72-01030

TRANSNUCLEAR

E-22051
March 7,2005

Ms. Mary Jane Ross-Lee
Spent Fuel Project Office, NMSS
U. S. Nuclear Regulatory Commission
11555 Rockville Pike M/S 0-6-F-18
Rockville, MD 20852

Subject: RAI Response for the NUHOMS® HD Storage System Docket No. 72-01030.
(TAC No. L23738)

Reference: RAI Response, TN letter E-21995

Dear Ms. Ross-Lee:

Subsequent to the referenced submittal, an error in our response to question 3-16 was discovered during verification. Our response to question 3-16 and the appropriate SAR pages have been revised to correct the erroneous information previously submitted. Please find enclosed the revised response for question 3-16 and the revised SAR pages for Appendix 3.9.3. Additionally revised SAR pages for Chapter 4 are enclosed which provide corrected temperatures for the un-finned heat shield configuration. Seven copies of the revised SAR pages are provided and marked as Revision 2A.

Per your request, also enclosed is TN's proprietary calculation 10494-87, rev 0. This is the confirmation calculation for the effective thermal conductivity within the neutron shield calculation utilizing the FLUENT CFD code, referenced in our response to RAI question 4-4. A CD containing input/output information for the calculation is also included.

This submittal includes proprietary information. In accordance with 10 CFR 2.390, an affidavit is enclosed for withholding the proprietary information from public disclosure.

If you have any questions, please contact me.

Sincerely,

Michael Mason

Michael Mason
Chief Engineer

Enclosures: as stated above

NMSS01

FOUR SKYLINE DRIVE, HAWTHORNE, NEW YORK 10532
Phone: 914-347-2345 • Fax: 914-347-2346 • E-mail: TRANSNCLR@AOL.COM

AFFIDAVIT

STATE OF NEW YORK }
}
}
}
COUNTY OF WESTCHESTER }

Before me, the undersigned authority, personally appeared Alan Hanson who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Transnuclear, Inc. and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Alan S. Hanson

ALAN HANSON

Sworn to and subscribed
Before me this 4 day
of March, 2005.

ANNE MARIE CLEARY
Notary Public, State of New York
No. 01CL6001814
Qualified in Westchester County
Commission Expires Jan. 26, 2006

(1) I am President of Transnuclear, Inc. and my responsibilities include reviewing the proprietary information sought to be withheld from public disclosure in connection with the licensing of spent fuel transport cask systems or spent fuel storage cask systems. I am authorized to apply for its withholding on behalf of Transnuclear, Inc.

(2) I am making this Affidavit in conformance with the provisions of 10CFR Section 2.390 of the commission's regulations and in conjunction with the Transnuclear application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Transnuclear in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) The following information is furnished pursuant to the provisions of paragraph 10CFR 2.390(b)(4) to determine whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Transnuclear.

(ii) The information is of a type customarily held in confidence by Transnuclear, is not customarily disclosed to the public and is transmitted to the commission in confidence.

(iii) The information sought to be protected is not now available in public sources to the best of our knowledge and belief and the release of such information might result in a loss of competitive advantage as follows:

(a) It reveals the distinguishing aspects of a storage system where prevention of its use by any of Transnuclear's competitors without license from Transnuclear constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a component or material, the application of which secures a competitive economic or technical advantage.

(c) Its use 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 a similar product.

(5) The information is being transmitted to the commission in confidence and, under the provision of 10CFR Section 2.390, it is to be received in confidence by the Commission.

(6) The information sought to be protected is not available in public sources to the best of our knowledge and belief.

(7) The proprietary information sought to be withheld is information referenced in our response to the RAI for the NUHOMS® -32PTH HD System. Specifically, Transnuclear calculation 10494-87 with attached CD

(8) This information should be held in confidence because it provides details of design calculations that were developed at significant expense. This information has substantial commercial value to Transnuclear in connecting with competition with other vendors for contracts.

The subject information could only be duplicated by competitors if they were to invest time and effort equivalent to that invested by Transnuclear provided they have the requisite talent and experience.

Public disclosure of this information is likely to cause substantial harm to the competitive position of Transnuclear, because it would simplify design and evaluation tasks without requiring a commensurate investment of time and effort.

3-16 Provide a brittle fracture analysis to evaluate the fracture toughness of the transfer cask bolts,

The statement concerning brittle fracture is not a concern because all the components comprising the transfer cask are all stainless steel, is not a true statement. As stated in 3.1.1.3 of the SAR, non-stainless steel members include the carbon steel closure bolts. The SAR does not have any supporting analysis or evaluation to demonstrate that these bolts will not fracture while in-service.

Response:

The transfer cask and its attachment bolts are designed and fabricated per ASME Subsection NC Code [3-16]. The fracture toughness requirements for the bolting material are specified in Section NC-2332.3. This section indicates that in order to meet the fracture toughness requirements, a Charpy V-notch test shall be performed. The test shall be performed at or below the Lowest Service Metal Temperature, and all three specimens shall meet the requirements of Table NC-2332.3-1. The size of lid bolt is 1.5" diameter, based on Table NC-2332.3-1 the required C_v value is 25 mils (lateral expansions).

In addition to the above Charpy V-notch test, a brittle fracture evaluation is performed to demonstrate that the brittle fracture is not a concern for the lid bolts.

The lid bolts are fabricated from SA-540 Gr. B24 Cl. 1 and have the following material properties:

Material Grade	Yield Strength, ksi (Room Temperature)	Ultimate Tensile Strength, ksi (Room Temperature)
SA-540 Gr. B24 Cl. 1	150	165

In accordance with the ASME Code, Section II, Part A [3-17], the bar stocks of these materials are quenched and fully tempered (1000 – 1100°F or higher) to produce a strong and tough microstructure.

ASM Metal Handbook (Volume 1) [3-18], Figure 26 (reproduced here in Figure 3-40) shows that a 4340 steel tempered at 1035°F for 1 ½ hours to produce a yield strength of 158 ksi exhibits a very low Charpy impact transition temperature (< -20°F) and an upper shelf energy of about 45 ft-lbs at –20°F.

Figure 31 (reproduced here in Figure 3-41) shows that a medium carbon low alloy steel tempered to a yield strength of 107 ksi (like SA-193, Grade B7) would have an upper shelf energy of about 52 ft-lbs and absorb about 48 ft-lbs at –20°F while material at a yield strength of 149 ksi (like SA-540 Gr. B24 Cl. 1) would have an upper shelf energy of 35 ft-lbs and absorb about 30 ft-lbs at –20°F.

The following table summarizes the equivalent impact energy of the SA-540 Gr. B24 Cl. 1 at –20°F and the Charpy values used for the brittle fracture evaluation performed as part of this submittal.

Material Grade	Yield Strength (ksi)	Charpy Value, -20°F (Ft-lbs)	Charpy Value Used for Brittle Fracture Evaluation (Ft-lbs)
4340 Steel Tempered at 1035°F for 1 ½ Hours (Fig. 3-40)	158	45	
Medium-Carbon Low Alloy (Fig. 3-41)	149	30	
SA-540 Gr. B24 Cl. 1	150		20**

** By comparaison with the similar yield strength materials, lower values are conservatively used for SA-540 Gr. B24 Cl.1 brittle fracture evaluations.

Brittle fracture evaluations of the lid bolt is performed based on a service temperature of –20°F. The work includes the following:

- Methodology
- Stress
- Material fracture toughness
- Fracture toughness criteria
- Allowable flaw calculations
- NDE Inspection Plan

Methodology

The allowable flaw size is calculated using the Singular Integral Equation and Asymptotic Approximation [3-19] (see Figure 3-42). The total applied stress intensity $K_{applied}$ is calculated based on the following equations.

$\sigma_{net} = P/(\pi\ a^2)$

$K_{applied} = \sigma_{net}\ (\pi\ a)^{1/2}\ F_1(a/b)$ (see Figure 3-42 for definitions)

Stress

The maximum tensile stress for the lid bolt is 106.6 ksi and is calculated in Appendix 3.9.3 Section 3.9.3.5 (page 3.9.3-13). The maximum net tensile stress is calculated based on 0.025" deep 360° circumferential crack.

$\sigma_{net} = 106.6\ [1.5/(1.5\text{-}2 \times 0.025)]^2 = 114.08$ ksi

Material Fracture Toughness

The Charpy impact value may be transformed into a fracture toughness value by using the empirical relation developed in Section 4.2 of NUREG/CR-1815 [3-20] as follows:

$K_{id} = [5E(C_v)]^{1/2}$

Where

K_{id} = Dynamic Fracture Toughness, psi -(in)$^{1/2}$
E = Modulus of Elasticity, 26.7 × 10^6 psi
C_v = Charpy Impact Value, 20 ft-lbs

Substituting the values given above,

$K_{id} = [5E(C_v)]^{1/2} = [5 \times 26.7 \times 10^6 (20)]^{1/2} = 51{,}672$ psi-in$^{1/2}$

Fracture Toughness Criteria

Using the method described in the ASME Code, Section XI, IWB-3613 [3-21], the limiting fracture toughness values are reduced by a factor of √2 for the accident condition and are calculated as follows:

$K_{allowable} \leq 51{,}672/\sqrt{2} = 36.54$ ksi-√in

Allowable Flaw Size Calculation

Using the above load definitions, fracture toughness values and assumed flaw size (0.025"), the total applied stress intensity K_1 (applied) is calculated based on the Singular Integral Equation and Asymptotic Approximation (see Figure 3-42).

$K_{applied} = \sigma_{net} (\pi a)^{1/2} F_1(a/b)$

2b = 1.5"   b = 0.75"

2a =1.5" -2 x 0.025" = 1.45"   a = 0.725"

a/b = 0.725/0.75 = 0.97 F_1 (a/b) = 0.18

$K_{applied} = 114.08 (\pi \times 0.725)^{1/2} (0.18) = 30.99$ ksi-√in ≤ 36.54 ksi-√in

NDE Inspection Plan

The results of the fracture toughness analysis shows that the critical flaws in the attachment bolts which would result in unstable crack growth or brittle fracture are larger than those generally observed in the bolt and bar stock.

The allowable flaw size for the attachment bolts is 0.025 in. The attachment bolts are fabricated per ASME Subsection NC code and only visual inspection is required by this code. In order to detect the surface indication, a PT or MT will be performed using NB code paragraph NB-2583.3. The requirement is that any linear nonaxial indications are unacceptable and therefore assuming 0.025" deep 360° circumferential crack for brittle fracture evaluation is conservative. The liquid penetrant or magnetic particle method will be in accordance with Section V, Article 6 of ASME Code [3-22].

References

3-16 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NC, 1998, including 2000 Addendum.

3-17 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section II, Part A, 1998, including 2000 Addendum.

3-18 American Society for Metals (ASM) Metal Handbook (Volume 1).

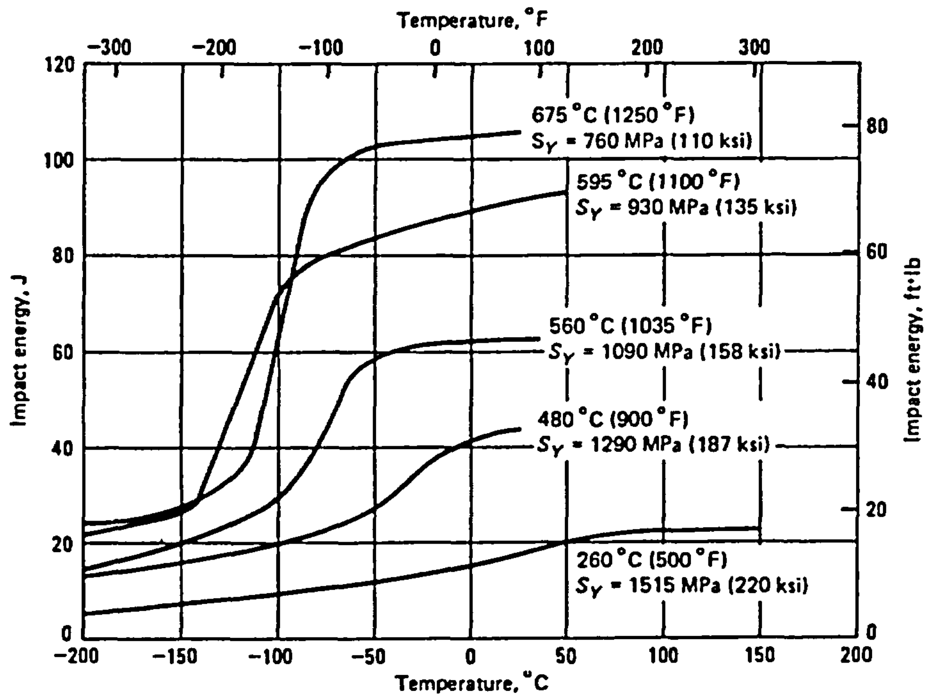
3-19 Singular Integral Equation (Bueckner) and Asymptotic Approximation (Benthem)

3-20 NUREG/CR-1815 "Recommendation for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Up to Four Inches Thick" Liwrence Livermore National Laboratory, June 15, 1981.

3-21 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section XI, 1989.

3-22 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section V, Article 6.

Fig. 26 Effect of tempering temperature on notch toughness

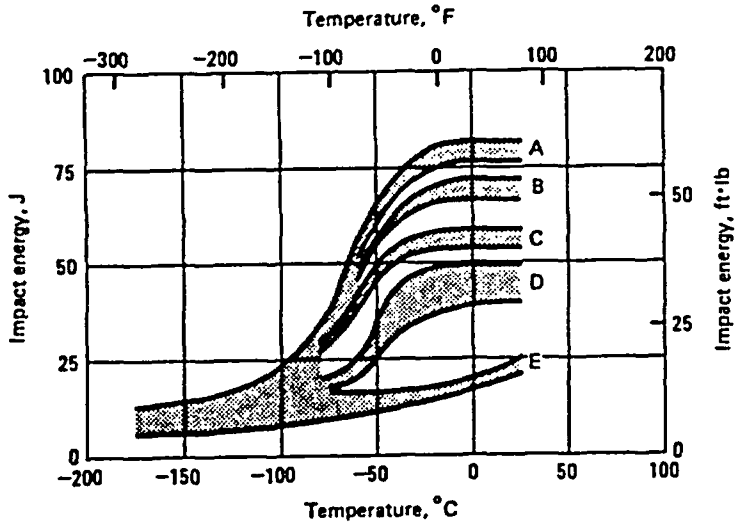


Variation of Charpy V-notch impact energy with temperature for various tempering temperatures. Specimens of 4340 steel were tempered 1.5 hr at the indicated temperatures. Yield strength obtained through each heat treatment also indicated. (Ref 15)

Figure 3-40

Effect of Tempering Temperature on Notch Toughness

Fig. 31 Correlation between notch toughness and yield strength

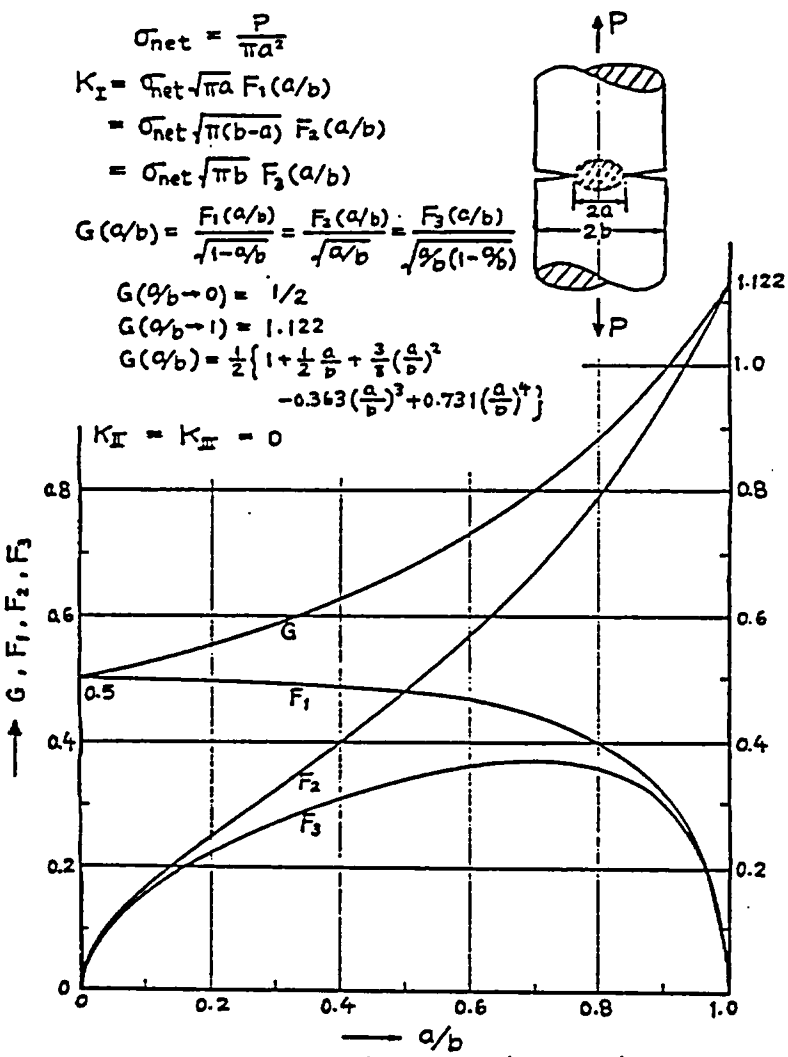


Yield strength	A	B	C	D	E
MPa	650	740	890	1025	1220
ksi	94	107	129	149	177

Variation in Charpy V-notch impact energy with temperature for a medium-carbon low-alloy steel tempered to various strength levels.

Figure 3-41

Correlation Between Notch Toughness and Yield Strength



$$\sigma_{net} = \frac{P}{\pi a^2}$$

$$K_I = \sigma_{net}\sqrt{\pi a}\,F_1(a/b) = \sigma_{net}\sqrt{\pi(b-a)}\,F_2(a/b) = \sigma_{net}\sqrt{\pi b}\,F_3(a/b)$$

$$G(a/b) = \frac{F_1(a/b)}{\sqrt{1-a/b}} = \frac{F_2(a/b)}{\sqrt{a/b}} = \frac{F_3(a/b)}{\sqrt{a/b(1-a/b)}}$$

$$G(a/b \to 0) = 1/2$$

$$G(a/b \to 1) = 1.122$$

$$G(a/b) = \frac{1}{2}\left\{1 + \frac{1}{2}\frac{a}{b} + \frac{3}{8}\left(\frac{a}{b}\right)^2 - 0.363\left(\frac{a}{b}\right)^3 + 0.731\left(\frac{a}{b}\right)^4\right\}$$

$$K_{II} = K_{III} = 0$$

Method: Singular Integral Equation (Bueckner), Asymptotic Approximation (Benthem)

Accuracy: Better than 1%

Referencees: Bueckner 1965, 1972, Benthem 1972

Other References: Lubahn 1959, Wundt 1959, Irwin 1961, Paris 1965, Zann 1965, Harris 1967

Figure 3-42

Singular Integral Equation and Asymptotic Approximation for Brittle Fracture Evaluation

3.9.3.12 Brittle Fracture Analysis of Top Cover Bolt

The transfer cask and its attachment bolts are designed and fabricated per ASME Subsection NC Code [6]. The fracture toughness requirements for the bolting material are specified in Section NC-2332.3. This section indicates that in order to meet the fracture toughness requirements, a Charpy V-notch test shall be performed. The test shall be performed at or below the Lowest Service Metal Temperature, and all three specimens shall meet the requirements of Table NC-2332.3-1. The size of lid bolt is 1.5" diameter, based on Table NC-2332.3-1 the required C_v value is 25 mils (lateral expansions).

In addition to the above Charpy V-notch test, a brittle fracture evaluation is performed to demonstrate that the brittle fracture is not a concern for the lid bolts.

The lid bolt is fabricated from SA-540 Gr. B24 Cl. 1 and has the following material properties.

Material Grade	Yield Strength, ksi (Room Temperature)	Ultimate Tensile Strength, ksi (Room Temperature)
SA-540 Gr. B24 Cl. 1	150	165

In accordance with the ASME Code, Section II, Part A [7], the bar stocks of these materials are quenched and fully tempered (1000 – 1100°F or higher) to produce a strong and tough microstructure.

ASM Metal Handbook (Volume 1) [8], Figure 26 (reproduced here in Figure 3.9.3-1) shows that a 4340 steel tempered at 1035°F for 1 ½ hours to produce a yield strength of 158 ksi exhibits a very low Charpy impact transition temperature (< -20°F) and an upper shelf energy of about 45 ft-lbs at –20°F.

Figure 31 (reproduced here in Figure 3.9.3-2) shows that a medium carbon low alloy steel tempered to a yield strength of 107 ksi (like SA-193, Grade B7) would have an upper shelf energy of about 52 ft-lbs and absorb about 48 ft-lbs at –20°F while material at a yield strength of 149 ksi (like SA-540 Gr. B24 Cl. 1) would have an upper shelf energy of 35 ft-lbs and absorb about 30 ft-lbs at –20°F.

The following table summarizes the equivalent impact energy of the SA-540 Gr. B24 Cl. 1 at –20°F and the Charpy values used for the brittle fracture evaluation.

Summary of the Equivalent Impact Energy

Material Grade	Yield Strength (ksi)	Charpy Value, -20°F (Ft-lbs)	Charpy Value Used for Brittle Fracture Evaluation (Ft-lbs)
4340 Steel Tempered at 1035°F for 1 ½ Hours (Fig. 3.9.3-1)	158	45	
Medium-Carbon Low Alloy (Fig. 3.9.3-2)	149	30	
SA-540 Gr. B24 Cl. 1	150		20**

** By comparison with the similar yield strength materials, lower values are conservatively used for SA-540 Gr. B24 Cl.1 brittle fracture evaluations.

A brittle fracture evaluation of the lid bolt is performed based on a service temperature of –20°F. The work includes the following:

- Methodology
- Stress
- Material fracture toughness
- Fracture toughness criteria
- Allowable flaw calculations
- NDE Inspection Plan

Methodology

The allowable flaw sizes were performed using the Singular Integral Equation and Asymptotic Approximation [9] (see Figure 3.9.3-3). The total applied stress intensity $K_{applied}$ is calculated based on the following equations.

$\sigma_{net} = P/(\pi\, a^2)$

$K_{applied} = \sigma_{net}\, (\pi\, a)^{1/2}\, F_1(a/b)$ (see Figure 3.9.3-3 for definitions)

Stress

The maximum tensile stress for the lid bolt is 106.6 ksi and is calculated in Appendix 3.9.3 Section 3.9.3.5 (page 3.9.3-13). The maximum net tensile stress is calculated based on 0.025" deep 360° circumferential crack.

$\sigma_{net} = 106.6\, [1.5/(1.5\text{-}2\text{x}0.025)]^2 = 114.08$ ksi

Material Fracture Toughness

The Charpy impact value may be transformed into a fracture toughness value by using the empirical relation developed in Section 4.2 of NUREG/CR-1815 [10] as follows:

$K_{id} = [5E(C_v)]^{1/2}$

Where

K_{id} = Dynamic Fracture Toughness, psi -(in)$^{1/2}$
E = Modulus of Elasticity, 26.7×10^6 psi
C_v = Charpy Impact Value, 20 ft-lbs

Substituting the values given above,

$K_{id} = [5E(C_v)]^{1/2} = [5 \times 26.7 \times 10^6 (20)]^{1/2} = 51{,}672$ psi-in$^{1/2}$

Fracture Toughness Criteria

Using the method described in the ASME Code, Section XI, IWB-3613 [11], the limiting fracture toughness values are reduced by a factor of $\sqrt{2}$ for the accident condition and are calculated as follows:

$K_{allowable} \leq 51{,}672/\sqrt{2} = 36.54$ ksi-$\sqrt{in}$

Allowable Flaw Size Calculation

Using the above load definitions, fracture toughness values and assumed flaw size (0.025"), the total applied stress intensity K_I (applied) is calculated based on the Singular Integral Equation and Asymptotic Approximation (see Figure 3.9.3-3).

$K_{applied} = \sigma_{net} (\pi a)^{1/2} F_I(a/b)$

2b = 1.5" b = 0.75"

2a =1.5" - 2 x 0.025" = 1.45" a = 0.725"

a/b = 0.725/0.75 = 0.97 F_I (a/b) = 0.18

$K_{applied} = 114.08 (\pi \times 0.725)^{1/2} (0.18) = 30.99$ ksi-$\sqrt{in} \leq 36.54$ ksi-$\sqrt{in}$

NDE Inspection Plan

The results of the fracture toughness analysis show that the critical flaws in the attachment bolts which would result in unstable crack growth or brittle fracture are larger than those generally observed in the bolt and bar stock.

The allowable flaw size for the attachment bolts is 0.025 in. The attachment bolts are fabricated per ASME Subsection NC code and only visual inspection is required by this code. In order to detect the surface indication, a PT or MT will be performed using NB code paragraph NB-2583.3. The requirement is that any linear nonaxial indications are unacceptable and therefore assuming 0.025" deep 360° circumferential crack for brittle fracture evaluation is conservative.

The liquid penetrant or magnetic particle method will be used in accordance with Section V, Article 6 of ASME Code [12].

3.9.3.13 Conclusions

1. Top cover and RAM access cover bolt stresses meet the acceptance criteria of NUREG/CR-6007 "Stress Analysis of Closure Bolts for Shipping Casks" [1].
2. The top cover and RAM cover bolt, insert, and flange thread engagement length is acceptable.

3.9.3.14 References

1. Stress Analysis of Closure Bolts for Shipping Cask, NUREG/CR-6007, 1992.
2. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section II, Part D, 1998 with 2000 addenda.
3. Helicoil Catalog, Heli-Coil 8-Pitch Inserts, Bulletin 913B.
4. Machinery Handbook, 21st Ed, Industrial Press, 1979.
5. Baumeister, T., Marks, L. S., *Standard Handbook for Mechanical Engineers*, 7th Edition, McGraw-Hill, 1967.
6. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NC, 1998, including 2000 Addendum.
7. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section II, Part A, 1998, including 2000 Addendum.
8. American Society for Metals (ASM) Metal Handbook (Volume 1).
9. Singular Integral Equation (Bueckner) and Asymptotic Approximation (Benthem)
10. NUREG/CR-1815 "Recommendation for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Up to Four Inches Thick" Liwrence Livermore National Laboratory, June 15, 1981.
11. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section XI, 1989.
12. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section V, Article 6.

The maximum component temperatures calculated using conservative assumptions are lower than the allowable limits. The maximum TC seal temperature (255°F / 124°C) during off-normal transfer conditions is well below the 400°F long-term limit specified for continued seal function. The maximum solid neutron shield temperature (265°F / 129°C) is below allowable limit of 300°F (149°C) and no degradation of the solid neutron shielding material is expected. The maximum pressure within the neutron shielding panel (38.5 psia / 23.8 psig) corresponding to the average temperature of the liquid neutron shield (265°F / 129°C) is below the set point of the pressure relief valve (54.7 psia / 40 psig).

For all the side heat shield configurations, the maximum local temperature of the HSM-H concrete structure is lower than 300°F as required in [22]. The concrete structure of the HSM-H is made using Type II cement with fine aggregates satisfying ASTM C33 or equivalents as defined in NUREG-1536 [22].

The calculated maximum fuel cladding temperature is lower than the temperature limit of 752°F (400°C) considered for normal conditions of storage and short-term operations in [2]. The comparison of the resultant maximum temperatures with the allowable limits is listed below:

Component	Transfer Conditions [1]	Allowable / Design Limit
Cask Lid Seal	205°F	400°F
Cask Bottom Plate Seal	190°F	400°F
Lead	337°F	621°F
Liquid Neutron Shield (Temp / Press)	265°F / 23.8 psig	45 psig
Solid Neutron Shield	213°F	300°F
Fuel Cladding	723°F	752°F

Component	Storage Conditions [6]	Allowable / Design Limit
Concrete in module with finned aluminum side heat shields @ 34.8 kW	213°F	300°F
Concrete in module with un-finned aluminum side heat shields @ 32.0 kW	219°F	300°F
Concrete in module with un-finned galvanized steel side heat shields @ 26.1 kW	213°F	300°F
Fuel Cladding @ 34.8 kW	684°F	752°F for normal conditions / 1058°F for off-normal conditions

The maximum DSC internal pressures for normal and off-normal storage conditions are 5.9 and 10.7 psig respectively. The maximum DSC internal pressure for normal transfer conditions is 6.4 psig and for off-normal transfer conditions is 11.2 psig. The DSC internal pressures are lower than the design pressure limits of 15 psig for normal and 20 psig for off-normal storage and transfer conditions.

[1] The TC and HSM-H models are run only with off-normal conditions at 115°F ambient. The resultant temperatures are used to evaluate the thermal performance for both normal and off-normal conditions. The fuel cladding temperature remains in all cases below the normal allowable limit of 752°F.

4.4 Thermal Evaluation for Accident Conditions

Three hypothetical accident cases during transfer operation are relevant for thermal evaluation:

- Loss of the TC liquid neutron shield due to damages on the shielding panel
- Loss of helium gas in annulus between the DSC and the TC
- Postulated fire engulfing the TC

It is considered in all the above cases that the transfer cask contains a fully loaded DSC. The fire accident is postulated in which maximum amount of 300 gallons of diesel fuel is spilled onto the ground in such a way as to completely engulf the transfer cask. Subsequent to the fire accident, it is assumed that the seals for the TC lid and the bottom cover plate will burn, and the liquid neutron shield will be released and evaporates completely. Therefore, the fire accident scenario bounds the loss of liquid neutron shield and the loss of helium gas in the accident cases. The fire accident case is analyzed to give the bounding fuel cladding temperature for the transfer accident cases.

Since the HSM-H is located outdoors, there is a remote probability that the air inlet and outlet openings will become blocked by snow or by debris from events such as flooding, high wind, and tornados. The perimeter security fence around ISFSI and the location of the air inlet and outlet openings reduces the probability of such an event. Nevertheless, it is conservatively considered in this analysis that all the inlet and outlet openings become blocked.

The thermal mass of the HSM-H, the construction of the vent openings, and the location of the fuel on the transfer vehicle limit the effect of a fire accident for the HSM-H. Therefore, the worst case fire accident is bounded by the fire accident case during transfer operation.

A new model is developed to evaluate the fire accident case during transfer operation. The HSM-H model described in Section 4.3 is slightly modified to evaluate the blocked vent accident case during storage. The DSC model is unchanged for this evaluation. Details of the models are discussed in section 4.4.1.

4.4.1 Thermal Models for Accident Conditions

4.4.1.1 Transient Transfer Cask Model

To determine the temperature distribution in the transfer cask and the DSC for fire accident case, a three dimensional model is developed using ANSYS [16]. This model is created by selecting the nodes and elements of the DSC model described in Section 4.3 at z-axis from 56.06" to 86.07". The shells of TC including the annulus are then modeled around the DSC using SOLID70 elements. LINK31 elements are created using the same methodology as described in Section 4.3.1.1 to simulate the radiation between the DSC shell and the TC inner shell. The three dimensional model represents a slice of the DSC within the transfer cask. The TC slice model is shown in Figure 4-26. Axial length of the slice model is 30".

Table 4-2
Maximum Component Temperatures for Storage Conditions at 115°F ambient

HSM-H with Finned Aluminum Side Heat Shields		
Component	**Maximum Temperature @ 34.8 kW (°F)**	**Allowable Max. Temp. (°F)**
Fuel cladding	684*	752 [2] †
Fuel compartment	656	
Basket Al plates	655	
Basket rails	511	
DSC shell	407	
Concrete structure	213	300 ‡
Top heat shield	199	
Side heat shield	188	
DSC supporting structure	268	

	Un-finned Aluminum Side Heat Shields @ 32.0 kW	Un-finned Galvanized Steel Side Heat Shields @ 26.1 kW	
Component	**Maximum Temperature (°F)**	**Maximum Temperature (°F)**	**Allowable Max. Temp. (°F)**
Fuel cladding	§	§	752 [2]
DSC shell	394	368	
Concrete structure	219	213	300
Top heat shield	196	186	
Side heat shield	241	190	
DSC supporting structure	264	247	

* The fuel cladding temperature is calculated based on bounding DSC shell temperatures with the maximum temperature of 422°F.

† The ambient temperature of 115°F is the maximum off-normal temperature. Based on reference [2], maximum allowable fuel cladding temperature is 1058°F (570°C) for off-normal storage conditions and 752°F (400°C) for normal storage conditions. The maximum fuel cladding temperatures in Table 4-2 are all below 752°F.

‡ The cement type and concrete aggregates satisfy the guidelines in NUREG 1536, Section V.2 [22]

§ Bounded by 34.8 kW case in the upper part of the table

HSM-H with
Un-finned Aluminum Side Heat Shield
32.0 kW

HSM-H with
Un-finned Galvanized Steel Side Heat
Shield, 26.1 kW

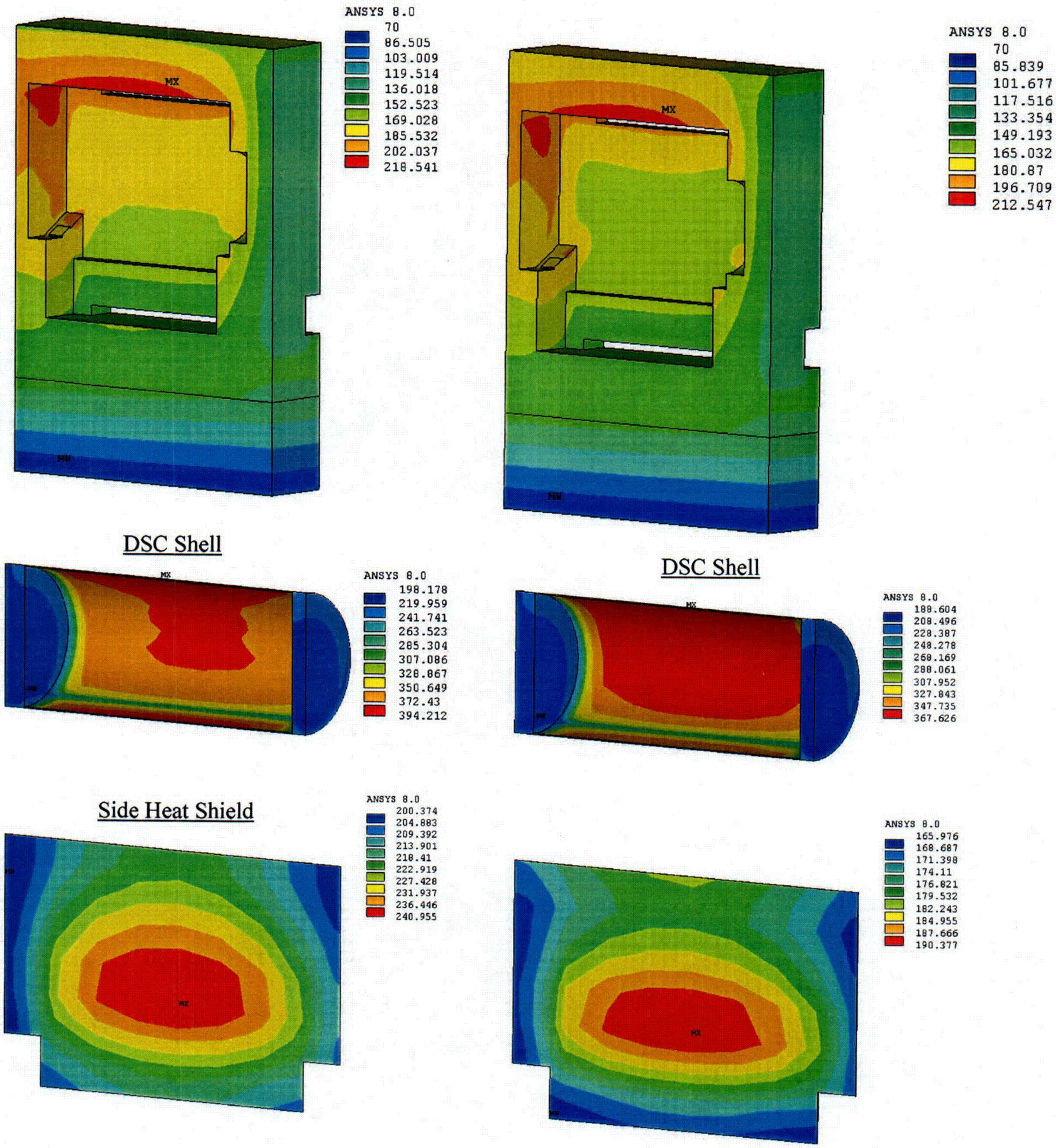


Figure 4-22
HSM-H Temperature Distribution 115°F Ambient
with Un-finned Side Heat Shields

C01