TREAT AS SENSITIVE INFORMATION

TRANSNUCLEAR

E-22383
May 20, 2005

Mr. Joseph M. Sebrosky
Spent Fuel Project Office, NMSS
U. S. Nuclear Regulatory Commission
11555 Rockville Pike M/S 0-6-F-18
Rockville, MD 20852

Subject: RAI 2 Response for the NUHOMS® HD Storage System Docket No. 72-01030. (TAC No. L23738)

Dear Mr. Sebrosky:

Please find enclosed Transnuclear's (TN) response to your Second Request for Additional Information (RAI) regarding the NUHOMS® HD Dry Storage System. Revised SAR pages have not been issued at this time. However, revised SAR pages will be submitted at a future date which appropriately incorporates the provided responses.

In addition to the responses to your RAIs, we are proposing a revision to SAR section 12.4.5 in the Technical Specifications. This proposed revision is based on the results of the thermal testing program performed by Transnuclear. The thermal test report was submitted and reviewed by the NRC under Amendment 8 to the standard NUHOMS® license 72-1004. As part of the testing program, different HSM-H heat shield configurations were utilized and the results indicate the fins on the side heat shield have a relatively minor effect on the thermal performance of the HSM/DSC and that there is significant safety margin and flexibility in the heat shield/HMS-H design. The revised section 12.4.5 is shown below.

12.4.5 *The HSM-H utilizes side heat shields to protect the HSM-H concrete surfaces and provide for enhanced heat transfer within the HSM-H. Three side heat shield configurations have been evaluated in the SAR: finned side heat shields, flat anodized aluminum plates and flat galvanized steel plates. Limits on the heat load of the DSC's shall be established for the heat shield material types and configuration used through testing or analysis.*

If you have any questions, please contact me.

Sincerely,

Michael Mason

Michael Mason
Chief Engineer

Enclosures: as stated above

NMSS01

REQUEST FOR ADDITIONAL INFORMATION
TRANSNUCLEAR, INC.
DOCKET NO. 72-1030

By application dated, May 5, 2004 as supplemented July 6 and October 28, 2004, Transnuclear, Inc. (TN) requested approval of the NUHOMS® HD Horizontal Modular Storage System. In a letter dated December 13, 2004, the staff sent you a request for additional Information (RAI) regarding this design. In letters dated February 18, 2005, and March 7, 2005, TN provided responses to the staff's RAI. The staff has reviewed your response and has determined that more information is needed in the structural area to assess compliance with 10 CFR Part 72. This request for additional information (RAI) identifies additional information needed by the U.S. Regulatory Commission (NRC) staff in connection with its review on the application. The requested information is listed by chapter number and title used in the applicant's safety analysis report (SAR). NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems (SRP)," was used by the staff in its review of the application.

Each individual RAI describes information needed by the staff for it to complete its review of the application and/or the SAR and to determine whether the applicant has demonstrated compliance with the regulatory requirements.

Chapter 2 Principal Design Criteria

2-6 (Related to First Round RAI 2-2)

Revise the technical specification and Chapter 2 of the SAR to include the definition of damaged fuel as defined in ISG-1, rev. 1.

The applicant's response (RAI response 2-2) is not consistent with the guidance in ISG-1, rev. 1 for damaged fuel. The applicant's definition of damaged fuel can be broader than that specified in the definition section of ISG-1, Rev. 1, but should as a minimum include those items listed in that section.

In accordance with 10 CFR 72.236(c), the spent fuel must be maintained subcritical under credible conditions. Further, 10 CFR 72.236(m) seeks to ensure safe fuel storage and handling and to minimize post-operational safety problems with respect to retrievability of the fuel from the storage system.

<u>Response</u>

The third paragraph in Section 2.1.1 will be revised as follows:

The 32PTH DSC can accommodate up to 16 structurally intact damaged fuel assemblies. A fuel assembly that is damaged in such a manner as to impair its structural integrity, has missing or displaced structural components such as grid spacers, or cannot be handled using normal handling methods can not be considered a candidate for storage in the 32 PTH DSC. Neither can fuel that is no longer in the form of an intact fuel bundle and consists of, or contains, debris such as loose fuel pellets, rod segments, etc.

Damaged fuel assemblies shall be placed into the sixteen inner most basket fuel compartments, as shown in Figure 2-2 of SAR, which contain top and bottom end caps that confine any loose material and gross fuel particles to a known, sub-critical volume during normal, off-normal and accident conditions and to facilitate handling and retrievability. Reactor records, visual/videotape records, fuel sipping, ultrasonic examination, and radio chemistry are examples of techniques utilized by utilities to identify damaged fuel.

The definition of damaged fuel in the Technical Specifications will be revised as follows:

DAMAGED FUEL- Spent nuclear fuel is considered damaged for storage or transportation purposes if it manifests any of the following conditions that result in either compromise of cladding confinement integrity or rearrangement (reconfiguration) of fuel bundle geometry: 1) The fuel contains known or suspected cladding defects greater than a pinhole leak or hairline crack that have the potential for release of significant amounts of fuel particles into the cask. 2) The fuel assembly a) has missing or displaced structural components such as grid spacers; b) Has missing or displaced structural components such as grid spacers ; c) is missing fuel pins which have not been replaced by dummy rods which displace a volume equal to or greater than the original fuel rod; d) cannot be handled using normal (i.e. crane and grapple) handling methods. (Exception: fuel assemblies with repaired lifting bails, support caps, or support tubes, etc., which permit normal handling may be classified as intact.) 3) The fuel is no longer in the form of an intact fuel bundle and consists of, or contains, debris such as loose fuel pellets, rod segments, etc. 4) The fuel assembly structural hardware or cladding material properties are in a degraded condition such that its ability to withstand the normal and design basis events of storage, or the normal and hypothetical accident conditions of transport as intact fuel is questionable.

STRUCTURALLY INTACT DAMAGED FUEL is DAMAGED FUEL that can be handled using normal handling methods. The extent of the damage is limited such that a fuel pellet is not able to pass through the damaged cladding during handling and retrievability is assured following normal and off-normal conditions. A fuel assembly that is damaged in such a manner as to impair its structural integrity, has missing structural components such as grid spacers, or cannot be handled using normal handling methods can not be considered a candidate for storage in the 32 PTH DSC. Neither can fuel that is no longer in the form of an intact fuel bundle and consists of, or contains, debris such as loose fuel pellets, rod segments, etc.

Chapter 3 Structural Evaluation

3-19 (Related to First Round RAI 3-13)

Provide analyses demonstrating that fuel rod cladding integrity is maintained for the drop scenarios evaluated in SAR Section 3.5.3.1 "Side Drop" and Appendix 3.9.8, Section 3.9.8.11.1 "Structural Integrity Evaluation." Analysis assumptions should be justified based on the physical and behavioral characteristics of the fuel rods in the assemblies. Cladding material properties should be consistent with high burnup fuel and include a thickness reduction due to oxidation.

First round RAI 3-13 requested justification for the fuel rod moment of inertia (MI) used in performing the side drop fuel rod structural integrity evaluation in Appendix 3.9.8, Section 3.9.8.11.1. Therein TN used a MI equal to ½ the MI of the cladding plus ½ the MI of the fuel. TN's response justified this approach by assuming composite behavior between the fuel and cladding based on physical conditions that exist during in-reactor operations that result in compressive radial stresses between the fuel and cladding. The staff found these in-reactor conditions to not be applicable to spent fuel in storage due to the significant difference in the pressure and temperature environments between in-reactor operation and storage conditions. (Essentially, in storage the fuel is in a highly fractured condition with little or no radical compression forces acting on the fuel.) It is also noted that in this first round response the applicant did not mention nor address the fact that for the drop analysis performed in Section 3.5.3.1 Table 3-12 the full MI of both the cladding and fuel was used.

After discussions with TN, the staff received a second analysis in an email dated March 25, 2005, (this second analysis is documented below) that did not rely on composite behavior between the fuel and cladding, and addresses both Appendix 3.9.8, Section 3.9.8.11.1 and Section 3.5.3.1 Part A of the second analysis addressed Appendix 3.9.8 – a one foot side drop load of 30g. This analysis treated the fuel rod as a continuous beam over multiple supports and considered the bending resistance (MI) of only the cladding. The staff found this approach acceptable. Part B of the second analysis addressed Section 3.5.3.1 Table 3-12 – a side drop load of 75g. For this analysis TN abandoned the approach used in Part A and instead pursued a displacement limited approach. TN assumed the fuel rod was not a continuous beam over multiple supports (the model that had been used in Part A), but rather assumed that it was a simply supported beam spanning between adjacent grid spacers – the most flexible condition possible – and imposed a displacement limit approximately equal to the maximum total gap between adjacent fuel rods plus the gap between the assembly and basket. Because of the simply supported beam assumption, the staff found the approach in Part B to be non conservative and inconsistent with actual fuel rod behavior during a side drop event and, therefore unacceptable.

This information is requested by the staff to assess compliance with 10 CFR 72.236 (b), (c), (d), (h) and (l).

<u>Response to Part B of RAI 3-13, dated March 25, 2005:</u>

Approach:

The 32PTH fuel rod cladding stresses were reevaluated for the cask 75g side drop. The structural evaluation of fuel rod cladding in this response differs from original evaluations in the following aspects:

Fuel Rod Cladding Stresses Analysis Comparisons

	Original Evaluation (SAR)	Evaluation in this Response
Support condition	Continuous support beam	Continuous support beam
Methodology	Hand calculation (calculated stress using an equal-span continuous beam formula with each span equals to the largest length of two grid supports)	Using ANSYS Model of one full length of fuel rod cladding as continuous beam (modeled all 1.5" wide grid supports at their actual locations)
Moment of inertia	$I_{total} = I_{cladding} + I_{fuel\ pellets}$	Only the fuel rod cladding is modeled, the density of modeled fuel rod cladding is increased to include the weight of fuel pellets
Weight (lb/in)	Total fuel assembly weight (1575#)/number of fuel rods /active fuel length (144")	Actual weight of fuel rod cladding, pellets, and end fittings is used

The fuel rod cladding thickness is reduced by 0.0027 in. to account for an assumed oxide thickness of 120 micron as discussed in 3-17 of response to RAI #1. The yield strength for the high burnup fuel at 725°F is 69,500 psi as discussed in 3-17 of response to RAI #1. However, Section 2.3 of UCID-21246, Dynamic Impact Effects on Spent Fuel Assemblies by Lawrence Livermore National Laboratory [1], indicates that for Zirconium type material, the yield strength will increase by 10,000 psi per each order of magnitude increase in strain rate, i.e., the yield strength of 69,500 psi would increase by 30,000 psi to 99,500 psi at a strain rate of about 0.5 in/in/sec which is typical of an accident drop as discussed in the above reference. Therefore, the yield strength of 99,500 psi is used as allowable stress for the accident drop conditions. All other parameters remain unchanged as indicated in the original analysis.

Finite Element Model:

An ANSYS [2] finite element model of the fuel rod is created for each fuel type, using PIPE16 elements. The finite element model geometry details and equivalent densities are computed in Table 1. The dimensions (lengths) of the fuel cladding for each fuel type are taken from reference [3]. The weight of fuel pellets is incorporated in cladding model by using equivalent densities. The weights of the top and bottom end fittings are distributed to the top and bottom spans of the fuel rod cladding models (Span L_T and Span L_B in Table 1). The typical finite element model and boundary conditions of fuel type WE15x15 are shown on Figure 1.

Analysis:

In an elastic analysis, 75g side drop load is applied as an acceleration. The maximum bending stresses for the fuel cladding from the ANSYS analyses are shown on Figures 2 to 6 and also summarized in Table 2.

Results:

Table 2 summarizes the maximum bending stresses from results of ANSYS 75g side drop analyses and axial stresses due to internal pressure. All the combined stresses are less than the yield strength of the cladding material (99,500 psi) with ample margin of safety.

3-20 Provide an analysis demonstrating that fuel cladding integrity is maintained for the end drop event evaluated in SAR Section 3.5.3.2. Analysis assumptions should be justified based on the physical and behavioral characteristics of the fuel rods (cladding and fuel) in the assemblies. Cladding material properties should be consistent with high burnup fuel and include a thickness reduction due to oxidation.

In Section 3.5.3.2 "End Drop" TN performed a static nonlinear ANSYS analysis of a simply supported fuel rod "column" with initial curvature loaded by an incrementally increasing axial force. Cladding and fuels were assumed to act as a composite (i.e., "fused with each other"). The cladding was given elastic-plastic properties and a tensile failure strain of 1.6%, while the fuel was given only elastic properties and no failure strain. Because the fuel has an elastic modulus more than twice that of the cladding and a solid cross-section, almost all of the lateral load resisting capacity ("buckling" strength) of the fuel rod, in the applicant's analysis, is provided by the fuel, not the cladding. The fuel is basically a coarse granular material with little tensile strength and therefore cannot be relied upon to resist tensile stress. This natural state of the fuel is not reflected in TN's analysis, which assumes that the fuel is a continuous solid with unlimited strength. The staff finds TN's analysis unacceptable.

This information is requested by the staff to assess compliance with 10 CFR 72.236 (b), (c), (d), (h), and (l).

Response:

The 75g fuel rod end drop analyses are reevaluated as follows:

<u>Fuel Rod Compressive Stress</u>

The compressive stresses in the fuel rod cladding of each fuel type are calculated by hand. The axial compressive stresses are calculated by assuming all the fuel assembly weight at 75g are taken by the fuel rod cladding only. Table 3 summarizes the axial compressive stresses for all fuel types. They are significantly less than the yield strength of 99,500 psi.

<u>Fuel Rod Buckling Analysis</u>

Another potential failure mode of fuel rod cladding during an end drop event is buckling of its sections between two grid supports. The lowest section, among all sections between grids, of each fuel rod cladding is most likely the first one to buckle for it carries the most weight from above. This lowest section of a fuel rod cladding is therefore analyzed for its critical buckling load. For each fuel rod type, the longest span of the fuel rod cladding between grids is modeled using ANSYS plastic PIPE20 elements. The maximum span between two grid supports in each fuel rod type is listed in Table 2. A force equal to the weight of an entire fuel assembly divided by the number of fuel rods in the assembly is applied to the top of the cladding. The fuel pellets inside the fuel cladding are not included in the ANSYS model; however, their weights are included in the load applied to the cladding.

The ANSYS large deformation option is used in the analysis. A ramped vertical inertial load is applied to the top of the ANSYS model. A small perturbation lateral load is applied at the mid point of the modeled cladding section to initiate a lateral deflection and to start buckling response of the fuel rod. Should the buckling of the fuel rod occur, the model becomes unstable and the ANSYS solution will not converge. The g load at the last converged sub-step solution in the ANSYS analysis is considered to be the critical axial buckling load.

The ANSYS model geometry and the applied load for each fuel rod type are listed in Table 4. A typical boundary condition and loading plot of the ANSYS buckling model are shown in Figure 7.

<u>Material Properties, High Burn Up Fuel Cladding (Zircaloy at 725°F)</u>

Yield Strength, S_y = 99,500 psi
Poisson Ratio, υ = 0.3
Young's Modulus, E = 10.6×10^6 psi
Tangent Modulus, E_T, is assumed to be 5% of Young's Modulus, E.
$E_T = 10.6 \times 0.05 \times 10^6$ psi $= 5.3 \times 10^5$ psi

Note: The stresses in the cladding at the buckling loads are reviewed and found to be below the cladding yield strength of 99,500 psi. In other words, the fuel cladding will buckle before it will yield.

The fuel gas pressure inside the fuel cladding, which helps resist buckling, is conservatively ignored in the analysis of the end drop event.

<u>Results</u>

Table 4 summarizes the parameters used in the end drop buckling analysis of all specified fuel cladding and the g loads at which ANSYS produced the last converged solution before buckling. The minimum critical buckling load for all the specified fuel claddings is calculated to be 88g for WE17X17OFA fuel rod. It is above the design drop load of 75g with a safety factor of 1.17

References:

1. UCID-21246 "Dynamic Impact Effects on Spent Fuel Assemblies" by Lawrence Livermore National Laboratory, October 20, 1987.

2. ANSYS User's Manual, Rev 6.0

3. DOE/ET/47912-3, Volume 3, September 1981, Nuclear Assurance Corporation, "Domestic Light Water Reactor Fuel Design Evolution".

Table 1
Input Data for Fuel Rod Cladding Side Drop ANSYS Runs

Item	WE 15x15	WE 17x17Std	17x17 MkBW	WE 17x17V5H	WE 17x17 OFA	CE 14x14 Std
Number of Supports(1)	7	8	8	8	8	8
Number Of Spans(1)	6	7	7	7	7	7
Total Length, L (in) (1)	152.152	151.635	151.635	151.635	151.635	147.174
Span L_1 (in) (1)	22.657	22.93	22.93	22.93	22.93	17.36
Span L_2 (in) (1)	24.69	19.05	19.05	19.05	19.05	17.36
Span L_3 (in) (1)	24.69	19.05	19.05	19.05	19.05	17.36
Span L_4 (in) (1)	24.69	19.05	19.05	19.05	19.05	17.36
Span L_5 (in) (1)	24.69	19.05	19.05	19.05	19.05	17.36
Span L_6 (in) (1)	17.46	18.95	18.95	18.95	18.95	17.36
Span L_7 (in) (1)	-	19.19	19.19	19.19	19.19	17.36
Span L_B (in) (1)	1.775	1.204	1.204	1.204	1.204	8.495
Span L_T (in) (1)	1.00	1.161	1.161	1.161	1.161	5.159
Cladding Tube, D_O (in)	0.4193	0.3713	0.3713	0.3713	0.3573	0.4373
Cladding Tube, $t_{(Corroded)}$ (in)	0.0216	0.0198	0.0213	0.0198	0.0198	0.0253
Cladding Tube, D_i (in)	0.3761	0.3317	0.3287	0.3317	0.3177	0.3867
Cladding Tube Volume, V_t (in^3/in)(2)	0.026987	0.02186	0.02342	0.02186	0.020994	0.032747
Tube Weight, w_1 (lb/in)(3)	0.006315	0.005116	0.00548	0.005116	0.004913	0.007663
Fuel Pellet, D (in)	0.3659	0.3225	0.3195	0.3225	0.3088	0.3765
Pellet Weight, w_2 (lb/in)(4)	0.040378	0.031368	0.030787	0.031368	0.028759	0.042751
(Tube+Pellet) w_s (lb/in)	0.046693	0.036484	0.036267	0.036484	0.033672	0.050414
Tube Eqv. Density, ρ_e (lb/in^3)(5)	1.730	1.669	1.549	1.669	1.604	1.540
Weight Bottom Fitting, W_B (lb)	12.566	12.566	12.566	12.566	12.566	12.566
Weight Top Fitting, W_T (lb)	17.416	18.012	18.012	18.012	18.012	18.012
$Tube_{Bot}$ Eqv. Density, ρ_B (lb/in^3)(6)	3.02	3.48	3.24	3.48	3.49	1.80
$Tube_{Top}$ Eqv. Density, ρ_T (lb/in^3)(7)	4.89	4.36	4.06	4.36	4.41	2.13

Notes:
(1) Number of supports and span lengths are taken from [3]. Support grids are 1.5 in. wide. See Figure 1 for individual span length definition
(2) $V_t = \pi/4[D_o^2 - D_i^2] \times 1.0$
(3) $w_1 = V_t \times \rho_{tube} = V_t \times 0.234$ lb/in
(4) $w_2 = \pi/4[D^2] \times 1.0 \times \rho_{Pellet} = \pi/4[D^2] \times 0.384$ lb/in
(5) $\rho_e = w_s / V_t$
(6) $\rho_B = [w_s + W_B/(\text{No. of tubes} \times L_B)] / V_t$
(7) $\rho_T = [w_s + W_T/(\text{No. of tubes} \times L_T)] / V_t$

Table 2
Maximum Fuel Rod Cladding Axial Stresses During 75g Side Drop

Fuel Assembly Type	WE15x15	WE 17x17std	17x17 MkBW	WE 17x17 Vantage5H	WE 17x17 OFA	CE 14× 14 Std
Fuel Cladding OD, D (in)	0.4193	0.3713	0.3713	0.3713	0.3573	0.4373
Clad Thick. (Corr.), t (in) (1)	0.0216	0.0198	0.0213	0.0198	0.0198	0.0253
Average Radius, R (in) (2)	0.1989	0.1758	0.1725	0.1758	0.1688	0.2060
Fuel Pallet OD, D_P (in) (1)	0.3659	0.3225	0.3195	0.3225	0.3088	0.3765
Number of Spans, N(8)	6	7	7	7	7	7
Max. Span Length (in)(8)	24.69	22.93	22.93	22.93	22.93	17.36
No. of Rods, N (1)	204	264	264	264	264	176
Cladding Tube Weight (lb/in)(3)	0.006315	0.005116	0.00548	0.005116	0.004913	0.007663
Fuel Pellet Weight (lb/in)(4)	0.040378	0.031368	0.030787	0.031368	0.028759	0.042751
W_S, [Tube + Pellet] (lb/in)	0.046693	0.036484	0.036267	0.036484	0.033672	0.050414
30 Foot Side Drop - Equivalent g load	75	75	75	75	75	75
Max. Bending Stress, S_b (psi) (5)	66,642	63,230	59,160	63,230	63,442	47,725
Internal Pressure, P (psi)	2,235	2,235	2,235	2,235	2,235	2,235
Pressure Axial Stress, $S_{press.}$(psi) (6)	10,289	9,921	9,183	9,921	9,525	9,100
$S_{Max} = S_b + S_{press.}$ (psi)	76,931	73,151	68,343	73,151	72,967	56,825
Allowable Stress, $S_{all} = S_y$ (psi)(7)	99,500	99,500	99,500	99,500	99,500	99,500
Factor of Safety, (S_y/ S_{Max})	1.29	1.36	1.46	1.36	1.36	1.75

Notes:
(1) Reduction of wall thickness by 0.0027 inch
(2) R = (D-t)/2
(3) Cladding Tube Weight = $[\pi / 4 \times (D^2 - (D - 2t)^2)] \times \rho_t = [\pi / 4 \times (D^2 - (D - 2t)^2)] \times 0.234$ lb/in.
(4) Fuel Pellet Weight = $[(\pi / 4) \times D_p^2] \times \rho_p = [(\pi / 4) \times D_p^2] \times 0.384$ lb/in.
(5) See Figures 2 to 6 for this response
(6) $S_{pressure} = (P \times R) / (2 \times t)$
(7) Yield strength of high burn up Zircaloy cladding tube at 725 °F
(8) From Table 1

Table 3
Fuel Rod Cladding Compressive Stresses During 75g End Drop

Fuel Assembly Type	WE15x15	WE 17x17Std	17x17 MkBW	WE 17x17 Vantage5H	WE 17x17OFA	CE 14x14 Std
Fuel Cladding OD, D (in)	0.4193	0.3713	0.3713	0.3713	0.3573	0.4373
Cladding Thick. t (in)	0.0216	0.0198	0.0213	0.0198	0.0198	0.0253
Fuel Assembly Wt. (lb) (One Fuel Assembly)	1,555	1,575	1,575	1,575	1,575	1,450
Fuel Cladding Area[(1)], in^2	0.0270	0.0219	0.0234	0.0219	0.0210	0.0327
End Drop g load	75	75	75	75	75	75
Force per Assembly At 75g (lb)	116,625	118,125	118,125	118,125	118,125	108,750
No of Rod per Assembly	204	264	264	264	264	176
Force on each Cladding, 75g (lb)	571.7	447.4	447.4	447.4	447.4	617.9
Axial Compressive Stress, S_{max} (psi)	21,174	20,431	19,120	20,431	21,305	18,896
Allowable Stress, S_y (psi)	99,500	99,500	99,500	99,500	99,500	99,500
Factor of Safety (S_y / S_{max})	4.7	4.87	5.20	4.87	4.67	5.27

Note:

(1) Area = $2\pi \times R \times t$, where R and t are from Table 2

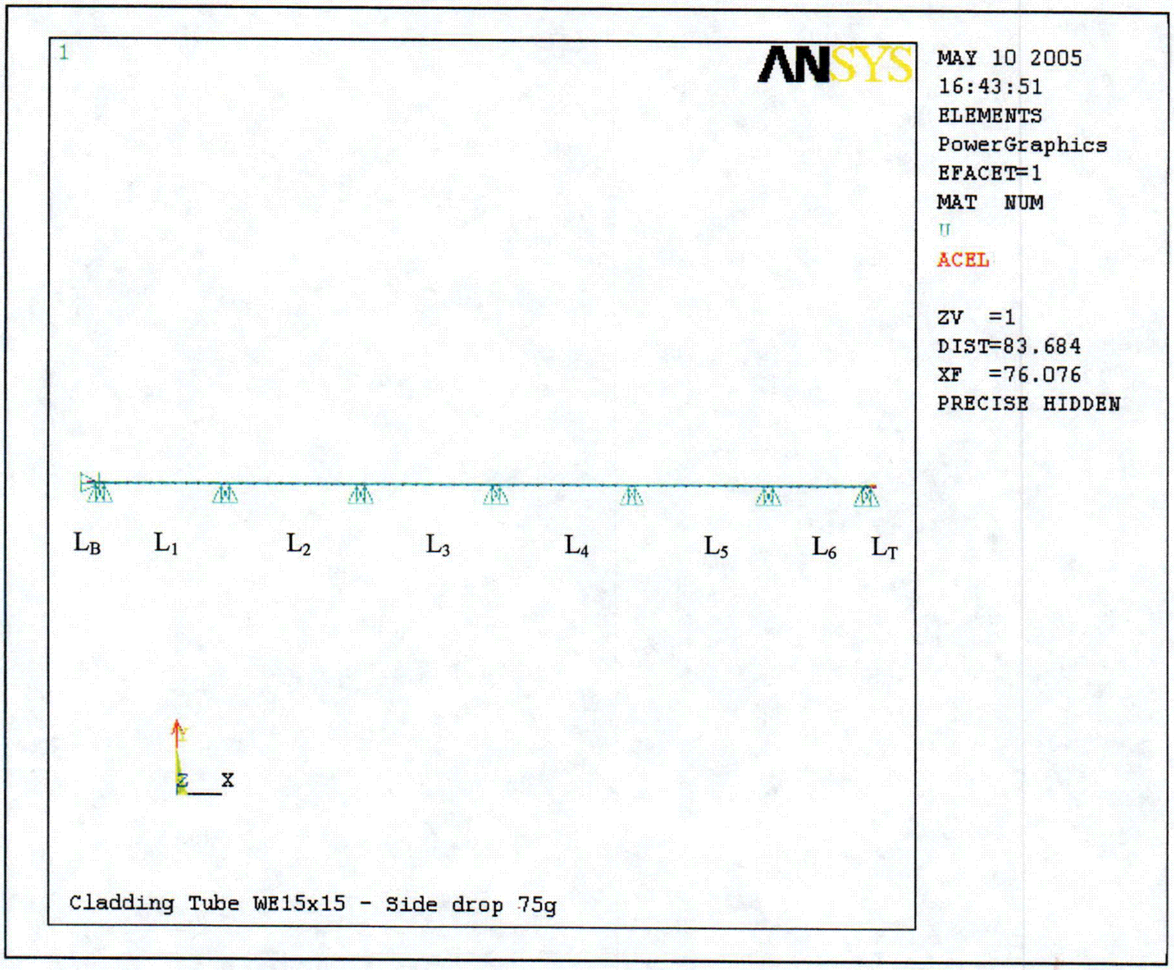
Table 4

Critical Buckling Loads for Fuel Rod Claddings During 75g End Drop

Fuel Assembly Type	WE15x15	WE 17x17std	17x17 MkBW	WE 17x17 Vantage5H	WE 17x17OFA	CE 14x14 std
Fuel Cladding OD (in)	0.4193	0.3713	0.3713	0.3713	0.3573	0.4373
Clad Thick. (in)	0.0216	0.0198	0.0213	0.0198	0.0198	0.0253
Max. Span between Grids (in)	24.69	22.93	22.93	22.93	22.93	17.36
Fuel Wt. per Assembly (lb)	1,555	1,575	1,575	1,575	1,575	1,450
No. of fuel rod per Assembly	204	264	264	264	264	176
rce per fuel rod (lb) , 0g	2286.8	1789.6	1789.6	1789.6	1789.6	2471.6
Critical Buckling Load (g)(1)	**103.75**	**99.25**	**105.5**	**99.25**	**88**	**>300**

Note:
(1) From ANSYS results

<u>Figure 1</u>
Finite Element Model and Boundary Conditions – WE 15x15



C01

Figure 2
Bending Stress – WE 15x15
(The bottom figure is an enlarged view of span)

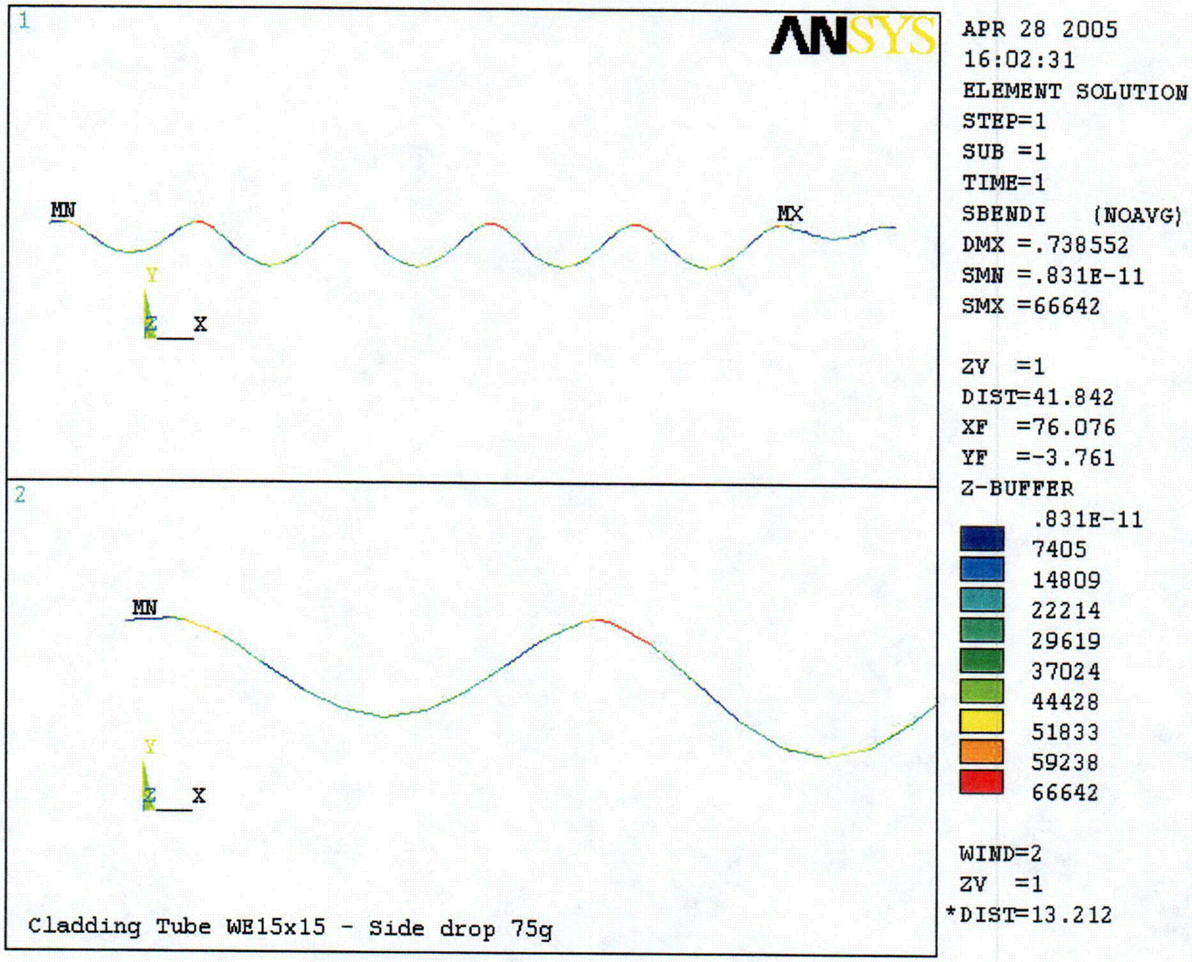


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Figure 3
Bending Stress – WE 17x17 Std and WE 17x17 Vantage 5H
(The bottom figure is an enlarged view of span)

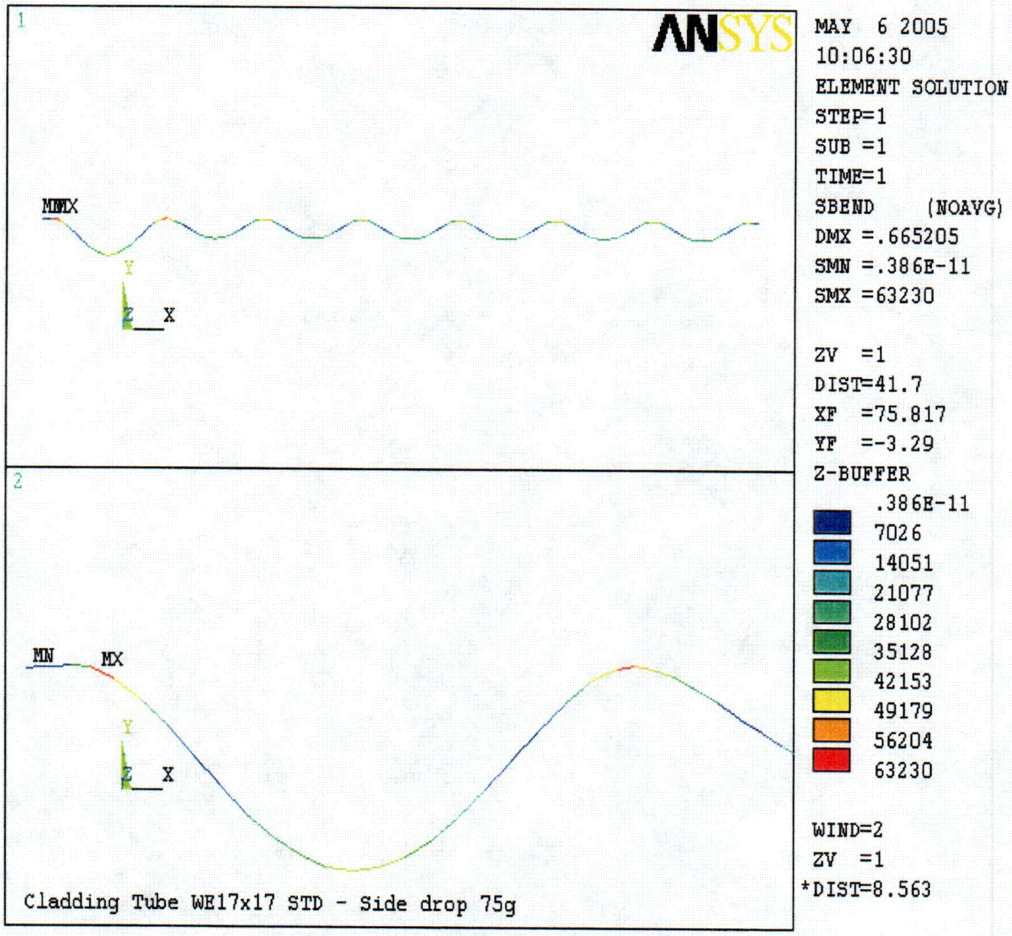

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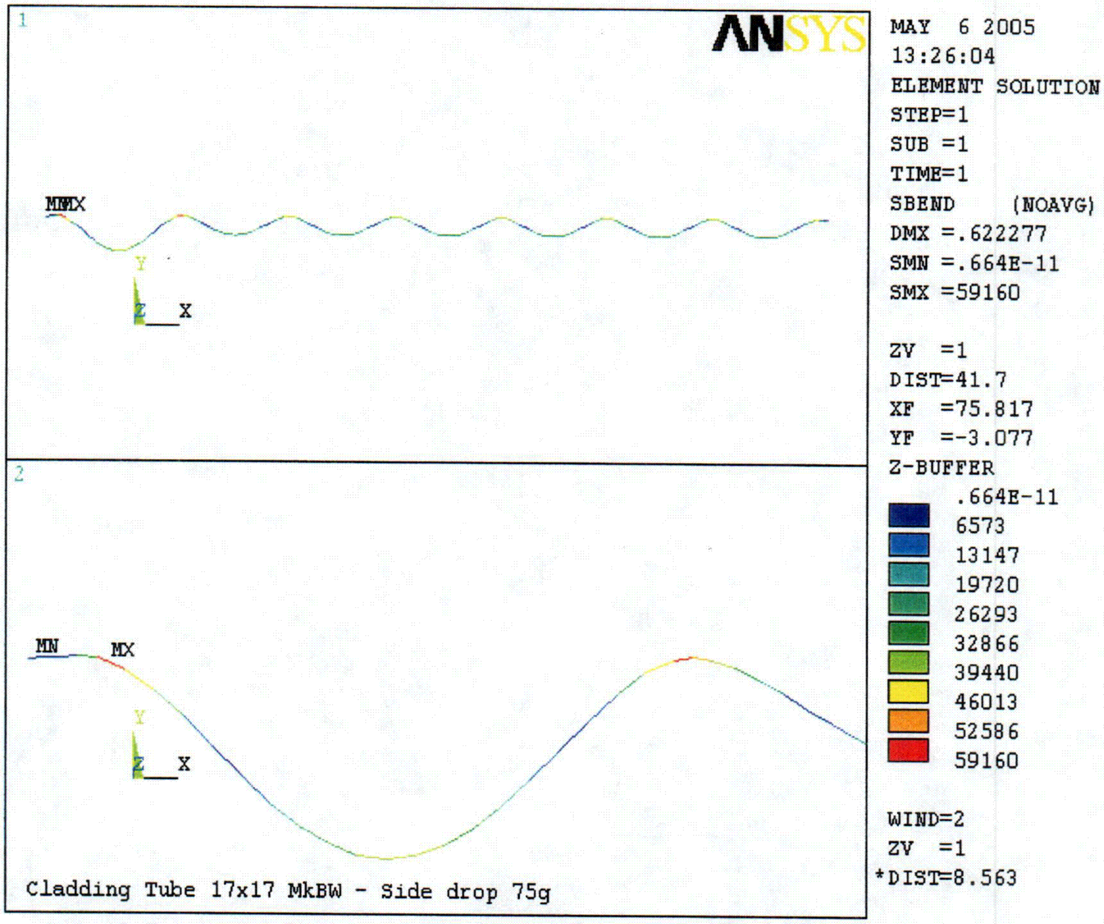
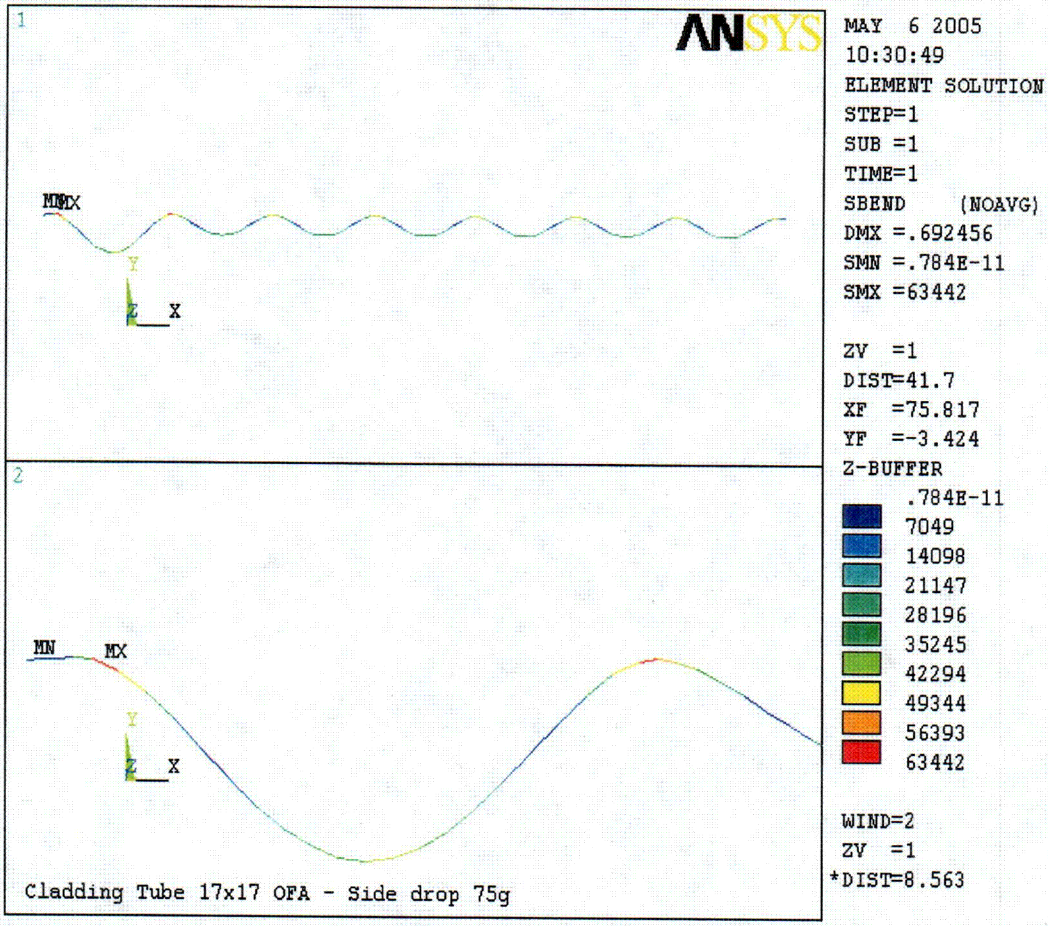
Figure 4
Bending Stress – 17x17 MkBW
(The bottom figure is an enlarged view of span)



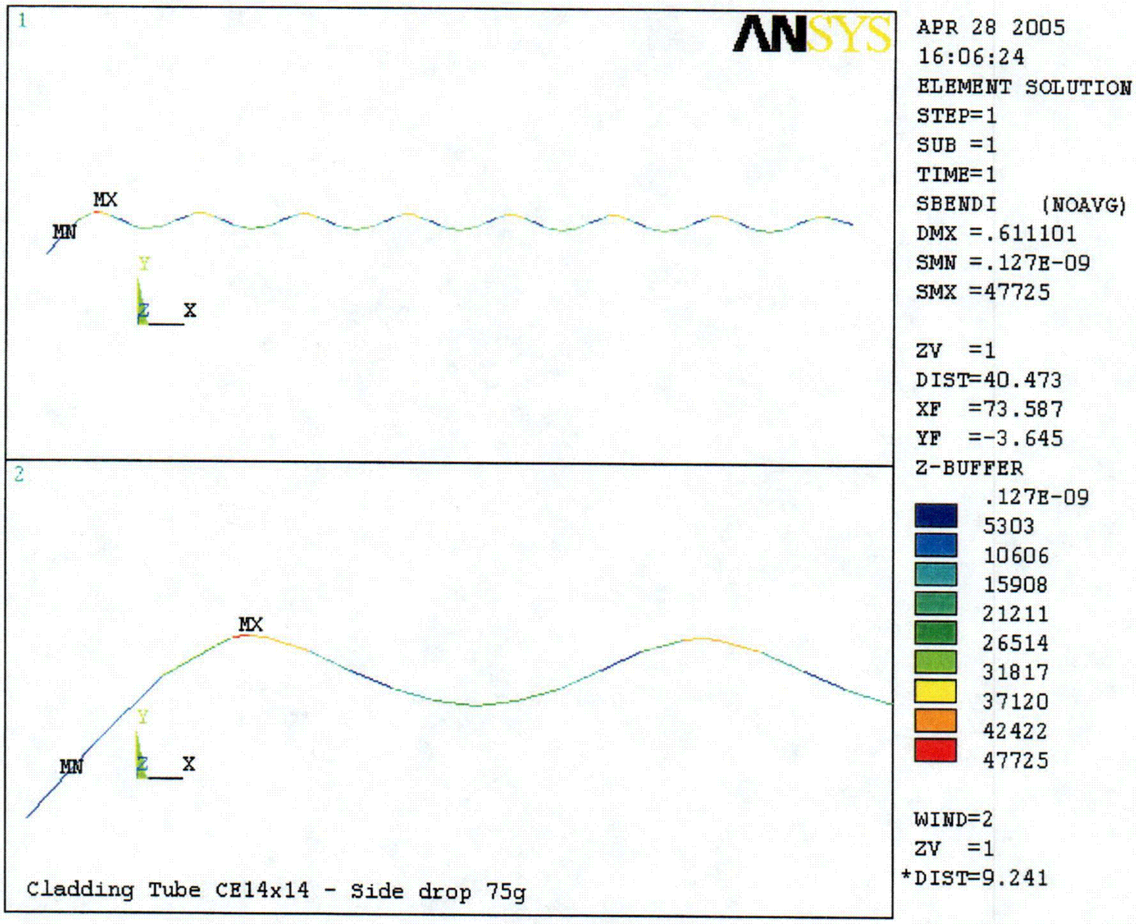
C04

Figure 5
Bending Stress – WE 17x17 OFA
(The bottom figure is an enlarged view of span)



C05

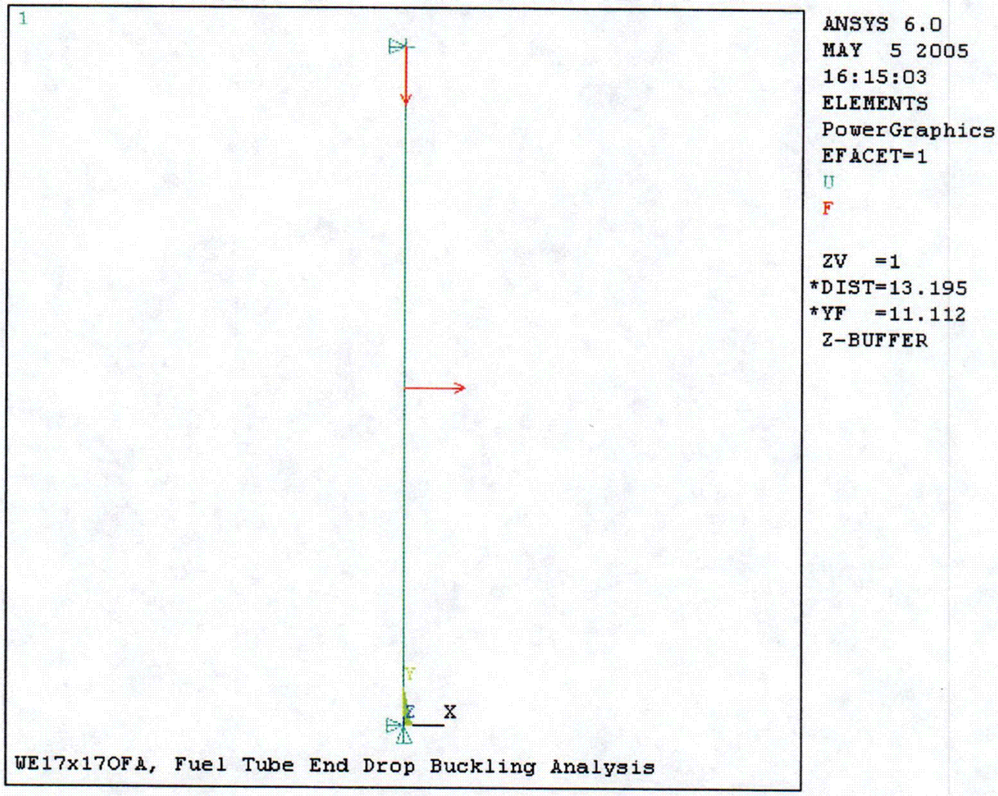
Figure 6
Bending Stress – CE 14x14 Std
(The bottom figure is an enlarged view of span)



cAG

Figure 7

Typical Boundary Condition and Loading Plot of End Drop Buckling Analysis



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