Install the Lid Retention System bolts if the Lid Retention System is used.

ALARA Note:
The Annulus Overpressure System is used to provide additional protection against MPC external shell contamination during in-pool operations. The Annulus Overpressure System is equipped with double locking quick disconnects to prevent inadvertent draining. The reservoir valve must be closed to ensure that the annulus is not inadvertently drained through the Annulus Overpressure System when the cask is raised above the level of the annulus reservoir.

d. If used, fill the Annulus Overpressure System lines and reservoir with demineralized water and close the reservoir valve. Attach the Annulus Overpressure System to the HI-STAR 100 overpack via the quick disconnect. See Figure 8.1.13.

Warning:
Cask placement in the spent fuel pool is the heaviest lift that occurs during the HI-STAR 100 unloading operations. The HI-STAR 100 trunnions must not be subjected to lifted loads in excess of 250,000 lbs. Users may elect to pump a measured quantity of water from the MPC prior to placement of the HI-STAR 100 in the spent fuel pool. See Table 8.1.1 and 8.1.2 for weight information.

e. Position the HI-STAR 100 overpack over the cask loading area with the basket aligned to the orientation of the spent fuel racks.

ALARA Note:
Wetting the components that enter the spent fuel pool may reduce the amount of decontamination work to be performed later.

f. Wet the surfaces of the HI-STAR 100 overpack and lift yoke with plant demineralized water while slowly lowering the HI-STAR 100 overpack into the spent fuel pool.

g. When the top of the HI-STAR 100 overpack reaches the approximate elevation of the reservoir, open the Annulus Overpressure System reservoir valve. Maintain the reservoir water level at approximately 3/4 full the entire time the cask is in the spent fuel pool.

h. If the Lid Retention System is used, remove the lid retention bolts when the top of the HI-STAR 100 overpack is accessible from the operating floor.

i. Place the HI-STAR 100 overpack on the floor of the cask loading area and disengage the lift yoke. Visually verify that the lift yoke is fully disengaged.

Note:
An underwater camera or other suitable viewing device may be used for monitoring the underwater operations.

j. Apply slight tension to the lift yoke and visually verify proper disengagement of the lift yoke from the trunnions.

k. Remove the lift yoke, MPC lid and drain line from the pool in accordance with directions from the site's Radiation Protection personnel. Spray the equipment with demineralized water as they are removed from the pool.

Warning:
The MPC lid and unloaded MPC may contain residual contamination. All work done on the unloaded MPC should be carefully monitored and performed.

l. Disconnect the drain line from the MPC lid.

m. Store the MPC lid components in an approved location. Disengage the lift yoke from MPC lid. Remove any upper fuel spacers using the same process as was used in the installation.

n. Disconnect the Lid Retention System if used.

8.3.3 MPC Unloading

1. Remove the spent fuel assemblies from the MPC using applicable site procedures.
2. Vacuum the cells of the MPC to remove any debris or corrosion products.
3. Inspect the open cells for presence of any remaining items. Remove them as appropriate.

8.3.4 Post-Unloading Operations

1. Remove the HI-STAR 100 overpack and the unloaded MPC from the spent fuel pool as follows:

    a. Engage the lift yoke to the top trunnions.

    b. Apply slight tension to the lift yoke and visually verify proper engagement of the lift yoke to the trunnions.

    c. Raise the HI-STAR 100 overpack until the HI-STAR 100 overpack flange is at the surface of the spent fuel pool.

ALARA Warning:
Activated debris may have settled on the top face of the HI-STAR 100 overpack during fuel unloading.

d. Measure the dose rates at the top of the HI-STAR 100 overpack in accordance with plant radiological procedures and flush or wash the top surfaces to remove any highly-radioactive particles.

e. Raise the top of the HI-STAR 100 overpack and MPC to the level of the spent fuel pool deck.

f. Close the Annulus Overpressure System reservoir valve if the Annulus Overpressure System was used.

g. Using a water pump, lower the water level in the MPC approximately 12 inches to prevent splashing during cask movement.

ALARA Note:
To reduce contamination of the HI-STAR 100 overpack, the surfaces of the HI-STAR 100 overpack and lift yoke should be kept wet until decontamination can begin.

h. Remove the HI-STAR 100 overpack from the spent fuel pool while spraying the surfaces with plant demineralized water.

i. Disconnect the Annulus Overpressure System from the HI-STAR 100 overpack via the quick disconnect. Drain the Annulus Overpressure System lines and reservoir.

j. Place the HI-STAR 100 overpack in the designated preparation area.

k. Disengage the lift yoke.

l. Perform decontamination on the HI-STAR 100 overpack and the lift yoke.

2. Carefully decontaminate the area above the inflatable seal. Deflate, remove, and store the seal in an approved plant storage location.

3. Using a water pump, pump the remaining water in the MPC to the spent fuel pool or liquid radwaste system.

4. Drain the water in the annulus.

5. Remove the MPC from the HI-STAR 100 overpack and decontaminate the MPC as necessary.

6. Decontaminate the HI-STAR 100 overpack.

7. Remove any bolt plugs, seal surface protector and/or waterproof tape from the HI-STAR 100 overpack top bolt holes.

8. Move the HI-STAR 100 overpack and MPC for further inspection, corrective actions, or disposal as necessary.

inspected in accordance with ASME Code Section III, Subsection NG (see exceptions in Chapter 2).

3. Welding shall be performed using welders and weld procedures that have been qualified in accordance with ASME Code Section IX and the applicable ASME Section III Subsections (e.g., NB, NG, or NF, as applicable to the SSC).

4. All welds shall be visually examined in accordance with ASME Code Section V, Article 9 with acceptance criteria per ASME Code Section III, Subsection NF, Article NF-5360, except the MPC fuel basket cell plate-to-cell plate welds, fuel basket support-to-canister welds, and fuel spacer welds which shall have acceptance criteria to ASME Code Section III, Subsection NG, Article NG-5360, except as modified by the Design Drawings. Table 9.1.3 identifies additional nondestructive examination (NDE) requirements to be performed on specific welds, and the applicable codes and acceptance criteria to be used in order to meet the inspection requirements of the applicable ASME Code Section III. Acceptance criteria for all NDE shall be in accordance with the applicable Code for which the item was fabricated, except as modified by the Design Drawings. These additional NDE criteria are also specified in the Design Drawings provided in Chapter 1 for the specific welds. Weld inspections shall be detailed in a weld inspection plan which shall identify the weld and the examination requirements, the sequence of examination, and the acceptance criteria. The inspection plan shall be reviewed and approved by Holtec International in accordance with its QA program. NDE inspections shall be performed in accordance with written and approved procedures by personnel qualified in accordance with SNT-TC-1A [9.1.3] *or other site-specific, NRC-approved program for personnel qualification.*

5. Machined surfaces of the metal components of the HI-STAR 100 System shall be visually examined in accordance with ASME Section V, Article 9, to verify they are free of cracks and pin holes.

6. Any welds requiring weld repair shall be repaired in accordance with the requirements of the ASME Code Section III, Article NB-4450, NG-4450, or NF-4450, as applicable to the SSC, and examined after repair in the same manner as the original weld.

7. Any base metal repairs shall be performed and examined in accordance with the applicable fabrication Code.

8. Grinding and machining operations of the MPC confinement boundary and HI-STAR 100 helium retention boundary shall be controlled through written and approved procedures and quality assurance oversight to ensure grinding and machining operations do not reduce base metal wall thicknesses of the confinement or helium

of the operation including the four aforementioned areas.

In order to ensure that the lifting trunnions do not have any hidden material flaws, the trunnions shall be tested at 300% of the maximum design (service) lifting load. The load (750,000 lbs) shall be applied for a minimum of 10 minutes. The accessible parts of the trunnions (areas outside the HI-STAR overpack), and the local HI-STAR 100 cask areas will then be visually examined to verify no deformation, distortion, or cracking has occurred. Any evidence of deformation, distortion or cracking of the trunnion or adjacent HI-STAR 100 cask areas will require replacement of the trunnion and/or repair of the HI-STAR 100 cask. Following any replacements and/or repair, the load testing shall be reperformed and the components re-examined in accordance with the original procedure and acceptance criteria. Testing will be performed in accordance with written and approved procedures. Certified material test reports verifying trunnion material mechanical properties meet ASME Code Section II requirements will provide further verification of the trunnion load capabilities. Test results shall be documented. The documentation shall become part of the final quality documentation package.

The acceptance testing of the trunnions in the manner described above will provide adequate assurance against handling accidents.

9.1.2.2 Hydrostatic Testing

9.1.2.2.1 HI-STAR 100 Helium Retention Boundary

The helium retention boundary of the HI-STAR overpack (e.g., the containment boundary during transportation) will be hydrostatically tested to 150 psig +10,-0 psig, in accordance with the requirements of the ASME Code Section III, Subsection NB, Article NB-6000. The test pressure of 150 psig is 150% of the Maximum Normal Operating Pressure (established per 10CFR71.85(b) requirements). This bounds the ASME Code Section III requirement (NB-6221) for hydrostatic testing to 125% of the design pressure (100 psig). The test shall be performed in accordance with written and approved procedures.

The overpack drain port will be used for filling the cavity with water and the vent port for venting the cavity. The approved test procedure shall clearly define the test equipment arrangement.

The overpack hydrostatic test may be performed at any time during fabrication after the containment boundary is complete. Preferably, the hydrotest should be performed after all overpack fabrication is complete, including attachment of the intermediate shells. The HI-STAR overpack shall be assembled for this test with the closure plate mechanical seal (only one required) *or temporary test seal* installed. Closure bolts shall be installed and torqued to the value specified in Chapter 8.

The calibrated test pressure gage installed on the overpack shall have an upper limit of approximately twice that of the test pressure. The hydrostatic test pressure shall be maintained for ten minutes. During this time period, the pressure gage shall not fall below 150 psig. At the end of package.

9.1.2.3 Materials Testing

The majority of material used in the HI-STAR overpack are ferritic steels. ASME Code Section III and Regulatory Guides 7.11 [9.1.7] and 7.12 [9.1.8] require that certain materials be tested in order to assure that these materials are not subject to brittle fracture failures.

Each plate or forging for the helium retention boundary (overpack inner shell, bottom plate, top flange, and closure plate) shall be required to be drop weight tested in accordance with the requirements of Regulatory Guides 7.11 and 7.12, as applicable. Additionally, per the ASME Code Section III, Subsection NB, Article NB-2300, Charpy V-notch testing shall be performed on these materials. Weld material used in welding the helium retention boundary shall be Charpy V-notch tested in accordance with ASME Section III, Subsection NB, Articles NB-2300 and NB-2430.

Non-helium retention boundary portions of the overpack, as required, shall be Charpy V-notch tested in accordance with ASME Section III, Subsection NF, Articles NF-2300, and NF-2430. The non-helium retention boundary materials to be tested include the intermediate shells, overpack port cover plates, and applicable weld materials.

Section 3.1 provides the test temperatures or T_{NDT}, and test requirements to be used when performing the testing specified above.

All test results shall be documented and shall become part of the final quality documentation package.

9.1.2.4 Pneumatic ~~Bubble~~ Testing of the Neutron Shield Enclosure Vessel

A pneumatic ~~bubble~~ *pressure* test of the neutron shield enclosure vessel will be performed ~~in accordance with Section V, Article 10, Appendix I, of the ASME Boiler and Pressure Vessel Code~~ following final closure welding of the enclosure shell returns and enclosure panels. The pneumatic test pressure shall be 37.5+2.5,-0 psig, which is 125 percent of the rupture disc relief set pressure. The test shall be performed in accordance with approved written procedures.

During the test, the two rupture discs on the neutron shield enclosure vessel will be removed. One of the rupture disc threaded connections will be used for connection of the air pressure line and the other rupture disc connection will be used for connection of the pressure gauge.

Following introduction of pressurized air into the neutron shield enclosure vessel, a 15 minute ~~minimum soak~~ *pressure hold* time will be required. *If the neutron shield enclosure vessel fails to hold pressure, an* ~~Following completion of the soak time,~~ approved soap bubble solution will be applied to *determine the location of the leak.* ~~all enclosure shell return and enclosure panel welds. The acceptance criteria for the bubble test will be no air leakage from any tested weld, as indicated~~

~~by continuous bubbling of the solution. If air leakage is indicated,~~ *tThe* ~~weld~~ *leak* shall be repaired using weld repair procedures in accordance with the ASME Code Section III, Subsection NF, Article NF-4450. The pneumatic ~~bubble~~ *pressure* test shall be reperformed until no ~~air leakage~~ *pressure loss* is observed.

All test results shall be documented and shall become part of the final quality documentation package.

9.1.3 Leakage Testing

Leakage testing shall be performed in accordance with the requirements of ANSI N14.5 [9.1.9]. Testing shall be performed in accordance with written and approved procedures.

9.1.3.1 HI-STAR Overpack

A helium retention boundary weld leakage test shall be performed at any time after the containment boundary fabrication is complete. Preferably, this test should be performed at the completion of overpack fabrication, after all intermediate shells have been attached. The leakage test shall have a minimum test sensitivity of 2.15×10^{-6} std cm^3/s (helium). Helium retention welds shall have indicated leakage rates not exceeding 4.3×10^{-6} std cm^3/s (helium). If a leakage rate exceeding the acceptance criteria is detected, the area of leakage shall be determined using the sniffer probe method or other means, and the area will be repaired per ASME Code Section III, Subsection NB, NB-4450 requirements. Following repair and appropriate NDE, the leakage testing shall be reperformed until the test criteria are satisfied.

> Note: If failure of the leakage rate retest occurs after initial repairs are completed, a nonconformance report shall be issued and root cause and corrective action shall be addressed before further repairs and retest are performed.

At the completion of overpack fabrication, helium leakage through the helium retention penetrations (consisting of the inner mechanical seal between the closure plate and top flange and the vent and drain port plug seals) shall be demonstrated to not exceed the leakage rate of 4.3×10^{-6} std cm^3/s (helium) at a minimum test sensitivity of 2.15×10^{-6} std cm^3/s (helium). This may be performed simultaneously with the boundary weld leakage test or may be performed separately using the methods described in the paragraph below.

Testing of the helium retention penetrations may be performed by evacuating and backfilling the overpack with helium gas. ~~to a pressure of 10 psig +4,-0 psig~~. A helium MSLD will be used (see Chapter 8 for details of test connections specifically designed for testing the penetration seals) to perform the test. Starting with the vent *or drain* port plug, the test cover is connected. The cavity on the external side of the vent port plug is evacuated and the vacuum pump is valved out. The MSLD detector measures the leakage rate of helium into the test cavity. ~~If the measured leakage does not exceed a leakage rate of 4.3×10^{-6} std cm^3/s (helium), the vent port plug seal is acceptable.~~ The minimum test sensitivity shall be 2.15×10^{-6} std cm^3/s (helium). If the leakage rate exceeds the acceptance criteria of 4.3×10^{-6} std cm^3/s (helium), the test chamber is vented and removed. The corresponding plug seal is removed, seal seating surfaces are inspected and cleaned, and the plug with a new seal is reinstalled and torqued to the required value. The test process is then repeated until the seal leakage rate is successfully achieved. The same process is repeated for the *remaining* overpack *vent or* drain port. The process is also used to test the closure plate seal except that the closure plate test tool (see Chapter 8 for detail) is used in lieu of the test cover.

If the total measured leakage rate for all tested penetrations does not exceed 4.6×10^{-6} std cm^3/sec, the leakage tests are successful. If the total leakage rate exceeds 4.6×10^{-6} std cm^3/sec, an evaluation should be performed to determine the cause of the leakage, repairs made as necessary, and the overpack must be re-tested until the total leakage rate is within the required acceptance criterion. All leak testing results for the HI-STAR overpack shall become part of the quality record documentation package.

9.1.3.2 MPC

On completion of welding the MPC shell to the baseplate, a confinement boundary weld leakage test shall be performed using a helium mass spectrometer leak detector (MSLD) having a minimum test sensitivity of 2.5×10^{-6} std cm^3/s (helium). A temporary test closure lid is used in order to provide a sealed MPC. The confinement boundary welds shall have indicated leakage rates not exceeding 5×10^{-6} std cm^3/s (helium). If a leakage rate exceeding the test criteria is detected, then the area of leakage shall be determined and the area repaired per ASME Code Section III, Subsection NB, NB-4450, requirements. Retesting will be performed until the leakage rate acceptance criteria is met.

> Note: If failure of the leakage rate retest occurs after initial repairs are completed, a nonconformance report shall be issued and root cause and corrective action shall be addressed before further repairs and retest are performed.

Leakage testing of the MPC lid-to-shell field weld shall be performed following completion of the MPC hydrostatic test performed per Subsection 9.1.2.2.2. Leakage testing of the vent and drain port cover plate welds will be performed after field welding of the cover plates and subsequent NDE. The description and procedures for these field tests are provided in Section 8.1, and the acceptance criteria are defined in the Technical Specifications.

All leak testing results for the MPC shall be documented and shall become part of the quality record documentation package.

9.1.4 Component Tests

9.1.4.1 Valves, Rupture Discs, and Fluid Transport Devices

There are no fluid transport devices associated with the HI-STAR 100 System. The only valve-like components in the HI-STAR 100 System are the specialty designed caps installed in the MPC lid for the drain and vent ports. These caps are recessed inside the MPC lid and covered by the fully-welded vent and drain port cover plates. No credit is taken for the caps' ability to confine helium or radioactivity. After completion of drying and backfill operations, the drain and vent port cover plates are welded in place on the MPC lid and are leak tested to verify the MPC confinement boundary.

There are two rupture discs installed in the upper ledge surface of the neutron shield enclosure vessel of the HI-STAR overpack. These rupture discs are provided for venting purposes under hypothetical fire accident conditions in which vapor formation from neutron shielding material degradation may occur. The rupture discs are designed to relieve at 30 psig (± 5 psig). Each manufactured lot of rupture discs shall be sample tested ~~to a written and approved procedure~~ to verify their point of rupture.

9.1.4.2 Seals and Gaskets

Two metallic mechanical seals are provided on the HI-STAR overpack closure plate to provide redundant sealing. Mechanical seals are also used on the overpack vent and drain port plugs of the HI-STAR overpack. Each primary seal is individually leak tested in accordance with Subsection 9.1.3.1. An independent and redundant seal is provided for each penetration (e.g., closure plate, port cover plates, and closure plate test plug). No confinement credit is taken for these redundant seals and they are not leakage tested. Details on these seals are provided in Chapter 7. Procedures for leakage testing are provided in Chapter 8.

9.1.5 Shielding Integrity

The HI-STAR 100 System has three specifically designed shields for neutron and gamma ray attenuation. For gamma shielding, there are successive carbon steel intermediate shells attached onto the outer surface of the overpack inner shell. The details of the manufacturing process are discussed in Chapter 1. Holtite-A neutron shielding is provided in the outer enclosure of the overpack. Additional neutron attenuation is provided by the encased Boral™ neutron absorber attached to the fuel basket cell surfaces inside the MPCs. Test requirements for each of the three shielding items are described below.

9.1.5.1 Fabrication Testing and Controls

Holtite-A:

Neutron shield properties of Holtite-A are provided in Chapter 1, Section 1.2.1.3.2. Each *manufactured* lot ~~(mixed batch)~~ of neutron shield material shall be tested to verify that the material composition *(aluminum and hydrogen)*, boron concentration, and neutron shield density *(or specific gravity)* meet the requirements specified in Chapter 1 and the Bill of Material sections. *A manufactured lot is defined as the total amount of material used to make any number of mixed* *batches comprised of constituent ingredients from the same lot/batch identification numbers supplied by the constituent manufacturer.* Testing will be performed in accordance with written and approved procedures *and/or standards*. Material composition, boron concentration, and density *(or specific gravity)* data for each *manufactured* lot of neutron shield material will become part of the quality documentation package.

The installation of the neutron shielding material shall be performed in accordance with written and qualified procedures. The procedures shall ensure that mix ratios and mixing methods are controlled in order to achieve proper material composition, boron concentration and distribution, and that pours are controlled in order to prevent gaps from occurring in the material. Samples of each *manufactured* lot of neutron shield material will be maintained by Holtec International as part of the quality record documentation package.

Steel:

All steel plates utilized in the construction of the HI-STAR 100 System shall be dimensionally inspected to assure compliance for minimum thickness in accordance with the Design Drawings in Section 1.5.

The total measured thickness of the inner shell plus intermediate shells shall be a minimum of 8.5 inches. The top flange, closure plate, and bottom plate of the overpack shall be measured to confirm their thicknesses meet Design Drawing requirements of Section 1.5. Measurements shall

be performed in accordance with written and approved procedures. The measurement locations and measurements shall be documented. Measurements shall be made through a combination of receipt inspection thickness measurements on individual plates and actual measurements taken prior to welding the overpack or intermediate shells. Any area found to be under the specified minimum thickness will be repaired in accordance with applicable ASME Code requirements.

No additional gamma shield testing of the HI-STAR 100 System is required. A gamma shielding effectiveness test per Subsection 9.1.5.2 will be performed on each fabricated HI-STAR 100 System after the first fuel loading.

General for All Shield Materials:

1. All test results shall be documented and become part of the quality documentation package.

2. Dimensional inspections of the cavities containing poured neutron shielding materials shall assure that the design required amount of shielding material is incorporated into the fabricated item.

9.1.5.2 Shielding Effectiveness Test

Following the first fuel loading of each HI-STAR 100 System, a shielding effectiveness test will be performed at the loading facility site to verify the effectiveness of the gamma and neutron shields. This test will be performed after the HI-STAR 100 System has been loaded with fuel, drained, sealed, and backfilled with helium.

The neutron and gamma shielding effectiveness tests will be performed using written and approved procedures. Calibrated neutron and gamma dose meters shall be used to measure the actual neutron and gamma dose rates at the surface of the HI-STAR overpack. Measurements will be taken at three cross sectional planes and at four points along each plane's circumference. Additionally, four measurements shall be taken at the top of the overpack closure plate. All dose rate measurements shall be documented and become part of the quality documentation package. The average results from each sectional plane shall be compared to the design basis limits for surface dose rates established in Chapter 5. The test is considered acceptable if the actual dose readings are lower or equal to the acceptance criteria in the Technical Specifications. If dose rates are higher than the Technical Specification limits, the required actions of the Technical Specifications shall be completed.

9.1.5.3 Neutron Absorber Tests

After manufacturing, a statistical sample of each lot of Boral is tested using wet chemistry and/or neutron attenuation techniques to verify a minimum ^{10}B content at the ends of the panel. Any panel in which ^{10}B loading is less than the minimum allowed will be rejected.

Tests are performed using written and approved procedures. Results shall be documented and become part of the HI-STAR 100 System quality records documentation package.

Installation of Boral panels into the fuel basket shall be performed in accordance with written and approved procedures *(or shop travelers)*. Travelers and/or quality control procedures shall be in place to assure each required cell wall of the MPC basket contains a Boral panel in accordance with the Design Drawings in Chapter 1. These quality control processes, in conjunction with Boral manufacturing testing, provide the necessary assurances that the Boral will perform its intended function. No additional testing will be required on the Boral.

9.1.6 Thermal Acceptance Test

The first fabricated HI-STAR overpack shall be tested to confirm its heat transfer capability. The test shall be conducted after the radial channels, enclosure shell panels, and neutron shield material have been installed and all inside and outside surfaces are painted per the Design Drawings in Section 1.5. A test cover plate shall be used to seal the overpack cavity. Testing shall be performed in accordance with written and approved procedures.

The thermal test is performed by heating the overpack cavity with a readily measurable source of thermal energy. Prior standard practice has utilized electrical heating systems for confirming

Table 9.1.1

MPC INSPECTION AND TEST ACCEPTANCE CRITERIA

Function	Fabrication	Pre-operation	Maintenance and Operations
Visual Inspection and Nondestructive Examination (NDE)	a) Assembly and examination of MPC components per ASME Code Section III, Subsections NB, NF, and NG, as defined on design drawings, per NB-5300, *NF-5300,* and NG-5300, as applicable. b) A dimensional inspection of the internal basket assembly and canister will be performed to verify compliance with design requirements. c) A dimensional inspection of the MPC lid and MPC closure ring will be performed prior to inserting into the canister shell to verify compliance with design requirements. d) NDE of weldments will be defined on the design drawings using standard American Welding Society NDE symbols and/or notations. e) Cleanliness of the MPC will be verified upon completion of fabrication. f) The packaging of the MPC at the completion of fabrication will be verified prior to shipment.	a) The MPC will be visually inspected prior to placement in service at the licensee's facility. b) MPC protection at the licensee's facility will be verified. c) MPC cleanliness and exclusion of foreign material will be verified prior to placing in the spent fuel pool.	a) None.

Table 9.1.1 (continued)

MPC INSPECTION AND TEST ACCEPTANCE CRITERIA

Function	Fabrication	Pre-operation	Maintenance and Operations
Structural	a) Assembly and welding of MPC components will be performed per ASME Code, Subsections NB, *NF*, and NG, as applicable. b) Materials analysis (steel, Boral, etc.), will be performed and records will be kept in a manner commensurate with "important to safety" classifications.	a) None.	a) An ultrasonic (UT) examination or multi-layer liquid penetrant (PT) examination of the MPC lid-to-shell weld shall be performed per ASME Section V, Article 5 (or ASME Section V, Article 6). Acceptance criteria for the examination are defined Table 9.1.3 and in the Design Drawings. b) ASME Code NB-6000 hydrostatic test shall be performed after MPC closure welding. Acceptance criteria are defined in Section 9.1.2.2.2.
Leak Tests	a) Helium leak rate testing will be performed on all MPC pressure boundary shop welds.	a) None.	a) Helium leak rate testing will be performed on MPC lid-to-shell, and vent and drain ports-to-MPC lid field welds after closure welding. Acceptance criteria are defined in the Technical Specifications.

Table 9.1.3 (continued)

HI-STAR 100 NDE REQUIREMENTS

MPC			
Weld Location	**NDE Requirement**	**Applicable Code**	**Acceptance Criteria (Applicable Code)**
Lid-to-shell	PT (root and final pass) PT (surface following hydrostatic test) UT or multi-layer PT	ASME Section V, Article 6 (PT) ASME Section V, Article 5 (UT) ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350 UT: ASME Section III, Subsection NB, Article NB-5332 PT: ASME Section III, Subsection NB, Article NB-5350
Closure ring-to-shell	PT (~~root and~~ final pass)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Closure ring-to-lid	PT (~~root and~~ final pass)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Closure ring radial welds	PT (~~root and~~ final pass)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Port cover plates-to-lid	PT (root and final pass)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Lift lug *and* lift lug baseplate~~,~~ and ~~fuel spacers~~	PT (surface)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NG, Article NG-5350

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Attachment 5

THERE ARE NO PROPOSED REVISIONS TO CHAPTER 10

evaluations are discussed in Section 11.1.4.

11.1.1 Off-Normal Pressures

There are three pressure regions in the HI-STAR 100 System and they are the MPC internal, the MPC external/overpack internal, and the overpack external pressure regions. Off-normal pressure at these three locations is evaluated at the point at which they act. The MPC internal pressure effects the MPC internal cavity. The MPC external/overpack internal pressure effects the MPC exterior and the overpack internal cavity. The overpack external pressure effects the exterior of the overpack.

11.1.1.1 Postulated Cause of Off-Normal Pressure

The off-normal pressure for the MPC internal cavity is a function of the initial helium fill pressure and the temperature obtained with maximum decay heat load design basis fuel. The maximum off-normal environmental temperature is 100°F with full solar insolation. The MPC internal pressure is further increased by the conservative assumption that 10% of the fuel rods rupture, 100% of the fill gas, and fission gases per NUREG-1536 are released to the cavity.

There is no cause or postulated cause for an off-normal MPC external/overpack internal pressure. There is no cause or postulated cause for off-normal overpack external pressure. Therefore, no off-normal overpack external pressure or off-normal MPC external/overpack internal pressure is evaluated.

11.1.1.2 Detection of Off-Normal Pressure

The HI-STAR 100 System is designed to withstand the MPC off-normal pressure without any effects on its ability to meet its safety requirements. There is no requirement for detection of off-normal pressure in the MPC.

11.1.1.3 Analysis of Effects and Consequences of Off-Normal Pressure

Chapter 4 calculates the MPC internal pressure with an ambient temperature of 80°F, 10% fuel rods ruptured, full insolation, and maximum decay heat and reports the maximum value of *60.2* ~~62.1~~ psig in Table 4.4.15 at an average calculated MPC cavity temperature of 499.2°K. Using this pressure, the off-normal temperature of 100°F (ΔT of 20°F or 11.1°K), and the ideal gas law, the off-normal resultant pressure is calculated to be below the normal condition MPC internal design pressure, as follows:

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

$$P_2 = \frac{P_1\ T_2}{T_1}$$

$$P_2 = \frac{(60.2\ \text{psig} + 14.7)\ (499.2°K + 11.1°K)}{499.2°K}$$

$$P_2 = 76.6\ \text{psia or } 61.9\ \text{psig}$$

The normal condition MPC internal pressure of 100 psig (Table 2.2.1) has been established to bound the off-normal condition. Therefore, no additional analysis is required. The normal condition design pressure, which is equal to the off-normal design pressure, is analyzed in Chapter 3 for Load Case E1. The results in Chapter 3 show that the stress values are below the normal condition allowables.

Structural

The structural evaluation of the MPC enclosure vessel for off-normal design internal pressure conditions is equivalent to the evaluation at normal design internal pressures, since the normal design pressure was set at a value which would encompass the off-normal condition. Therefore, the resulting stresses from the off-normal design condition are equivalent to that of the normal design condition and are well within the allowable stress limits, as discussed in Section 3.4.

Thermal

The MPC internal pressure for off-normal conditions is calculated as presented above. As can be seen from the value calculated above, the 100 psig design basis internal pressure for off-normal conditions used in the structural evaluation bounds the calculated value.

Shielding

There is no effect on the shielding performance of the system as a result of this off-normal event.

Criticality

There is no effect on the criticality control features of the system as a result of this off-normal event.

Confinement

There is no effect on the confinement function of the MPC as a result of this off-normal event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring

11.1.2.5 Radiological Impact of Off-Normal Environmental Temperatures

Off-normal environmental temperatures have no radiological impact as the confinement barrier and shielding integrity are not affected.

11.1.3 Leakage of One Seal

The HI-STAR 100 System has multiple boundaries to contain radioactive fission products within the confinement boundary and the helium atmosphere within the helium retention boundary (overpack internal cavity). The radioactive material confinement boundary is defined by the MPC shell, baseplate, MPC lid, and vent and drain cover plates. The closure ring provides a redundant welded closure to prevent the release of radioactive material from the MPC cavity. Confinement boundary welds, including the MPC lid-to-shell weld, are inspected by radiography or ultrasonic examination except for field welds on the closure ring and vent/drain port cover plates. The closure ring and vent/drain port cover plates are examined by the liquid penetrant method on the root *(for multi-pass welds)* and final pass. The welds on the MPC lid, vent and drain port covers are leakage tested. The MPC is also hydrostatically tested.

An additional redundant boundary to the release of radioactive materials is provided by the overpack helium retention boundary which is formed by the overpack bottom plate, inner shell, top flange, closure plate, closure plate bolts, inner metallic seal, and port plugs/seals. The overpack helium retention boundary welds are inspected by radiography. Vent and drain ports penetrate the helium retention boundary and are sealed by a port plug with a metallic seal. The closure plate inner seal, and the vent and drain port plug seals are helium leak tested following each loading.

The MPC lid-to-MPC shell weld is postulated to fail to confirm the safety of the HI-STAR 100 confinement boundary. The failure of the MPC lid weld is equivalent to the MPC drain or vent port cover weld failing. The MPC lid-to-shell weld has been chosen because it is the main closure weld for the MPC. It is extremely unlikely that the volumetric (or multi-layer liquid penetrant) inspection and helium leak test would fail to detect a poor welded seal. The MPC lid weld failure affects the MPC confinement boundary; however, no leakage will occur.

11.1.3.1 Postulated Cause of Leakage of One Seal in the Confinement Boundary

Failure of the MPC confinement boundary is highly unlikely. The MPC confinement boundary is shown to withstand all normal, off-normal, and accident conditions. There are no credible conditions which could damage the integrity of the MPC confinement boundary. The weld between the MPC lid and MPC shell is liquid penetrant inspected on the root and final pass, volumetrically (or multi-layer PT) examined, hydrostatically tested, and helium leak tested. The initial integrity of the closure welds will be maintained throughout the design life because the MPC is stored within an inert atmosphere within the overpack. Failure of the MPC lid weld would require all of the following:

1. Improper weld by a qualified welding machine or welder using approved welding

Radiation Protection

Since there is a very localized reduction in shielding and no effect on the confinement capabilities as discussed above, there is a negligible effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the non-mechanistic tip-over of the HI-STAR 100 System does not affect its safe operation.

11.2.2.3 Tip-Over Dose Calculations

The tip-over accident could cause localized damage to the neutron shield and outer enclosure shell where the neutron shield impacts the ISFSI pad. The gamma shielding will not be affected. The overpack surface dose rate in the affected area could increase due to damage of the neutron shield. However, there should be no noticeable increase in the ISFSI site or controlled area boundary dose rate, because the affected areas will likely be small. Once the overpack is uprighted, some local dose increase could occur. The cask post-accident shielding analysis in Chapter 5 assumes complete loss of the neutron shield and bounds the dose rates anticipated for the tip-over accident. The analysis of the tip-over accident has shown that the MPC confinement barrier will not be compromised and, therefore, there will be no release of radioactivity.

11.2.2.4 Tip-Over Accident Corrective Action

The handling accident corrective action procedure outlined in Subsection 11.2.1.4 is applicable for the recovery of the tip-over accident.

11.2.3 Fire

11.2.3.1 Cause of Fire

Although the probability of a fire accident affecting a HI-STAR 100 System during storage operations is low due to the lack of combustible materials at the ISFSI, a fire resulting from an on-site transporter fuel tank contents is postulated and analyzed. The analysis shows that the HI-STAR 100 System continues to perform its structural, confinement, and subcriticality functions.

11.2.3.2 Fire Analysis

The thermal environment to which the HI-STAR 100 System would be exposed under a hypothetical fire accident is specified to be the same as that required in 10CFR71.73(c)(4). The overpack surfaces are therefore considered to receive an incident thermal radiation and convective heat flux from an ambient 1475 °F fire condition environment. The duration of fire resulting from an on-site transporter fuel tank spill is calculated as follows:

Volume of Fuel (V) = 50 gallons (6.68 ft^3) (Specified by Subsection 2.2.3.3)

Overpack Baseplate (D_i) = 83-1/4" (6.9375 ft) (Overpack Drawing 1397, Section 1.5)

Fuel Spill Ring Width (L) = 1 meter (IAEA Specification [11.2.6])

$$\textbf{Fuel Spill Diameter } (D_o) = 83\text{-}1/4'' + 2\text{m} \times \frac{1''}{0.0254\text{m}}$$
$$= 161.99''(13.4991 \text{ ft})$$

$$\textbf{Fuel Spill Area } (A) = \frac{\pi}{4}(D_o^2 - D_i^2)$$
$$= 105.3 \text{ ft}^2$$

$$\textbf{Spill Depth } (d) = \frac{V}{A} = \frac{6.68}{105.3}$$
$$= 0.0634 \text{ ft } (0.761'')$$

Fuel Consumption Rate (R) = 0.15 inch/min (~~IAEA Specification~~ [11.2.7])

$$\textbf{Fire Duration} = \frac{d}{R} = \frac{0.761}{0.15}$$
$$= 5.075 \text{ min } (305 \text{ seconds})$$

Within this time period, the cask outside surface and its contents will undergo a transient temperature rise due to the heat absorbed from the fire. Full effects of insolation before, during, and after the fire are included in the HI-STAR 100 System transient analysis. During the postulated fire event, the neutron shield material is exposed to high temperatures. Therefore, conservatively, an upper bound material thermal conductivity is assumed during the fire to maximize heat input to the cask. During the post-fire cooldown phase, no credit is taken for conduction through the neutron shield. The temperature history of a number of critical points in the HI-STAR 100 System transient fire analysis are tracked during the fire and the subsequent relaxation of temperature profiles during the post-fire cooldown phase. The impact of transient temperature excursions on HI-STAR 100 System materials is assessed in this section. During the fire, a cask surface emissivity specified in 10CFR71.73(b)(4) is applied to maximize radiant heat input. Destruction of the paint covering the external cask surfaces due to exposure to intense heat during fire is a credible possibility. Therefore, a lower emissivity of the exposed carbon steel surface is conservatively applied for post-fire cooldown analysis. This approach provides a conservatively bounding response of the HI-STAR 100 System to the fire accident condition.

Heat input from the fire to the HI-STAR 100 System is from a combination of radiation and convection heat transfer to all overpack exposed surfaces. This can be expressed by the following equation:

$$q_F = h_{fc} (T_F - T_s) + 0.1714\varepsilon \left[\left(\frac{T_F + 460}{100}\right)^4 - \left(\frac{T_s + 460}{100}\right)^4 \right]$$

where:

q_F = surface heat input flux (Btu/ft^2-hr)

T_F = fire condition temperature (1475°F)

T_S = transient surface temperature (°F)

h_{fc} = forced convection heat transfer coefficient [Btu/ft^2-hr-°F]

ε = surface emissivity = 0.9 (per 10CFR71)

The forced convection heat transfer coefficient is calculated to bound the convective heat flux contribution to the exposed cask surfaces due to fire induced air flow. For the case of air flow past a heated cylinder, Jacob [11.2.3] recommends the following correlation for convective heat transfer obtained from experimental data:

$$Nu_{fc} = 0.028\ Re^{0.8} \left[1 + 0.4 \left(\frac{L_{st}}{L_{tot}}\right)^{2.75} \right]$$

where:

L_{tot} = length traversed by flow

L_{st} = length of unheated section

K_f = thermal conductivity of air evaluated at the average film temperature

Re = flow Reynolds Number based on L_{tot}

Nu_{fc} = Nusselt Number ($h_{fc}\ L_{tot}/K_f$)

A consideration of the wide range of temperatures to which the exposed surfaces are subjected during fire and the temperature dependent trend of air properties requires a careful selection of parameters to determine a conservatively large bounding value of the convective heat transfer coefficient. Table 11.2.1 provides a summary of parameter selections with justifications which provide the basis for application of this correlation to determine the forced convection heating of the HI-STAR 100 System during this short-term fire event.

After the fire event, the outside environment temperature is restored to initial ambient conditions and the HI-STAR 100 System transient analysis is continued, to evaluate temperature peaking in the interior during the post-fire cooldown phase. Heat loss from the outside exposed surfaces of the overpack is determined by the following equation:

$$q_S = 0.19\ (T_S - T_A)^{4/3} + 0.1714\varepsilon \left[\left(\frac{T_S + 460}{100}\right)^4 - \left(\frac{T_A + 460}{100}\right)^4 \right]$$

where:

q_s= surface heat loss flux (Btu/ft^2-hr)

T_S = transient surface temperature (°F)

T_A = ambient temperature (100°F)

ε = surface emissivity of exposed carbon steel surface

The FLUENT thermal analysis model was used to perform the fire condition transient analysis. Based on this analysis, the maximum temperature attained in different portions of the cask during the fire followed by a post-fire cooldown are summarized in Table 11.2.2. From the results, it is apparent that due to the large bulk mass and long radial path lengths for flow of heat, the MPC basket centerline temperatures are relatively unaffected by this short duration fire event. However, the overpack enclosure shell and neutron shield material in its immediate vicinity experience a significant temperature increase. The short-duration temperature rise experienced by the periphery of the neutron shield may result in partial loss of its ability to shield neutrons. The neutron shields' inner surface peak transient temperature at the hottest spatial location (314°F) is slightly higher than the 300°F long-term temperature limit. This short-term elevated temperature exposure, lasting for a few hours, is not expected to significantly degrade the neutron shield materials shielding function at this location. A pressure relief system is provided on the overpack outer enclosure shell to prevent any overpressurization in the neutron shield region during the fire event. Figures 11.2.1 through 11.2.3 plot the transient temperature-time history of HI-STAR 100 components identified as significant for fire accident performance evaluation. Figure 11.2.4 provides an axial temperature plot of the hottest rod in the post-fire cooldown.

Increased pressure of the MPC due to the temperature rise is also considered. From the maximum temperature rise of the MPC during the post-fire cooldown phase, maximum average MPC cavity temperatures are calculated by adding this temperature increment to the initial condition (before start of fire) MPC cavity average temperature for each MPC and applying the ideal gas law. The initial condition MPC cavity average temperatures and pressures have been determined by analytical methods described in Chapter 4. Maximum fire accident pressures in the MPC cavity based on a conservatively bounding 216°F (120°C) MPC cavity temperature rise are reported in Table 11.2.3. Maximum pressure calculations include a 100% fuel rod rupture condition *(including hypothetical BPRA rods rupture for PWR fuel)* and conservatively determined rod fill gas and fission gases

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the lightning accident does not affect the safe operation of the HI-STAR 100 System.

11.2.11.3 Lightning Dose Calculations

An evaluation of lightning strikes demonstrates that the effect of a lightning strike has no effect on the confinement boundary or shielding materials. Therefore, no further analysis is necessary.

11.2.11.4 Lightning Accident Corrective Action

The HI-STAR 100 System will not sustain any damage from the lightning accident. There is no surveillance or corrective action required.

11.2.12 Burial Under Debris

11.2.12.1 Cause of Burial Under Debris

Burial of the HI-STAR 100 System under debris is not a credible accident. During normal storage operations at the ISFSI, there are no structures over the casks. The minimum regulatory distance of 100 meters from the ISFSI to the nearest site boundary and the controlled area around the ISFSI concrete pad precludes the close proximity of substantial amounts of vegetation.

There is no credible mechanism for the HI-STAR 100 System to become completely buried under debris. However, for conservatism, complete burial under debris is considered.

11.2.12.2 Burial Under Debris Analysis

Burial of the HI-STAR 100 System does not impose a condition that would have more severe consequences for criticality, confinement, shielding, and structural analyses than that performed for the other accidents analyzed. The debris would provide additional shielding to reduce radiation doses. The accident external pressure bounds any credible pressure loading caused by the burial under debris.

Burial under debris can affect thermal performance because the debris acts as an insulator and heat sink. This will cause the HI-STAR 100 System and fuel cladding temperatures to increase. A thermal analysis has been performed to determine the time for the fuel cladding temperatures to reach the short term accident condition temperature limits during a burial under debris accident.

To demonstrate the inherent safety of the HI-STAR 100 System, a bounding analysis which considers the debris to act as a perfect insulator is considered. Under this scenario, the contents of the HI-STAR 100 System will undergo a transient heat up under adiabatic conditions. The minimum time required for the fuel cladding to reach the short term design fuel cladding temperature limit depends on the amount of thermal inertia of the cask, the cask initial conditions, and the spent nuclear fuel decay heat generation. All three of these parameters are conservatively bounded by the values in Table 11.2.4.

Using the values stated in Table 11.2.4, the bounding cask temperature rise of less than 5 °F per hour is determined. This provides in excess of 60 hours of time before the cladding temperatures exceed the short term fuel cladding temperature limit.

The MPC-68 has the highest steady-state fuel cladding temperature. If 300°F is postulated as the permissible temperature rise the resultant pressure in the MPC cavity can be calculated as a result of the burial under debris accident.

Chapter 4 calculates the MPC internal pressure with an ambient temperature of 80°F, 10% fuel rods *ruptured*, full insolation, and maximum decay heat, and reports the maximum value of *60.2* ~~62.1~~ psig in Table 4.4.15 at an average MPC cavity temperature of 499.2°K. Using this pressure, an assumed increase in the average temperature of 300°F (499.2°K to 665.9°K), and the ideal gas law, the resultant MPC internal pressure is calculated below.

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

$$P_2 = \frac{P_1\,T_2}{T_1}$$

$$P_2 = \frac{(60.2\ \text{psig} + 14.7)\ (665.9\,^{\circ}\text{K})}{499.2\,^{\circ}\text{K}}$$

$$P_2 = 99.9\ \text{psia or}\ 85.2\ \text{psig}$$

The normal MPC internal design pressure of 100 psig (Table 2.2.1) bounds the resultant pressure calculated above. Therefore, no additional analysis is required.

<u>Structural</u>

Table 11.2.3

MAXIMUM HI-STAR 100 SYSTEM FIRE ACCIDENT CONDITION
MPC CAVITY PRESSURES†

Condition	Pressure (psig)	
	MPC-24††	MPC-68
Without fuel rod rupture	*57.9* ~~75.8~~	75.1
With 100% fuel rod rupture	*124.2* ~~122.5~~	108.7
Accident Design Pressure	125	125

† Pressure analysis is based on NUREG-1536 criteria (i.e., 100% rods fill gas and 30% of radioactive gases are available for release from a ruptured rod) and a conservatively bounding 216°F (120°C) MPC cavity temperature rise.

†† PWR fuel includes hypothetical BPRA rods rupture in the pressure calculations.

11.4 REFERENCES

[11.2.1] Chun, et al., "Dynamic Impact Effects on Spent Fuel Assemblies", Lawrence Livermore National Laboratory, UCID-21246, October 1987.

[11.2.2] ESEERCO Project EP91-29 and EPRI Project 3100-02, "Debris Collection System for Boiling Water Reactor Consolidation Equipment", B&W Fuel Company, October 1995.

[11.2.3] Jacob, M., "Heat Transfer", John Wiley & Sons, Inc. page 555, (1967).

[11.2.4] Cianos, N., and Pierce, E.T., "A Ground Lightning Environment for Engineering Usage", Technical Report No. 1, SRI Project No. 1834, Standard Research Institute, Menlo Park, CA, August 1997.

[11.2.5] Avallone, E.A., and Baumeister, T., Mark's Standard Handbook for Mechanical Engineering, Ninth Edition, McGraw Hill Inc., 1987.

[11.2.6] IAEA Safety Standards, "Regulations for the Safe Transport of Radioactive Material", International Atomic Energy Agency, Vienna, 1985.

[11.2.7] "Thermal Measurements in a Series of Large Pool Fires", Sandia Report SAND85-0196.TTC-0659.UC71, August 1987.

~~[11.2.7] Chun et al., "Dynamic Impact Effects of Spent Fuel Assemblies", LLNL, UCID-21246 (October 1987).~~

12.3 TECHNICAL SPECIFICATIONS

Technical Specifications ~~and Bases~~ for the HI-STAR 100 System are provided in Appendix A to CoC 72-1008. Fuel specifications and design features are provided in Appendix B to CoC 72-1008. Bases for the Technical Specifications in CoC Appendix A are provided in TSAR Appendix 12.A. The format and content of the HI-STAR 100 System Technical Specifications and Bases are that of the Improved Standard Technical Specifications for power reactors, to the extent they apply to a dry spent fuel storage cask system. NUMARC Document 93-03, "Writer's Guide for the Restructured Technical Specifications" [12.3.9] was used as a guide in the development of the Technical Specifications and Bases.

B 2.1 SFSC Integrity

B 2.1.1 Multi-Purpose Canister (MPC)

BASES

BACKGROUND

An OVERPACK with an empty MPC is placed in the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Certificate of Compliance. A lid is then placed on the MPC. The OVERPACK and MPC are raised to the top of the spent fuel pool surface. The OVERPACK and MPC are then moved into the cask preparation area where dose rates are measured and the MPC lid is welded to the MPC shell and the welds are inspected and tested. The water is drained from the MPC cavity and vacuum drying is performed. The MPC cavity is backfilled with helium and leakage tested. Additional dose rates are measured and the MPC vent and drain cover plates and closure ring are installed and welded. Inspections are performed on the welds. The OVERPACK lid is installed and secured. The annulus space between the MPC and OVERPACK is drained, vacuum dried and backfilled with helium gas. The OVERPACK seals are tested for leakage. Contamination measurements are completed prior to moving the OVERPACK and MPC to the ISFSI.

MPC cavity vacuum drying is utilized to remove residual moisture from the MPC fuel cavity after the MPC has been drained of water. Any water that has not drained from the fuel cavity evaporates from the fuel cavity due to the vacuum. This is aided by the temperature increase due to the temperature of the fuel and by the heat added to the MPC from the optional warming pad, if used.

After the completion of vacuum drying, the MPC cavity is backfilled with helium to a pressure greater than atmospheric pressure.

(continued)

BASES (continued)

BACKGROUND (continued)	Backfilling of the MPC fuel cavity with helium promotes *gaseous* heat *dissipation* ~~transfer from the fuel~~ and the inert atmosphere protects the fuel cladding. Providing a helium pressure greater than atmospheric pressure ~~ensures that there will be no in-leakage of air over the life of the MPC~~ *at room temperature (70°F), eliminates air inleakage over the life of the MPC because the cavity pressure rises due to heat up of the confined gas by the fuel decay heat during storage*. In-leakage of air could be harmful to the fuel. Prior to moving the SFSC to the storage pad, the MPC helium leak rate is determined to ensure that the fuel is confined.
APPLICABLE SAFETY ANALYSIS	The confinement of radioactivity during the storage of spent fuel in the MPC is ensured by the multiple confinement boundaries and systems. The barriers relied on are the fuel pellet matrix, the metallic fuel cladding tubes in which the fuel pellets are contained, and the MPC in which the fuel assemblies are stored. Long-term integrity of the fuel and cladding depend on storage in an inert atmosphere. This is accomplished by removing water from the MPC and backfilling the cavity with an inert gas *at a positive pressure (> 1 atm)*. The thermal analyses of the MPC assume that the MPC cavity is filled with dry helium.
LCO	A dry, helium filled and sealed MPC establishes an inert heat removal environment necessary to ensure the integrity of the multiple confinement boundaries. Moreover, it also ensures that there will be no air in-leakage into the MPC cavity that could damage the fuel cladding over the storage period.
APPLICABILITY	The dry, sealed and inert atmosphere is required to be in place during TRANSPORT OPERATIONS and STORAGE OPERATIONS to ensure both the confinement barriers and heat removal mechanisms are in place during these operating

(continued)

BASES

APPLICABILITY
(continued)

periods. These conditions are not required during LOADING OPERATIONS or UNLOADING OPERATIONS as these conditions are being established or removed, respectively during these periods in support of other activities being performed with the stored fuel.

ACTIONS

A note has been added to the ACTIONS which states that, for this LCO, separate Condition entry is allowed for each SFSC. This is acceptable since the Required Actions for each Condition provide appropriate compensatory measures for each MPC not meeting the LCO. Subsequent SFSCs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If the cavity vacuum drying pressure limit has been determined not to be met during TRANSPORT OPERATIONS or STORAGE OPERATIONS, an engineering evaluation is necessary to determine the potential quantity of moisture left within the MPC cavity. Since moisture remaining in the cavity during these modes of operation may represent a long-term degradation concern, immediate action is not necessary. The Completion Time is sufficient to complete the engineering evaluation commensurate with the safety significance of the CONDITION.

A.2

Once the quantity of moisture potentially left in the MPC cavity is determined, a corrective action plan shall be developed and implemented to the extent necessary to return the MPC to an analyzed condition. Since the quantity of moisture estimated

(continued)

BASES

ACTIONS

A.2 (continued)

under Required Action A.1 can range over a broad scale, different recovery strategies may be necessary. Since moisture remaining in the cavity during these modes of operation may represent a long-term degradation concern, immediate action is not necessary. The Completion Time is sufficient to develop and complete the corrective actions commensurate with the safety significance of the CONDITION.

B.1

If the helium backfill ~~density~~ *pressure* limit has been determined not to be met during TRANSPORT OPERATIONS or STORAGE OPERATIONS, an engineering evaluation is necessary to determine the ~~quantity of~~ helium *pressure* within the MPC cavity. Since too much ~~or too little helium~~ in the MPC cavity during these modes represents a potential overpressure ~~or heat removal degradation~~ concern, an engineering evaluation shall be performed in a timely manner. The Completion Time is sufficient to complete the engineering evaluation commensurate with the safety significance of the CONDITION.

B.2

Once the ~~quantity of~~ helium *pressure* in the MPC cavity is determined, a corrective action plan shall be developed and initiated to the extent necessary to return the MPC to an analyzed condition. Since the ~~quantity of~~ helium *pressure* estimated under Required Action B.1 can range over a broad scale, different recovery strategies may be necessary. Since elevated ~~or reduced~~ helium ~~quantities~~ *pressures* existing in the MPC cavity represent potential overpressure ~~or heat removal degradation~~ concerns, corrective actions should be developed and implemented in a timely manner. The Completion Time is sufficient to develop and complete the corrective actions commensurate with the safety significance of the CONDITION.

(continued)

BASES

ACTIONS (continued)

C.1

If the helium leak rate limit has been determined not to be met during TRANSPORT OPERATIONS or STORAGE OPERATIONS, an engineering evaluation is necessary to determine the potential leak rate and quantity of helium remaining within the cavity. The significance of the situation is mitigated by the existence of the OVERPACK containment boundary. Since an increased helium leak rate represents a potential challenge to MPC heat removal and the off-site doses calculated in the TSAR confinement analyses, reasonably rapid action is warranted. The Completion Time is sufficient to complete the engineering evaluation commensurate with the safety significance of the CONDITION.

C.2

Once the cause and consequences of the elevated leak rate from the MPC are determined, a corrective action plan shall be developed and initiated to the extent necessary to return the MPC to an analyzed condition. Since the recovery mechanisms can range over a broad scale, based on the evaluation performed under Required Action C.1, different recovery strategies may be necessary. Since an elevated helium leak rate represents a challenge to heat removal rates and off-site doses, reasonably rapid action is required. The Completion Time is sufficient to develop and complete the corrective actions commensurate with the safety significance of the CONDITION.

(continued)

BASES

ACTIONS (continued)

D.1

If the MPC fuel cavity cannot be successfully returned to a safe, analyzed condition, the fuel must be placed in a safe condition in the spent fuel pool. The Completion Time is reasonable based on the time required to move the OVERPACK to the cask preparation area, perform fuel cooldown operations, re-flood the MPC, cut the MPC lid welds, move the TRANSFER CASK into the spent fuel pool, remove the MPC lid, and remove the spent fuel assemblies in an orderly manner and without challenging personnel.

SURVEILLANCE REQUIREMENTS

SR 2.1.1.1, SR 2.1.1.2, and SR 2.1.1.3

The long-term integrity of the stored fuel is dependent on storage in a dry, inert environment. Cavity dryness is demonstrated by evacuating the cavity to a very low absolute pressure and verifying that the pressure is held over a specified period of time. A low vacuum pressure is an indication that the cavity is dry. Having the proper helium backfill ~~density~~ *pressure* ensures adequate heat transfer from the fuel to the fuel basket and surrounding structure of the MPC. Meeting the helium leak rate limit ensures there is adequate helium in the MPC for long term storage and the leak rate assumed in the confinement analyses remains bounding for off-site dose.

All three of these surveillances must be successfully performed during LOADING OPERATIONS to ensure that the conditions are established for TRANSPORT OPERATIONS and STORAGE OPERATIONS which preserve the analysis basis supporting the cask design.

REFERENCES

1. TSAR Sections 4.4, 7.2, 7.3 and 8.1

BASES (continued)

ACTIONS

A note has been added to the ACTIONS which states that, for this LCO, separate Condition entry is allowed for each SFSC. This is acceptable since the Required Actions for each Condition provide appropriate compensatory measures for each SFSC not meeting the LCO. Subsequent SFCSs that don't meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If none of the SFSC lifting requirements are met, immediate action must be initiated and completed expeditiously to comply with one of the three lifting requirements in order to preserve the SFSC design and analysis basis.

SURVEILLANCE REQUIREMENTS

SR 2.1.3.1

The SFSC lifting requirements of LCO 2.1.3 must be verified to be met after the SFSC is suspended from, or secured in the transporter and prior to the transporter beginning to move the SFSC to or from the ISFSI. This ensures potential drop accidents during TRANSPORT OPERATIONS are bounded by the drop analyses.

For compliance with LCO 2.1.3.a, lifting heights are to be measured from the lowest surface on the overpack to the potential impact surface.

REFERENCES

1. TSAR, Sections 3.4.10, 8.1, and 8.3

BASES

SURVEILLANCE REQUIREMENTS

SR ~~3.1.3.1~~ *2.1.4.1*

The long-term integrity of the stored fuel is dependent on the material condition of the fuel assembly cladding. By minimizing thermally-induced stresses across the cladding the integrity of the fuel assembly cladding is maintained. The integrity of the MPC is dependent on controlling the internal MPC pressure. By controlling the MPC internal temperature prior to re-flooding the MPC there is no formation of steam during MPC re-flooding.

The MPC helium exit gas temperature limit ensures that there will be no large thermal gradients across the fuel assembly cladding during MPC re-flooding and no formation of steam which could potentially overpressurize the MPC.

Fuel cool down must be performed successfully on each SFSC before the initiation of MPC re-flooding operations to ensure the design and analysis basis are preserved.

REFERENCES

1. TSAR, Sections 4.4.1, 4.5.1.1.4, and 8.3.2.

CHAPTER 13: QUALITY ASSURANCE

13.0 INTRODUCTION

This section provides a summary of the quality assurance program implemented for activities related to the design, qualification analyses, material procurement, fabrication, assembly, testing and use of structures, systems, and components of the HI-STAR 100 System designated as important to safety.

Table 2.2.6 identifies the structures, systems and components (SSCs) of the HI-STAR 100 System that are considered important to safety. Table 8.1.4 identifies the ancillary equipment needed for handling and loading operations that has been designated as important to safety.

13.1 GRADED APPROACH TO QUALITY ASSURANCE

For the HI-STAR 100 System, a graded approach to quality is used by Holtec. ~~Generally,~~ ~~t~~*T*his graded approach *is controlled by Holtec Quality Assurance (QA) program documents.* ~~only affects the controls for material manufacturing and material procurement. Section 13.3, which provides a summary of the QA program to be used on the HI-STAR 100 System (as well as applicable ancillary equipment designated as important to safety) also describes the graded approach to quality when applicable.~~

NUREG/CR-6407 [13.1.1] provides descriptions of ~~classification~~ *quality* categories A, B and C. These descriptions are provided below.

Category A: Category A items include structures, systems, and components whose failure could directly result in a condition adversely affecting public health and safety. The failure of a single item could cause loss of primary containment leading to release of radioactive material, loss of shielding, or unsafe geometry compromising criticality control.

Category B: Category B items include structures, systems, and components whose failure or malfunction could indirectly result in a condition adversely affecting public health and safety. The failure of a Category B item, in conjunction with the failure of an additional item, could result in an unsafe condition.

Category C: Category C items include structures, systems, and components whose failure or malfunction would not significantly reduce the packaging effectiveness and would not be likely to create a situation adversely affecting public health and safety.

Using these descriptions along with classification assignments from NUREG/CR-6407 [13.1.1], Holtec International has assigned a classification category to each individual component of the HI-STAR 100 System. The categories are identified in Table 2.2.6.

Activities affecting quality are defined by the purchaser's procurement contract for *use of the HI-STAR 100 System on* a site-specific *Independent Spent Fuel Storage Installation (ISFSI).* ~~storage application with the HI-STAR 100 System~~. They may include any or all of the following: design, procurement, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair and monitoring of HI-STAR 100 structures, systems, and components which are important to safety. Regardless of the provisions of the procurement contract, the quality requirements set forth in this document

13.2 PROJECT ORGANIZATION

The HI-STAR 100 System project has been established under Holtec International's project identification number ~~H-~~5014. This project has been designated as important to safety (ITS), which automatically mandates a rigorously formulated and carefully articulated project management system in accordance with the Holtec Quality Assurance Manual (HQAM). The first requirement of the HQAM is to identify a project team, and to prepare and approve a Project Plan. The HQAM mandates that all activities of an important to safety project be carried out in accordance with the Project Plan. Subsection 13.3 herein presents the essential elements of the HI-STAR 100 project programmatic quality requirements.

The HI-STAR 100 project team consists of a project manager, *the licensing manager,* the QA manager, and a team of technical specialists. A description of Holtec's organizational structure, functions, lines of responsibility, and levels of authority can be found in the *Holtec Quality Assurance documents* ~~HQAM~~.

13.3 QUALITY ASSURANCE PROGRAM

13.3.1 Overview

~~All~~ *i*Important to safety (ITS) work on the HI-STAR 100 project is performed by Holtec International in accordance with Holtec International's quality assurance program which is designed to satisfy the requirements imposed within 10CFR50 Appendix B, 10CFR71, Subpart H, and 10CFR72, Subpart G. The following provides a summary of Holtec International's quality assurance program implementation to comply with the applicable regulatory requirements.

13.3.2 Quality Assurance Program Documents

Holtec International's quality assurance program has three levels of controlling documents. The highest level, and overall controlling document, is the Holtec International Quality Assurance Manual (HQAM) which provides the requirements and commitments that Holtec International must follow during the course of any nuclear safety-related or important to safety project. The manual is organized into ~~18~~ *19* sections, *the first 18 of which correspond to the eighteen QA program criteria* ~~with each section covering a separate criterion in a similar order to that~~ in the above referenced regulations. *The nineteenth section incorporates additional miscellaneous QA procedures .*

The second level of quality assurance program controlling documents is the Holtec International quality procedures (HQPs). These procedures provide specific details on how Holtec International will implement the requirements and commitments imposed within the quality assurance manual. A current matrix of Holtec International QA Procedures cross referenced to the 18 QA criteria of 10CFR72, Subpart G, is provided in Appendix 13.B. As required, additional HQPs may be prepared and implemented on ITS projects, but HQPs. ~~will not be removed from the QA program.~~

Standard and project specific procedures comprise the third level of quality assurance program controlling documents. These procedures are used to control specific project activities and requirements which are not addressed within the Holtec International quality procedures. Examples of this would be a visual weld examination procedure, liquid penetrant examination procedure, or an in-process inspection procedure. These procedures are considered quality assurance records and are controlled in accordance with Holtec International's quality assurance program.

13.3.3 Quality Assurance Program Content

The requirements and commitments of Holtec International's quality assurance program as specified in the Holtec International quality assurance manual and corresponding quality procedures and project specific procedures (hereafter called quality assurance program documents) are summarized below. Each criterion is summarized separately.

1. Organization

Holtec International's quality assurance program documents define the quality assurance program related responsibilities of all Holtec International personnel, as well as the breakdown of the organizational responsibilities within Holtec International. The Holtec International organization is detailed in the HQAM and HQP 1.0.

Holtec International's quality assurance program requires that the president of Holtec International review the status of the quality program on an annual basis. Furthermore, as part of Holtec International upper management's commitment to Holtec International's quality assurance program, a statement of policy authored by the president of Holtec International is contained in the quality assurance manual. This policy defines Holtec International's commitment to meeting the requirements of 10CFR50 Appendix B, 10CFR71, Subpart H and 10CFR72, Subpart G, as applicable, on all safety-related and important to safety projects and also delegates overall responsibility of quality program maintenance to the Quality Assurance Manager. The listing of Structures, Systems, and Components (SSC), defined as important to safety for the HI-STAR 100 System, is provided in Table 2.2.6 of this TSAR.

The Quality Assurance Manager is the person responsible for establishing and maintaining the QA Program. He reports to the Executive Vice President of Holtec International on all quality matters and has the authority and organizational freedom to enforce QA requirements, identify problem areas, recommend or provide solutions to QA problems, and verify the effectiveness of those solutions. As necessary, the Quality Assurance Manager can communicate directly to the President of Holtec International on quality-related issues. The minimum qualification requirements for the position of Quality Assurance Manager are *contained in the Holtec QA program procedures. Regardless of the education and experience requirements, the QA Manager shall be knowledgeable of the applicable codes and standards.* ~~a bachelor's degree in engineering, physical sciences, or mathematics from an accredited institution with at least three years of experience in quality assurance activities, or a high school diploma with seven years of QA experience and ten years knowledge of the applicable codes and standards.~~

The Quality Assurance Manager has the following typical responsibilities:

a. Monitor quality issues and keep Management informed of significant conditions adverse to quality.

b. Initiate, recommend, or provide solutions and verify implementation of corrective action to nonconforming conditions.

c. Control or stop further processing, delivery, or installation of a nonconforming item, deficiency, or unsatisfactory condition until proper dispositioning has occurred.

d. Maintain and control the HQAM, HQPs, and standard and project procedures.

e. Review contractual documents to assure inclusion of applicable quality assurance requirements.

f. Interface with clients and regulators during audits.

g. Schedule, perform, and/or oversee audits/surveillances of suppliers of quality-related activities to verify proper implementation of the quality assurance program.

h. Schedule, perform, and/or oversee audits of internal activities to verify compliance with the HQAM.

i. Approve Quality Procedures and Project Plans.

j. Perform *periodic* ~~an annual~~ review of nonconformance reports to identify adverse quality trends for management review and assessment.

k. Coordinate annual QA review meetings to assess the adequacy and effectiveness of QA activities.

l. Schedule and conduct training and indoctrination of personnel performing activities affecting quality.

m. Maintain current qualifications/certifications for personnel performing quality-related activities, as appropriate.

n. Maintain a current Approved Vendors List for vendors approved to provide quality-related items/services.

o. Maintain a current list of approved computer programs.

Some of the above listed activities may be performed by personnel designated by the Quality Assurance Manager, although the Quality Assurance Manager retains overall responsibility for assuring proper implementation of the Quality Assurance Program.

Holtec International may contract with another organization to perform work on important to safety activities. The other organization could be a design agent, manufacturer, supplier, or subcontractor. Any organization performing functions affecting quality of important to safety work must have a QA position with the required authority and organizational freedom, as well as, direct access to upper levels of management. ~~Direct communication between the Holtec International Quality Assurance Manager and the other organizations will be established as part of the procurement documents.~~ However, Holtec International shall retain overall responsibility for the QA Program.

~~Specific organizational charts of other participating organizations providing related activities on SSCs identified as important to safety shall be detailed in their QA documents and shall be in full compliance with the requirements of 10CFR Part 72.~~

2. Quality Assurance Program

The Holtec International quality assurance program requires that ~~all~~ activities important to safety involving design, procurement, fabrication, inspection and testing are performed in accordance with written procedures. A current listing of Holtec International quality procedures is provided in Appendix 13.B. This list is subject to change with the addition of new procedures. Additional project specific procedures are written as needed when specific project requirements are not covered by quality procedures. These additional project specific quality procedures are considered quality assurance records which are controlled in accordance with Holtec International's quality assurance program. QA manuals and procedures, as well as project specific procedures, are controlled and distributed in accordance with the quality assurance program.

All Holtec International personnel performing important to safety activities must be indoctrinated in the Holtec International quality assurance program prior to performing important to safety work in order *to* assure requirements of the QA program are understood. Additionally, a training session is held each year for Holtec International personnel in order to review specific quality assurance requirements. The effectiveness of the quality program is assessed by upper management through annual audits, in-process assessments, and other means.

Holtec International personnel performing inspection, testing or auditing activities are qualified in accordance with written procedures using guidelines established by the

American Society for Nondestructive Testing, American Society of Mechanical Engineers, American National Standards Institute, or other recognized authority, as applicable. These procedures define education, training, experience, and examination requirements for qualifying personnel to perform inspection, testing or auditing. Qualification records are maintained by the quality assurance manager, or designee, and include certification records, bases for qualification, qualification time period, experience and training records, and examination scores, as applicable. Proficiency of qualified personnel shall be maintained as required through retraining, re-examination, and/or re-certification.

Contractors used by Holtec International to perform important to safety work may have their own quality assurance program which meets or exceeds Holtec International's, or shall perform the work under Holtec International's quality assurance program.

QA programs of contractors performing important to safety work are reviewed by Holtec's quality assurance organization through audits, assessments, and surveillances to assure applicable QA criteria will be met.

A project plan is written for each important to safety project prior to the start of work. This project plan defines the design bases for the project and lists the applicable quality and standard procedures to be used on the project. Additional details on the project plan are provided in Section 13.4.

Disputes involving quality which arise from the difference of opinion between personnel from other departments will be resolved by the QA Manager.

3. Design Control

Holtec International's quality assurance program documents establish measures necessary to assure the control of the design process, from input through verification. A design basis is defined in a design specification at the start of each cask project so that appropriate codes, standards and other relevant documents are used during the course of the design process. Design parameters, as well as miscellaneous design requirements, such as maintenance, repair and storage, are also defined within the Holtec design specification.

Drawings, procedures and design reports are the three main documents produced by Holtec International through its design process. Holtec International quality program requirements for procedures and drawings are defined in criterion 5 of the HQAM. Measures are established to assure applicable requirements from design bases documents are translated into drawings, procedures, and reports.

Quality assurance program documents are established to identify and control the authority and responsibilities of all individuals or groups responsible for design reviews and verification activities.

Holtec International's quality assurance program documents require that all design reports include, as applicable, a defined purpose, assumptions, references, inputs, outputs and results. Design reports are signed by the author and are reviewed by the Quality Assurance Manager and the Project Manager. Additionally, the design report is verified by an individual or group of individuals other than the author of the report. Verification may be made either by qualification testing, design review or *alternate* ~~alternative~~ calculations. When qualification testing is used, the prototype shall be subjected to the most adverse design conditions. Appendix 13.A provides an example copy of Holtec International's current *Design Verification Checklist* ~~Document QA Verification Form~~ used on the HI-STAR 100 project.

Measures are established to assure that design verification shall be performed by qualified personnel who did not perform the design analysis. The verifier shall not have influenced inputs or approaches utilized in the analysis. The analyst's supervisor may perform the verification pursuant to the requirements of NQA-1 [13.3.1].

Holtec International quality assurance program documents require that design verification, if other than by prototype or lead production quality testing, must be satisfactorily completed prior to release for fabrication unless the timing cannot be met. In this case, written justification must be provided to the Quality Assurance Manager or designee and unverified portions of the design must be identified and controlled.

Changes to a Holtec International design report and specification are subject to the same design controls and must be reviewed and approved in a similar manner to the original. ~~Changes in design for items regulated under 10CFR71 or 10CFR72 and that may result in conditions differing from those prescribed in the Certificates of Compliance must be approved by the NRC prior to implementation.~~

Errors in design shall be addressed in accordance with Criteria 15 and 16.

When applicable, use of commercial items in an important to safety system, structure, or component shall be reviewed for suitability to *their* ~~its~~ intended function.

Measures are established for the review and disposition of vendor documents including procedures and drawings.

Measures are established in the QA program to assure valid industry standards and specifications are used in the selection of design inputs (including suitable materials and processes).

4. Procurement Document Control

Holtec International's quality assurance program establishes measures to control the preparation, review, approval and issuance of all important to safety purchase orders. Only suppliers approved in accordance with criterion 7 shall be qualified to supply important to safety items.

Measures are established within Holtec International's quality assurance program to ensure that all purchase orders contain the following information, codes, standards, and specifications, as applicable:

a. a statement of the scope of work to be performed by the vendor;

b. the design basis technical requirements including codes, standards, specifications, etc., to which the item must be designed or manufactured;

c. quality assurance requirements including, but not limited to, compliance by the vendor with the requirements of 10CFR21 [13.3.2], 10CFR50, Appendix B, 10CFR71, Subpart H, or 10CFR72, Subpart G; and direct reference to the vendor's quality assurance program.

d. permission to gain access to the supplier's or subtier supplier's plant facilities and records;

e. identification of documentation required to be supplied by the vendor for approval by Holtec;

f. requirements for reporting and approving disposition of nonconformances;

g. required procedures, tests, and inspections; and

h. record retainage and control requirements.

Purchase orders for important to safety structures, systems, or components must be reviewed and approved (through signature on the purchase order) by the Quality Assurance Manager and the Project Manager or their designee. The QA Manager is responsible for verifying that the purchase order has been prepared, reviewed, and approved in accordance with the QA program. This review includes verification that the items specified above have been included, as applicable.

Changes and revisions to purchase orders shall be subjected to the same or equivalent review and approval requirements as the original document.

5. Instructions, Procedures and Drawings

Holtec International quality assurance program documents require that ~~all~~ activities that are important to safety must be prescribed and accomplished in accordance with written instructions, procedures or drawings. Methods for complying with the 18 criteria set forth within 10CFR50 Appendix B, 10CFR71, Subpart H, and 10CFR72, Subpart G, are also required to be described within defined procedures.

Instructions, procedures and drawings are required by the Holtec International quality assurance program to include qualitative and quantitative acceptance criteria in order to verify that activities important to safety have been satisfactorily accomplished.

Measures are established through the Holtec International quality assurance program to prepare, review, approve, and control these instructions, procedures and drawings. The review of these documents is required to be performed by a cognizant verifier other than the author. Additionally, instructions, procedures and drawings must be reviewed and approved by the Quality Assurance Manager, or designee. Revisions to instructions, procedures and drawings are required to be reviewed and approved in a similar manner to the original revision.

6. Document Control

Holtec International's quality assurance program documents establish methods to control the review, approval, and issuance of documents and changes thereto, before release, to ensure that the documents are adequate and applicable quality requirements have been incorporated. Documents that must be controlled shall include, but not be limited to: design specifications; design reports; design and fabrication drawings; procurement documents; QA manuals; design criteria documents; and procedures and instructions (i.e., fabrication, inspection, and testing).

Measures are established in quality assurance program documents to define individuals or organizations responsible for the review, approval, and control of the documents identified above. Document revisions are required to be reviewed, approved, and controlled in a similar manner to the original document. Review of documents is required to be performed by qualified personnel.

Quality assurance program documents require that documents required to perform a specific activity shall be available at the location where the activity is being performed. Quality assurance program documents also require that obsolete or superseded documents are controlled in order to prevent their inadvertent use.

An index of project documents is maintained in order to allow identification of the latest revision of applicable documents. This list includes, but is not limited to, design reports, specifications, procedures, and drawings.

7. Control of Purchased Material, Equipment and Services

Holtec International quality assurance program documents define measures to ensure that important to safety materials, equipment and services conform to procurement documents. Procedures are established to define requirements for procurement document control, supplier evaluation and selection, vendor surveillance, and receipt inspection in order to assure purchased items are properly controlled from the procurement phase through item receipt.

Holtec International quality assurance program documents require that Holtec International qualified personnel evaluate all Holtec International subcontractors supplying important to safety activities prior to contract award. A vendor shall be evaluated to determine its technical capability as well as its production capability. Those vendors found to have satisfactory technical and production capabilities are submitted to the quality assurance department for a quality assurance evaluation. The quality assurance evaluation, which shall be documented, shall assess past performance and also determine the capabilities of the vendor to comply with required codes and QA criteria through audit, *surveillance,* ~~survey~~ or other *source evaluation, as applicable.* ~~means~~. Unacceptable conditions discovered by Holtec International quality assurance are addressed through nonconformances and audit findings, as applicable. Holtec International shall impose its own quality assurance program on vendors which are determined not to have an adequate quality assurance program; or shall require changes in the supplier's quality assurance program to make it acceptable to Holtec International; or shall perform dedication of the items through surveillance, inspections, and tests in accordance with Holtec International's QA program, *as applicable*. ~~All~~ Suppliers of important to safety items, equipment, and services must be placed on Holtec International's Approved Vendors List. ~~prior to contract issuance.~~ Specific requirements for placing vendors on the Approved Vendor List are defined within Holtec International quality assurance program documents. *As applicable,* ~~Typically~~, this includes an audit, *surveillance, or other source evaluation* of the vendor to verify QA program conformance to applicable codes and implementation of the QA program. Measures for performing audits, *surveillance, or other source evaluation* are defined in quality assurance program documents. The QA program requires triennial audits, *surveillance, or other source evaluation* of vendors in order to verify continued implementation of their QA program and maintenance on the Approved Vendors List.

Measures for performing supplier surveillances are defined within Holtec International quality assurance program documents. Source surveillance is used to determine that in-process work is being performed by the supplier in accordance with purchase order requirements. The Project Manager, in conjunction with the Quality Assurance Manager, must determine the extent of source surveillance required for a particular job or supplier based on the important to safety classification, complexity of the item, and quantity. Holtec International quality assurance program documents define types of surveillance activities that may be performed including hold point verification. Project-specific procedures and procurement documents define, when applicable, necessary inspection points to be performed by Holtec, and inspection and test acceptance criteria. Surveillance reports are required to be written for all surveillances performed.

Measures for performing receipt inspection activities are defined within Holtec International quality assurance program documents. Receipt inspection is performed in order to verify received items meet all requirements of the purchase order. The extent of receipt inspection to be performed on vendor-furnished items in order to assure items are properly identified and conform to purchase order requirements is established through Holtec International quality and project procedures. Inspection records *material test reports,* and/or certificates of conformance attesting to the acceptance of the item are reviewed for acceptability as part of the receipt inspection process. When item acceptance is contingent on post-installation testing or inspection, the acceptance criteria must be defined with vendors through procurement documents prior to item use. Items and materials that have completed receipt inspection and are released for fabrication or further use are controlled in accordance with quality assurance program documents.

Measures have been established through Holtec International quality assurance program documents to control items discovered during receipt inspection to have a nonconforming condition. These measures include segregation and identification of items, evaluation of the nonconforming items, and disposition with justification, as required.

Holtec International quality assurance program documents establish measures to assure that a supplier provides all documentation for a received part as required by the purchase order. These documents include, but are not limited to, material test reports, inspection and test reports, certificates of conformance and nonconformance reports, as applicable. Review of these documents for conformance to procurement documents is required. ~~as part of receipt inspection or final inspection activities.~~

~~Items classified as important to safety Category A meet all requirements specified in this criteria. Items classified as important to safety Category B meet all requirements of this criteria except audits. Audits, if required, will typically only evaluate for material and process controls. The vendor does not need to have a complete 10CFR72, Subpart G QA program. Items classified as important to safety Category C meet all requirements of this criteria except evaluations, audits and/or surveillances are not required and the vendor does not need to be placed on the Approved Vendors List. The vendor does not need to have a 10CFR72, Subpart G QA program. Typically, item traceability to documentation is required, and test reports and certificates of compliance are still required to verify item acceptability to the procurement document requirements.~~

8. Identification and Control of Materials, Parts and Components

Holtec International quality assurance program documents establish measures to ensure that materials, parts and components, including partially fabricated assemblies, are adequately identified and controlled in order to preclude the use of incorrect or nonconforming items. Measures are established by Holtec International through its quality documents to ensure that limited life items are controlled in order to preclude their use once the shelf life of these items has expired.

Measures are established by Holtec International through quality assurance program documents in order to provide means for material, part or component identification so that items maintain traceability to appropriate documentation such as drawings and test reports throughout fabrication, installation and use, and to preclude use of incorrect or defective items. Markings are required to be made such that they are not detrimental to the item. Any specific identification or marking requirements are identified through drawings, procedures, or specifications.

9. Control of Special Processes

Holtec International quality assurance program documents establish measures to ensure that special processes such as welding, lead pouring, neutron shield material installation, and NDE examinations are controlled. Specific special processes are typically identified in fabrication specifications. Procedures, equipment, and personnel used to perform special processes are required to be qualified in accordance with applicable codes, standards and specifications. Special process operations must be performed by appropriately qualified personnel using written and approved procedures, *as applicable* ~~(or equivalent)~~. Special process operations are required to be documented and verified. All special process records including procedure, equipment and personnel qualifications, as well as special process operation results are required to be maintained as quality records.

10. Licensee Inspection

All inspections are required to be performed in accordance with written procedures in order to verify conformance of quality affecting activities. Drawings and specifications are used in conjunction with the procedures to define specific acceptance criteria. Inspection procedures include, as applicable, identification of characteristics and activities to be inspected, acceptance and/or rejection criteria, methods of inspection, identification of the individuals or groups responsible for performing the inspection operation, recording of inspection results, identification of hold and witness points, approval requirements for inspection data and inspection prerequisites such as personnel qualifications. Inspection results are documented and signed by the applicable inspector. Inspections through sampling shall use known standards as applicable for the basis of acceptance.

Measures are established within Holtec International quality assurance program documents to ensure that all structures, systems, and components important to safety are, upon receipt, inspected to verify that the item meets purchase order requirements. Control of materials, both before and after receipt inspection, are defined for both accepted and nonconforming material within Holtec International quality assurance program documents.

Measures for in-process control are established through project-specific procedures for situations when direct inspection would be impractical. In-process controls when required, may include, but are not limited to, monitoring of processing methods, equipment and personnel, as well as review of in-process documentation.

Measures are established within the quality assurance program documents to assure that reworked or repaired items are inspected to the original requirements, or approved deviation and new requirements.

Holtec International quality assurance program documents establish measures to ensure that all nonconformances identified during the course of fabrication are resolved during final inspection; that all items which are inspected must be identifiable and traceable to specific records; and that all inspection records must be reviewed by the Holtec International QA Manager, or designee, to verify the inspection requirements have been satisfied.

Holtec International quality assurance program documents require that all inspectors shall be qualified in accordance with applicable codes and standards and shall be properly trained. All inspector qualification records are maintained within the quality assurance files and are required to be kept current. Measures are defined within Holtec International quality assurance program documents to ensure that inspection personnel are independent from personnel performing the activity being inspected.

11. Test Control

Holtec International quality assurance program documents establish measures to ensure that applicable test programs (i.e., load tests, leak tests, hydrostatic tests, production tests, etc.) are performed in accordance with written procedures *as applicable*. Test procedures include, as applicable: test equipment and calibration requirements; material requirements; personnel qualifications; prerequisites (including environmental conditions); detailed performance instructions; hold points; acceptance and rejection criteria; instructions for documenting and evaluating results; and documentation approval requirements.

The acceptance test program is defined in Chapter 9 of the TSAR for the HI-STAR 100 System and will be implemented for each system to verify that SSCs conform to the specified requirements and will perform satisfactorily in service.

Only qualified personnel shall evaluate test results for acceptability.

12. Control of Measuring and Test Equipment

Holtec International quality assurance program documents establish measures to ensure that measurement and test equipment shall be calibrated, adjusted and maintained at prescribed intervals or prior to use. All calibrations are required to be performed in accordance with written procedures or standards. Measuring and test equipment is required to be labeled or tagged in order to indicate the planned date of the next calibration and to allow traceability back to calibration records.

Measures are established within Holtec International quality assurance program documents to ensure that all calibrations of measuring and test equipment are performed using calibration standards that are both traceable and have known valid relationships to nationally recognized standards. When no known recognized standard exists, the basis for the calibration is required to be defined and documented.

Measures are established within Holtec International quality assurance program documents to control measuring and test equipment which is found to be out of calibration. These controls include validation of all previous inspection and test results from the time the item was found to be out of calibration back to the time of the previous acceptable calibration of the same item. Any measuring or test equipment found to be out of calibration is required by Holtec International quality assurance program documents to be repaired and re-calibrated prior to next use, or replaced.

A master list of calibrated tools and equipment is required to be kept in order to maintain a complete calibration status of each item.

13. Handling, Storage and Shipping

Holtec International quality assurance program documents establish measures to ensure that cleaning, handling, storage and shipping of items are accomplished in accordance with design requirements to preclude damage, loss, or deterioration by environmental conditions. These activities are performed in accordance with written instructions or procedures as necessary. Measures for establishing provisions for the use of special handling, lifting or storage equipment in order to adequately identify and preserve items, components or assemblies are provided within Holtec International quality assurance program documents.

Measures are established within Holtec International quality assurance program documents to ensure that a review of packaging be performed prior to item shipment in order to assure packaging meets approved drawings, specifications and codes. Additionally, verification of completion of all documentation including procedures, manuals and inspection and test results is required to be performed prior to shipment. Physical identification of the item shall be verified prior to shipment.

14. Inspection, Test and Operating Status

Holtec International quality assurance program documents establish measures to ensure the inspection, test and operating status of items is known by organizations responsible for quality activities.

Measures are established by Holtec International through its quality assurance program documents to control the application and removal of status indicators such as markers and tags. Additionally, Holtec International quality assurance program documents establish measures to ensure that if required operations such as tests or inspections are bypassed, such action is taken through controlled procedures and under cognizance of the quality assurance department.

Controls on nonconforming items are summarized in criterion 15.

15. <u>Nonconforming Materials, Parts or Components</u>

Holtec International quality assurance program documents establish measures to ensure control of nonconforming important to safety items, services, and activities. This includes provisions for the identification, documentation, tracking, segregation, review, disposition of nonconforming items, and notification of the affected organizations, as appropriate.

Holtec International quality assurance program documents establish measures to ensure that nonconforming items, services or activities shall be reviewed and dispositioned. Provisions are included to ensure that nonconforming services or activities, including those of suppliers, for which the recommended disposition is "accept-as-is" or "repair", shall be submitted to the client for approval, *if required.*

Measures are established within Holtec International quality assurance program documents to require nonconformances to be identified through deviation reports and corresponding corrective actions (which may include repair, rework, and inspection requirements). Individuals responsible for review and disposition of nonconforming items are identified within Holtec International quality assurance program documents.

Measures are established within Holtec International quality assurance program documents to control further processing, delivering, or installation of nonconforming or defective items pending a decision on its disposition. Measures are established through Holtec International quality assurance program documents to ensure that nonconforming items are segregated and controlled until proper disposition is completed.

Holtec International quality assurance program documents establish measures to ensure that the acceptability of nonconforming items is verified by inspecting or testing the nonconforming item against original requirements after designated repair or rework. Final disposition of nonconforming items shall be defined and documented.

Measures are established within Holtec International quality assurance program documents to permit anyone who detects a nonconformance to report it in accordance with quality assurance program documents. Provisions are established to ensure that nonconformances are evaluated for the purpose of determining if reporting pursuant to 10CFR21 [13.3.2] is required.

Holtec International quality assurance program documents require that nonconformances be assessed by the Quality Assurance Manager on a defined basis to determine any quality trends. Any trends or significant results shall be evaluated by appropriate management personnel for development of correction actions.

Nonconformance reports are considered part of the quality records package. As-built conditions are required to be documented as applicable.

16. Corrective Action

Holtec International quality assurance program documents establish measures to ensure that causes of conditions adverse to quality are promptly identified and reported to upper management through deviation reports and corrective action reports. Measures are also established to ensure that corrective actions are performed on identified nonconforming conditions or items, and that follow-ups are performed and documented as applicable to verify implementation and effectiveness of the corrective action.

Measures are established within Holtec International quality assurance program documents to ensure that follow-up activities are performed to verify that corrective actions have been correctly implemented so as to minimize the possibility of recurrence of the nonconforming condition. Individuals responsible for verifying and documenting corrective action are identified within Holtec International quality assurance program documents.

Measures are established within Holtec International quality assurance program documents to document and evaluate significant conditions adverse to quality through root cause evaluations. These evaluations are performed by cognizant levels of management.

17. Quality Assurance Records

Holtec International quality assurance program documents require that evidence of activities affecting quality shall be documented and shall provide sufficient information to permit identification of the record with the items or activities to which it applies. Quality assurance records include, but are not limited to, design, procurement, manufacturing and installation records; audits (internal and external); nonconformance reports; inspection and test results; drawings (including as-built) and specifications; analysis reports (i.e., failure, seismic, etc.); personnel qualifications and training (including retraining) records; procedures (i.e., inspection, testing, calibration, etc.); calibration records; equipment qualification; corrective action reports; operating logs and completed travelers; material test reports; and design review documents.

Holtec International quality assurance program documents require that inspection and test records shall, as applicable, contain observations, evidence of inspection or test performance, results of inspections or tests, names of inspectors, date of tests, test personnel and data recorders, equipment identification, and evidence of acceptability. Any nonconforming conditions shall be addressed in accordance with criterion 15.

Holtec International quality assurance program documents establish measures to ensure that documents defined as quality assurance records are legible and that they reflect the total of work performed.

All quality assurance records are defined as either "lifetime" or "nonpermanent", as appropriate. Holtec International quality assurance program documents define which quality assurance records are "lifetime" and which are "nonpermanent". "Lifetime" records are those records that pertain to the design, fabrication and installation of a particular item such that the records can demonstrate the capability of the item and provide evidence of all activities supporting the acceptability of the item. These records demonstrate the capability for safe operation; provide evidence of repair, rework, replacement or modification; aid in determining the cause for an accident or malfunction of an item; or provide a baseline for inservice inspection. Examples of "lifetime" records include design reports, drawings, procedures and inspection reports. "Nonpermanent" records are those records that show evidence of an activity being performed but do not meet the criteria for "lifetime" records. Examples of "nonpermanent" records include document transmittal forms and surveillance reports. "Nonpermanent" record retention times are defined within Holtec International quality assurance program documents.

Holtec International quality assurance program documents establish measures to ensure quality assurance records are properly controlled from receipt through long term storage. Responsibilities for receipt, storage, retrieval and disposal of quality assurance records are provided within Holtec International quality assurance program documents. Records are required to be indexed so that they are readily retrievable.

Holtec International quality assurance program documents define storage requirements in order to assure quality assurance records are not damaged or destroyed. Quality assurance records are required to be stored in boxes, cabinets or shelves and shall be protected from such conditions as water, fire, etc. Measures are established through Holtec International quality assurance documents to ensure records requiring special storage requirements are stored properly. Quality assurance record storage areas are required by Holtec International quality assurance program documents to have controlled access. In the case where a quality assurance record is damaged or lost, it is required to be replaced immediately in a controlled manner by responsible personnel.

18. Audits

Holtec International quality assurance program documents define a comprehensive audit program including independence of the auditors from the area being audited, audit schedule requirements, identification of auditors and their required qualifications, access provisions for audit personnel, documentation requirements, methods for reporting audit findings, and methods for corrective actions and follow-ups.

Holtec International quality assurance program documents require that schedules be defined for internal and external audits. Audit plans are required to be written for each audit and shall define the key activities or areas to be audited.

Audits are performed in accordance with written procedures and/or checklists. Audits are performed in order to provide a comprehensive independent verification and evaluation of procedures and activities affecting quality, and to verify and evaluate a suppliers QA program, procedures, and activities. As appropriate, audit teams may contain members who are technical experts in the areas being audited. Holtec International internal audits are required to be performed annually and shall review all aspects of Holtec International's quality assurance program in order to determine the effectiveness of the program. External audits are performed per criterion 7 and shall evaluate all applicable and Holtec International relevant portions of the vendor's quality assurance program.

Holtec International quality assurance program documents establish qualification requirements for auditors including lead auditors. Additionally, responsibilities of audit personnel regarding the performance of the audit as well as the follow-up documentation (i.e., audit report, findings etc.) are defined within the same documents.

The Holtec International quality assurance program documents establish requirements for the performance of pre- and post- audit conferences. The pre-audit conference is used to define the scope of the audit as well as the specific areas to be audited, and define a schedule and agenda for the audit. The post-audit conference is used to discuss the results of the audit with the audited party.

Holtec International quality assurance program documents establish measures for writing of audit reports and provide instructions for the processing of findings and their corresponding corrective actions. Corrective action responses are required to clearly state the corrective action taken to correct the nonconforming condition and date of implementation. Audit reports shall be transmitted to responsible personnel at the audited organization for review and implementation of corrective actions, when required. Reports of internal audits shall be transmitted to the president of Holtec International.

Holtec International quality assurance program documents require that the audit team verify that corrective action responses are made in a timely manner, that the corrective action responses are adequate, and that corrective actions have been properly implemented.

13.5 REGULATORY COMPLIANCE

The structure of the Holtec International organization and the assignment of responsibilities for each activity ensures that the designated responsible parties will perform the necessary work to achieve and maintain the quality requirements specified in the HQAM. Conformance to established requirements will be verified by individuals and groups not directly responsible for the performance of the work. The QA Manager, who directly reports to the Executive Vice President of Holtec International, has been designated as the party responsible for verifying quality, and he has the required authority and organizational freedom, including independence from influence of cost and schedule, to effectively complete his responsibilities. The QA Manager can also communicate directly to the President of Holtec International regarding quality assurance activities.

The Holtec International Quality Assurance Program is documented in the HQAM, HQPs and project specific procedures, and provides adequate control over activities affecting quality, as well as structures, systems, and components that are important to safety, to the extent consistent with their relative importance to safety. The QA program describes a management system and controls, that when properly implemented, will comply with the requirements of Subpart G to 10CFR Part 72 and 10CFR Part 21 [13.3.2].

All design analyses and engineering documentation for the thermal, structural, confinement, criticality, shielding, and operational capabilities of the HI-STAR 100 System for normal, off-normal and postulated accident conditions are carried out in accordance with the 18 criteria in the HQAM. In addition, those activities and items designated as important to safety and related to the material specification and procurement for the HI-STAR overpack and MPC canister, as well as the HI-STAR 100 lifting equipment, are subject to Holtec QA program procedures. Governing procedures include those for procurement document control, control of purchased items and services, material handling, and instructions and drawings which control material requirements.

Further, the fabrication, testing and inspection of the HI-STAR 100 System by Holtec International and its subcontractors will be conducted in accordance with all QA program requirements, including those activities and project procedures addressed by the 18 criteria, especially those covering design control, identification, and control of materials, parts and components, test control, inspection procedures, control of special processes, control of measuring and test equipment, and inspection and test status documentation.

The operation, maintenance, repair and modification of the HI-STAR 100 System will be governed by the licensee's (e.g., utility) QA program with support and record maintenance as required by Holtec's QA program and regulatory requirements. These activities will be verified and audited on a periodic basis with respect to control of nonconforming materials, parts or components, corrective action, quality assurance records, audits, and reviews of ongoing inspections, surveillances, and operating status.

In conclusion, the Holtec International QA Program complies with the applicable NRC regulations and industry standards, and will be implemented for the HI-STAR 100 dry cask storage system.

13.6 REFERENCES

[13.1.1] NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety," February 1996.

[13.1.2] Holtec International Quality Assurance Program Topical Report for 10CFR71, Subpart H and 10CFR72, Subpart G, Holtec International Report HI-941152, Rev. 2 (8/4/94).

[13.1.3] NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," January 1997.

[13.3.1] NQA-1, "Quality Assurance Program Requirements for Nuclear Facilities"

[13.3.2] U.S. Code of Federal Regulations, Title 10, "Energy", Part 21, "Reporting of Defects and Noncompliance."

APPENDIX 13.A

~~DOCUMENT QA VERIFICATION FORM~~

DESIGN VERIFICATION CHECKLIST

APPENDIX 13.A CONTAINS A TOTAL OF ~~7~~ *10* PAGES, INCLUDING THIS PAGE

DESIGN VERIFICATION CHECKLIST

DOCUMENT I.D.

		Rev. 0			Rev. 1			Rev. 2			Rev. 3			Rev. 4			Rev. 5			Rev. 6		
		A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR
A.	**GENERAL (Complete Section A for all document types.)**																					
A.1	Is the individual a discipline expert?																					
A.2*	Confirm that your work on this project had not led to discovery of an error which may affect other projects.																					
A.3	Confirm that your workscope for this document has not led to a finding which may warrant Part 21 action?																					
A.4	Would you undertake to inform the Project Manager in writing if any change in a sister document of which you become aware would affect this document?																					
A.5‡	Have the author and principal reviewer accumulated more than ten QIPs in this census period? †																					
A.6	Have the author and reviewers consulted the Project Plan (latest issue) to acquaint themselves of the design basis?																					
A.7	Have you compared the results in this work product to similar work products in a previous project?																					
A.8	Are all computer codes utilized in the work validated within the company's QA System?																					
A.9	Have alternate calculations been carried out and reported within this document?																					

* Inform the QA Manager and Project Manager in writing within three working days, if the answer is non-affirmative.

‡ Personnel with greater than ten QIPs in any one year are not qualified to perform a safety-related function with Holtec's QA System.

LEGEND: Y: YES N: NO I: INAPPLICABLE U: UNKNOWN

DOCUMENT NO.

		Rev. 0			Rev. 1			Rev. 2			Rev. 3			Rev. 4			Rev. 5			Rev. 6		
		A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR
A.10	Have alternate calculations been carried out and filed elsewhere (if yes, denote the location and document portion covered). ( )																					
A.11	Are the computer code(s) used in this work product appropriate for this application?																					
A.12	Does this work product use input data?																					
	A.12.1 From other reports?																					
	A.12.2 From drawings?																					
	A.12.3 From the Technical Specification?																					
A.13	Have you filed any evidence of review (e.g., marked text) of this work product in the Review Folder?																					
A.14	Is the purpose (or Scope) of this work product clearly articulated?																					
A.15	Have you accounted for applicable lessons learned relevant to past similar work products?																					
A.16	Do you take complete technical "ownership" of the work product, i.e., no misgivings?																					
A.17	Have you consulted all applicable USNRC Information Notices relevant to this work product?																					
B.	**ASSUMPTIONS AND INPUTS (Complete Section B for Calculation Packages and Computer Code Validation Reports only.)**																					
B.1	Are assumptions necessary to perform the design or analysis adequately described and reasonable?																					

LEGEND: Y: YES N: NO I: INAPPLICABLE U: UNKNOWN

DOCUMENT I.D.

		Rev. 0			Rev. 1			Rev. 2			Rev. 3			Rev. 4			Rev. 5			Rev. 6		
		A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR
B.2	Where necessary, are the assumptions identified for subsequent reverification when the detailed design or analysis activities are completed?																					
B.3	Are the inputs into the design or analysis adequately stated and their source documented?																					
B.4	Is the input information from the latest appropriate revision of the source document?																					
B.5	Is the status (preliminary, conceptual, etc.) of the input source identified for later confirmation of the validity of the input?																					
B.6	Have you confirmed that all input data is taken from valid sources (e.g., Design Specification, client correspondence, or a robust recognized reference)?																					
B.7	Have you verified that input data are taken correctly?																					
B.8	Are all input Ids listed to enable future retrieval? (for Calculation Packages only)																					
B.9	Is the computer environment identified? (for Calculation Packages only)																					
B.10	Have all computer files generated in the course of preparation of this document, but not used in this document, deleted from our computer system? (Failure to do so will cause a mandatory two QIRs.)																					
C.	**DESIGN OR ANALYSIS REQUIREMENTS (Complete Section C for Calculation Packages, Licensing Reports, and Technical Reports only.)**																					
C.1	Are the applicable codes, standards, and regulatory requirements (including issue and addenda) properly identified or referenced?																					

LEGEND: Y: YES N: NO I: INAPPLICABLE U: UNKNOWN

DESIGN VERIFICATION CHECKLIST

DOCUMENT I.D.

		Rev. 0			Rev. 1			Rev. 2			Rev. 3			Rev. 4			Rev. 5			Rev. 6		
		A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR
C.2	Are the acceptance criteria incorporated in the design or analysis documents sufficient to allow verification that design or analysis requirements have been satisfactorily accomplished?																					
D.	**METHOD OF DESIGN OR ANALYSIS (Complete Section D for Calculation Packages only.)**																					
D.1	Is the method used appropriate considering the purpose and type of design or analysis and the use and acceptability of the results (i.e., margin to limits)?																					
D.2	Is the method in accordance with applicable codes, standards, and regulatory requirements?																					
D.3	Has the method been employed elsewhere in industry or in license applications?																					
D.4	Are the numerical methods selected appropriate for the system being analyzed?																					
D.5	Is the level of discretization adequate for a "converged" solution?																					
D.6	Are the boundary conditions appropriate for the problem being analyzed?																					
D.7	Are there any error notices issued by the code developer(s) which may pertain to this problem?																					
E.	**COMPUTER CODES (Complete Section E for Calculation Packages only.)**																					
E.1	Are codes identified along with source, and the program, subroutines, libraries, inputs, and outputs listed?																					
E.2	Is the code suitable for the present analysis? Does the computer model (coding, time steps, etc.) adequately represent the physical systems?																					

LEGEND: Y: YES N: NO I: INAPPLICABLE U: UNKNOWN

DESIGN VERIFICATION CHECKLIST

DOCUMENT I.D.

		Rev. 0			Rev. 1			Rev. 2			Rev. 3			Rev. 4			Rev. 5			Rev. 6		
		A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR
E.3	Are all computer codes used in the report appropriately referenced?																					
E.4	Are all computer output file IDs provided for future retrieval?																					
F.	**DESIGN OUTPUT (Complete Section F for Calculation Packages and Computer Code Validation reports only.)**																					
F.1	Is the output data from this report clearly defined for use in subsequent reports, if required?																					
F.2	Is the magnitude of all results reasonable?																					
F.3	Is the trend direction reasonable?																					
F.4	Did you confirm validity of outputs by careful scrutiny of calculations and results?																					
G.	**COMPUTER CODE VALIDATION (Complete Section G for Computer Code Validation reports only.)**																					
G.1	Is the method used for validating the computer code reasonable?																					
G.2	Is the method of validation through comparison to classical problems/solutions?																					
G.3	Is the method of validation by comparison with other computer program results?																					
G.4	Is the method of validation by comparison to experimental data?																					
G.5	Are the test cases sufficiently representative of the end-use of the program (both in quantity of test problems and types of test problems)?																					
G.6	Do the results of the validation confirm the working acceptability of the code?																					
H.	**MISCELLANEOUS ITEMS (Complete Section H for all reports which contain design work.)**																					

LEGEND: Y: YES N: NO I: INAPPLICABLE U: UNKNOWN

DESIGN VERIFICATION CHECKLIST

DOCUMENT I.D.

		Rev. 0			Rev. 1			Rev. 2			Rev. 3			Rev. 4			Rev. 5			Rev. 6		
		A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR
H.1	Have adequate maintenance features and requirements been specified?																					
H.2	Are accessibility and other design provisions adequate for performance of needed maintenance and repair?																					
H.3	Has adequate accessibility been provided to perform the in-service inspection expected to be required during the plant life?																					
H.4	Are adequate identification requirements specified?																					
H.5	Are the specified parts, equipment, and processes suitable for the required application?																					
H.6	Have the design interface requirements been satisfied?																					
H.7	Are the specified materials compatible with each other and the environmental conditions to which the material will be exposed?																					
H.8	Has the design properly considered radiation exposure to the public and plant personnel?																					

I.	THIS SECTION TO BE FILLED IN BY THE PROJECT MANAGER OR DESIGNEE							
I.1	Have you confirmed that this document does not contain information which is at variance with data in the sister document?							
I.2	Will this document be distributed to clients (client deliverables)?							
I.3	Will this document be sent to the NRC?							
I.4	May this document be referenced in an NRC SER?							
I.5	Does this document provide support material for an NRC SER?							

LEGEND: Y: YES N: NO I: INAPPLICABLE U: UNKNOWN

DESIGN VERIFICATION CHECKLIST

DOCUMENT I.D.

		Rev. 0			Rev. 1			Rev. 2			Rev. 3			Rev. 4			Rev. 5			Rev. 6		
		A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR
I.6	Are there multiple authors for this document (i.e., multiple checklists)?																					
I.7	Are all assigned authors and reviewers qualified under the company's Personnel Certification Program?																					
I.8	Has the work product of a similar nature been produced previously by Holtec personnel?																					
I.9	Will a sister document (such as a Calculation Package) be prepared which contains additional analysis information on this item?																					
I.10	Will such sister document be subject to Design Verification and validation?																					
I.11	Has qualification testing in support of the technical work product (or any portion thereof) been performed?																					
I.12	Do results of this work become input data for others?																					
I.13	If this document is to be submitted outside the company, do you understand that it must be submitted with a Document Transmittal Form?																					
J.	**THIS SECTION TO BE FILLED IN BY THE QA MANAGER**																					
J.1	Are you a member of the QA Organization?																					
J.2	Have the author and reviewer signed off on the "Review and Certification" log?																					
J.3	Is a "Table of Contents" included?																					
J.4	Does the report identify the project number and unique report number?																					
J.5	Is a purpose identified?																					
J.6	Are assumptions identified and are they classified and/or justified?																					
J.7	Is a "Summary of Revisions" included or does the revised pages contain revision bars?																					

LEGEND: Y: YES N: NO I: INAPPLICABLE U: UNKNOWN

DOCUMENT I.D.

		Rev. 0			Rev. 1			Rev. 2			Rev. 3			Rev. 4			Rev. 5			Rev. 6		
		A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR
J.8	Are all pages in the report numbered?																					
J.9	Is the total number of pages for appendices, attachments, or supplements indicated or do these pages indicate the report number?																					
J.10	Is the identity of each page in the main body report identifiable, such that a missing page is recognizable?																					
J.11	Are sources of all input data identified and are the input sources valid?																					
J.12	Is the QA and Administrative Information included?																					
J.13	Are all computer programs used in the report identified (program, version, computing environment) and QA validated in Holtec's program library?																					
J.14	Does the report contain a list of references?																					
J.15	Are applicable codes, standards, and technical references listed?																					
J.16	Have the technical requirements/criteria been documented, if applicable?																					
J.17	Have the quality assurance requirements been documented, if applicable?																					
J.18	Are the requirements of the software documented?†																					
J.19	Is the design of software documented (technical description)?†																					
J.20	Does the design provide for at least two test cases to validate the program and are the acceptance criteria documented?†																					
J.21	Is the implementation phase documented and does it include the program code?†																					

† Fill out only for computer code development and validation reports.

LEGEND: Y: YES N: NO I: INAPPLICABLE U: UNKNOWN

DESIGN VERIFICATION CHECKLIST

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		A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR	A	PR	SR
J.22	Has a user manual/user instructions been prepared?†																					
J.23	Has the testing phase been performed and the results of the test cases documented?†																					
J.24	Has the installation and checkout phase been documented?†																					
J.25	Has the operations and maintenance phase been documented?†																					
J.26	Has the retirement of the program been documented, if applicable?†																					
J.27	Has each phase of the relevant software life cycle been signed by the preparer and reviewer?†																					

USE THIS SPACE FOR ADDITIONAL COMMENTS (DISCLOSE YOUR INITIALS AND DATE)

INITIALS __________ DATE __________

INITIALS __________ DATE __________

INITIALS __________ DATE __________

† Fill out only for computer code development and validation reports.

LEGEND: Y: YES N: NO I: INAPPLICABLE U: UNKNOWN