TRANSNUCLEAR

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Approach for Response to TN-40 Transport Application RAI
July 2, 2008

Transnuclear, Inc.

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Enclosure 3

Meeting Agenda

- Introduction
- Discussion of Approach
- Structural RAIs
- Thermal RAIs
- Schedule for Responses to RAIs
- Questions

Introduction

- TN's Proposed Approach to RAI Responses for TN-40 Transport Application will be Discussed in Two Meetings with NRC
  - All RAIs except Nuclear (Criticality and Shielding) Analysis RAIs will be discussed today
  - Nuclear Analysis RAIs will be discussed in a meeting tentatively scheduled with the staff on July 16^{th} 2008
- Only Significant RAIs Requiring Discussion of Our Proposed Approach with the Staff are Included in These Meetings

Application for Prairie Island Nuclear Generating Plant Fuel Only

- *Current Application is for 14X14 Unconsolidated Intact PWR Fuel*
- *To Expedite NRC Approval, Only Prairie Island Specific Fuel Will be Allowed*

Discussion of Trunnion Load Test RAIs

- *RAIs 1-4, 2-4, 8-1*
  - *1-4 Request for test to be 3 times design load per ANSI N14.6*
  - *2-4 Add NUREG-0612 as a source of requirements*
  - *8-1 Request for testing at 3 times design load*

Discussion of Trunnion Load Test RAIs

- *Part 71 Transport License to apply only to Prairie Island fuel*
- *Testing issue addressed in RAI raised by the NRC in 1995*
- *The NSP response states:*

  1) ANSI N14.6 does not apply to spent fuel cask trunnions which are permanently attached to the cask,

  2) Permanently attached cask trunnions are not "special lifting devices", and

  3) NUREG-0612 governs the design of the cask trunnions.
- *An issue is the applicability of ANSI N14.6 as defined in Section 1.3 of N14.6.*

  1.3 This standard shall apply to special lifting devices that transmit the load from lifting attachments, which are structural parts of the container, to the hook(s) of the overhead hoisting system.

Discussion of Trunnion Load Test RAIs

- *Trunnions of the TN-40 casks are the lifting attachments and they are a structural part of the container*
- *The NRC concluded during the RAI response in 1995 that the 150% load testing of the trunnions is sufficient.*
- *Therefore the TN-40 cask trunnions are not designed and tested to the requirements of ANSI N14.6.*
- *They are designed to the requirements of NUREG-0612 and load tested to 150% as stated the SAR.*

Discussion of ADOC and Scale Test RAIs

- RAIs 2-7, 2-9, 2-27, 2-28, 2-30, 3-13
  - 2-7 Provide overview of use of ADOC vs. test results
  - 2-9 Justify 20° slapdown angle as worst case
  - 2-27 Summary g-loads on page 2.10.7-11 should use 78g rather than 42g as shown
  - 2-28 Verify that the side-drop deceleration of 51 g is bounding
  - 2-30 Justify why the ADOC calculated transverse deceleration of 78g for the 20° slapdown is not used
  - 3-13 Demonstrate that the Impact Limiters remain firmly attached to the cask after 30 foot drop

Discussion of ADOC and Scale Test RAIs

- Design of Impact Limiter based on ADOC
  - Each drop orientation evaluated for maximum and minimum wood crush properties
  - A series of slapdown orientations used to select worst case
  - Dynamic Load Factors calculated to use with ADOC results
    - 42g mentioned in SAR part of this calculation
    - Value is not used in any TN-40 structural analysis. It will be deleted from the SAR

Discussion of ADOC and Scale Test RAIs

▶ Design of Impact Limiter based on ADOC (cont.)

Impact Angle 30 Foot Drop	Maximum g-Load Maximum Wood Properties			
	Axial	Transverse		
	C.G.	Second Impact	First Impact	C.G.
0°	4	51	50	51
5°	7	g_{nor} = 27 g_{rot} = 52	g_{nor} = 24 g_{rot} = 35	27
10°	10	g_{nor} = 27 g_{rot} = 51	g_{nor} = 27 g_{rot} = 39	27
15°	15	g_{nor} = 28 g_{rot} = 52	g_{nor} = 32 g_{rot} = 44	32
20°	**22**	**g_{nor} = 27 g_{rot} = 49**	**g_{nor} = 39 g_{rot} = 51**	**39**
30°	26	g_{nor} = 33 g_{rot} = 57	g_{nor} = 32 g_{rot} = 35	33
40°	21	3	39	18
45°	27	3	36	19
50°	29	8	25	17
60°	29	8	15	11
70°	38	8	12	10
63.8°	32	8	14	11
80°	44	4	7	5
90°	49	3	1	2

Discussion of ADOC and Scale Test RAIs

▶Design of Impact Limiter based on ADOC (cont.)

Impact Angle (degrees)	Max Force (kips)	Applied Moment (in. lb.)
15 (Primary Impact)	9629	8.18E+08
15 (Secondary Impact	7813	-7.28E+08
20 (Primary Impact)	**11846**	**1.00E+09**
20 (Secondary Impact)	**7526**	**-6.98E+08**
30 (Primary Impact)	11246	7.71E+08
30 (Secondary Impact)	9506	-8.08E+08

Discussion of ADOC and Scale Test RAIs

▶ *Design of Impact Limiter based on ADOC (cont.)*

20° Slapdown, First Impact

From ADOC Output:

Max. G Load at t = 0.048 sec.

Impact Force

at First Impact End = 11846 kips

Vertical G Load

at Impact End due to Impact Force

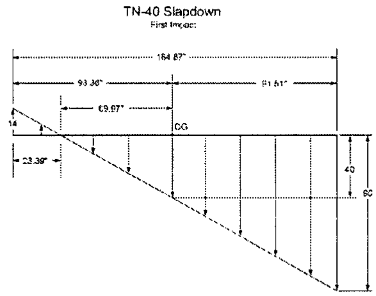
= 11846/272 = 43g

Transverse G Load (Normal to the Cask)

at Impact End = 43 x cos 20° = 40g

Maximum combined Transverse and Rotational G Load

at Impact End = 90g



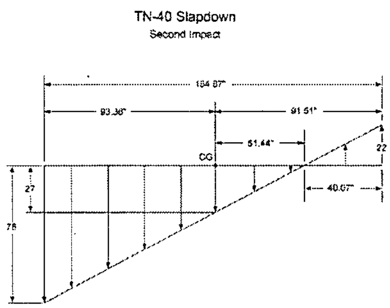
The transverse acceleration (40g) produces local impact loads

The rotational acceleration (50g) produces bending moment in the cask

Discussion of ADOC and Scale Test RAIs

▶ *Design of Impact Limiter based on ADOC (cont.)*

20° Slapdown, Second Impact



From ADOC Output:

Max. G Load at t = 0.155 sec.

Impact Force

at Second Impact End = 7526 kips

Transverse G Load

at Impact End due to Impact Force

= 7526/272 = 27g

Maximum Combined Transverse and Rotational G Load

at Impact End = 76g

The transverse acceleration (27g) produces local impact loads

The rotational acceleration (49g) produces bending moments in Cask

Discussion of ADOC and Scale Test RAIs

1/3 Scale Test Results

- Drop orientations included
  - Side
  - CG over Corner
  - Slapdown (@20° initial impact angle)
  - End
  - Pin Drop
- Impact limiters performed as designed
  - Minimal damage to limiter shell
  - Limiters remained attached, protecting the ends of the cask
- Measured accelerations slightly higher than predicted

Discussion of ADOC and Scale Test RAIs

1/3 Scale Test Results (continued)

30 foot Drop Orientation	*g* Load Measured by Drop Test	*g* Load Calculated by ADOC	Basket & Fuel Analysed Load	Cask Body · Limit Load
90° End Drop	57*g* Axial	49*g* Axial	75*g*	116*g*
0° Side Drop	57*g* Transverse	51*g* Transverse	75*g*	85*g*
CG Over Corner	34*g* Axial	32*g* Axial	Bounded by End and Side	48*g* Axial 21*g* Transverse
20° Slap Down	61*g* (1) (Transverse + Rotational)	27*g* Transverse 49*g* Rotational	Bounded by End and Side	68*g* Transverse 38*g* Axial + Rotational

Note:
(1) Measured g load did not separate the transverse g loads and rotational g loads.

Discussion of ADOC and Scale Test RAIs

- **Conclusion**
  - ADOC results in values that are valid for use in structural analyses
  - Basket and fuel analyses use side drop accelerations rather than the slap down accelerations
  - This is justified by noting that the rotational g-loads have a little effect on the basket (and thus the fuel rods) because the cask stiffness is greater than the basket stiffness
  - Cask body analyses include effect of rotational acceleration

Discussion of RAIs on Basket Fusion Welds

- RAIs 2-2, 2-12, and 2-22
  - Weld quality factors per code
  - Justification for the quality factors used

Discussion of RAIs on Basket Fusion Welds

- RAIs 2-2, 2-12, and 2-22 (continued)
  - Not a code weld, alternative to code are listed in SAR Section 2.11.
  - Qualified by testing.
  - Weld qualification procedure, including weld operators and equipment; three test specimens are prepared and tested to failure, and the acceptance criteria will be met on the basis of failure of the base metal prior to weld failure; the weld nugget at the bond line shall be free of defects and shall be at least 1/2" in diameter; three additional specimens will undergo sectioning and micro etching to determine depth of weld penetration.
  - Mechanical testing is performed to verify proper machine settings and operation prior to the start of each working shift. The acceptance is failure of the base metal prior to the failure of the weld area.
  - The welds are visually inspected afterwards to verify the normality of the weld zone.

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Discussion of RAIs on Basket Fusion Welds

- RAIs 2-2, 2-12, and 2-22 (continued)
  - The weakest portion of the weld joint is shown to be the base metal
  - Structural analyses show that the stresses in the base metal are below the appropriate ASME allowable
  - Basket integrity is maintained and the welds are qualified
  - Stress values for the welds will be removed from the SAR

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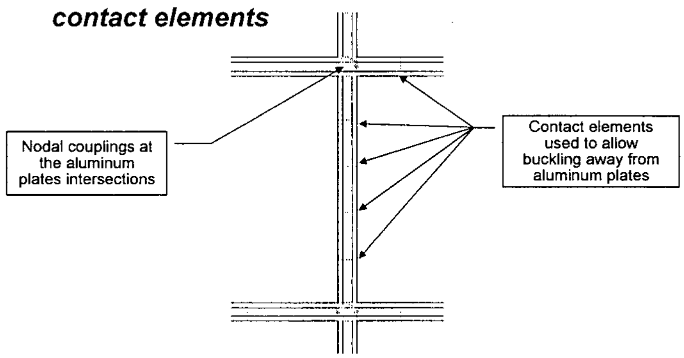
Discussion of RAIs on Basket Structural Analysis

- *RAIs 2-16, 2-17, 2-19 and 2-23*
  - *Justify nodal couplings don't result in unrealistically high flexural rigidity for the basket wall panel*
  - *Show nodal coupling at the aluminum plates intersection*
  - *Nodal couplings prevent the steel wall panel from buckling away from aluminum plates*
  - *Justify the safety factors of 1.18, 1.23 and 1.24*

Discussion of RAIs on Basket Structural Analysis

- *RAIs 2-16, 2-17, 2-19 and 2-23 (continued)*
  - *Sensitivity study of the buckling analyses was performed where nodal couplings were replaced by contact elements*



Discussion of RAIs on Basket Structural Analysis

Original Buckling Analysis with Couples

Basket Side Drop Orientation	Last Converged Load (g)	Actual Max. Load (g)	Factor of Safety
0°	145.44	75	1.94
30°	88.54	75	1.18
45°	92.54	75	1.23
60°	92.54	75	1.23
90°	115.15	75	1.54

Minimum Buckling Load of 88.54 g

Sensitivity Study of the Buckling Analysis with Contact

Basket Side Drop Orientation	Last Converged Load (g)
0°	95.2
30°	91.8
45°	97.6
90°	96.6

Minimum Buckling Load of 91.8 g

Min factor of safety – 88.54 / (57 x 1.1) = 1.41

-57g transverse acceleration from side drop test

-1.1 DLF calculated for the basket

Discussion of RAIs on Basket Structural Analysis

- *Factors of safety imbedded into ASME code for stainless steel vary from 1.41 to 2.21 (NUREG/CR-6322)*
- *Factors of safety are used to account for geometrical imperfection, residual stresses, load eccentricity and uncertainties related to the magnitude of the applied loads*
- *TN analyses model a full 360 degree sector of the basket with elastic-plastic material and large deflection effects*
- *TN analyses also use a conservative magnitude of the fuel weight*
- *Sensitivity study was also performed to evaluate the impact of geometrical imperfections*

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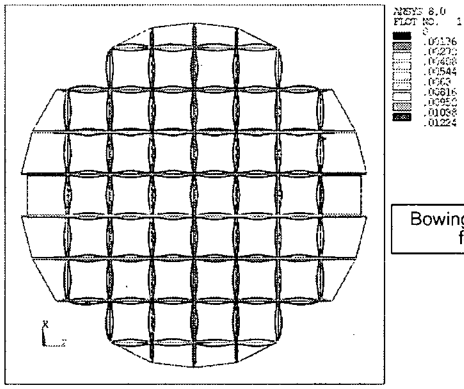
Discussion of RAIs on Basket Structural Analysis



Bowing exaggerated for affect

- Imperfections representing the first buckling mode are included
- 0 degree buckling analysis is performed
- Buckling load remained the same
- Current safety margins are sufficient

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Discussion of RAIs on Fuel Rod Cladding

- ***RAIs 2-24, 2-25, and 2-26***
  - ***High burn up material property has higher Young's modulus and yield strength than regular burn up***
  - ***Justify the assumption that fuel rods in contact with the end fitting are to result in the most damage to the fuel cladding***

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Discussion of RAIs on Fuel Rod Cladding

- ***RAIs 2-24, 2-25, and 2-26 (continued)***
  - ***Rerun the analysis with regular burn up material properties***
  - ***Sensitivity study was performed to investigate the impact of the gap between the fuel cladding and end fittings***
    - ***Regular burn up material properties were used***
    - ***The response curve from the TN40 test was used***
    - ***Gaps of 0.0 in, 0.04 in, 0.3 in, and 0.5 in were used***
    - ***Rod bow of 0.015 in was used instead of 0.071 in (consistent with NUREG-1864)***
    - ***The methodology was the same as presented in the SAR***

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Discussion of RAIs on Fuel Rod Cladding

Sensitivity Study of the Fuel Cladding to End Fitting Gap

Gap (in)	Max Strain (%)
0.0	1.2
0.04	1.1
0.3	0.9
0.5	0.8

Sensitivity study shows that assuming no gap between the fuel cladding and end fitting is the most damaging configuration

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Discussion of RAIs on Thermal Analysis

- *RAI 3-7 Flow Regimes Assumed in NCT Thermal Analysis and Convective Heat Transfer Boundary Condition Application in the Model.*
  - *The natural convection regime type (i.e. laminar or turbulent) is based on ambient and wall temperature difference reflected in Raleigh number Ra.*
  - *Correlations for Nusselt number cover both laminar and turbulent regimes with range of Ra number 10^{-10} <Ra<10^{7} for horizontal cylinder and 10^{-1}<Ra<10^{12} for vertical plates. Since these ranges cover both laminar and turbulent convection, no assumption of the flow regime is required for convection coefficient calculation.*
  - *The total heat transfer coefficients are defined as temperature dependent material property and applied to the cask and impact limiter outer surfaces in the model.*
  - *Clarification is included in the SAR section.*

Discussion of RAIs on Thermal Analysis

RAI 3-8 Discussion and Sensitivity Analysis of Gaps in the Model

- *The gap of 0.01" - 0.2" thickness considered in SAR are between:*
  weld plugs and stainless steel compartment,
  small aluminum rail and basket plate,
  small conduction plate of the large rail and basket plate,
  each adjacent plates,
  peripheral aluminum basket plates and inner shell,
  peripheral aluminum basket plates and inner shell (radial gap)
  axial gaps between cask and impact limiters.
- *Good contact is expected between adjacent basket components, but uniform gaps are included to bound contact uncertainty. Thermal resistance to the heat flow from fuel to the cask shell is lower with partial contact compared to the uniform gaps.*
- *No conductivity is considered for the Boral plate of 0.075" thickness compensating more than adequately expected fabrication tolerances.*

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Discussion of RAIs on Thermal Analysis

- The sensitivity study was performed to evaluate effect of doubling the largest gap between cask components.
- The results of the sensitivity study shows that maximum temperatures go up by negligible amount (~1°F).
- The gaps in the model are justified as conservative.

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RAI Response Schedule

- TN plans to submit the RAI response by the due date of July 28, 2008

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Questions