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MFN 09-788, Rev. 1

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U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Subject: **Revised Response to Portion of NRC Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6 – Fuel Racks - RAI Number 9.1-145**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) revised response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) 9.1-145 sent by NRC Letter 391, Reference 1. GEH provided its original response to RAI 9.1-145 in Reference 2.

The revised response corrects references to LTR NEDO-33373 (formerly LTR NEDC-33373P), from Revision 3 to Revision 4; includes an evaluation of the compressive loads induced during the Service Level D load combination against ASME Code buckling limits when imperfections are considered; and corrects the ASME safety factor.

GEH revised response to RAI Number 9.1-145 is addressed in Enclosure 1. Enclosure 2 contains the LTR markups associated with this response.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

D068
NRO

References:

1. MFN 09-725, Letter from U.S. Nuclear Regulatory Commission to Jerald G. Head, *Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6*, November 9, 2009
2. MFN 09-788, Response to Portion of NRC Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6 - Fuel Racks - RAI Number 9.1-145, December 15, 2009

Enclosures:

1. Revised Response to Portion of NRC Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6 – Fuel Racks - RAI Number 9.1-145
2. Revised Response to Portion of NRC Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6 – Fuel Racks - RAI Number 9.1-145 – LTR Markups

cc:	AE Cubbage	USNRC (with enclosures)
	JG Head	GEH/Wilmington (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	TL Enfinger	GEH/Wilmington (with enclosures)
	eDRF Section	0000-0110-4466

Enclosure 1

MFN 09-788, Rev. 1

Revised Response to Portion of NRC Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6

Fuel Racks

RAI Number 9.1-145

NRC RAI 9.1-145

Section 1.4.7 of NEDE-33373P, rev. 3 provides that the stress limits for Service Level D were based on F-1332 of Appendix F to ASME B&PV Code, Section III, Division I, and provides the stress limits for various stress conditions except for compressions. Requirements for compressive stresses are provided under F-1332.5 which then refers to the rules of F-1331.5 (a). Without an evaluation of the racks subject to compressive stresses in accordance with the rules of F-1331.5 (a), the staff considers the applicant's Service Level D analysis is incomplete.

The staff requests that the applicant provide an evaluation of rack plates subjected to compressive loads induced during the Service Level D load combination against buckling limits per F-1331.5 (a) of Appendix F to ASME B&PV Code, Section III, Division I.

GEH Response (Original)

NEDC-33373P will be revised to include an evaluation of the compressive loads induced during the Service Level D load combination against ASME Code buckling limits. The evaluations are contained in Appendices B1 and D of NEDC-33373P.

GEH Response (Revision 1)

NEDO-33373 (formerly NEDC-33373P) will be revised to include an evaluation of the compressive loads induced during the Service Level D load combination against ASME Code buckling limits. The evaluations will be contained in Appendices B1 and D of NEDO-33373. The LTR markup pages are replaced in their entirety by Revision 1 of this response to include buckling analysis results when imperfections are considered and to correct the ASME safety factor.

DCD/LTR Impact (Revision 1)

No DCD changes will be made in response to this RAI.

Sections 1.4.7 and 2.4.9 of LTR NEDO-33373 will be revised and Appendices B1 and D will be added, as shown in the attached markups. All changes are enclosed in black, rectangular boxes. Changes associated with Revision 1 of this response are enclosed in red, clouded boxes.

Enclosure 2

MFN 09-788, Rev. 1

Revised Response to Portion of NRC Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6

Fuel Racks

RAI Number 9.1-145

LTR Markups

Level D Conditions (Appendix F, F-1332)

$P_m \leq$ Minimum of 1.2 S_y or 0.7 S_u = 195.2 MPa
$P_m + P_b \leq 1.5 \cdot (P_m$ limit) = 292.8 MPa
$\tau \leq 0.42 \cdot S_u$ = 198.6 MPa
For compressive stresses, see Appendix B1.

Welds

Level A Conditions (NF-3324.5 and Table NF-3324.5(a)-1)

Fillet welds:

Shear Stress on effective throat $\leq 0.3 \cdot S_u^{(1)}$ =165.4 MPa
Shear Stress on base metal $\leq 0.4 \cdot S_y$ =65.1 MPa
Tension or compression parallel to axis of weld ≤ Same as base metal
(1) Base metal tensile strength range between 489.5 MPa and 551.5 MPa (71 and 80 ksi), minimum weld metal tensile strength, 551.5 MPa (80 ksi).

Level D Conditions (Appendix F, F-1332)

Shear Stress $\leq 0.42\ S_u$ = 198.6 MPa
Tension or compression parallel to axis of weld ≤ Same as base metal

Links metal Type 630 H1075

Level D Conditions (Appendix F, F-1332)

$P_m \leq$ Minimum of 1.2 S_y or 0.7 S_u = 699.8 MPa
$P_m + P_b \leq 1.5 \cdot (P_m$ limit) = 1049.7 MPa
$\tau \leq 0.42 \cdot S_u$ = 419.9 MPa

1.5 DETAILED MODEL: RESPONSE SPECTRUM ANALYSIS

A detailed finite element model (FEM) for the 15x12 FSR is developed and analyzed with the response spectrum analysis method.

1.5.1 Assumptions

The calculation procedure used for the present stress report has been performed based on the following assumptions of FSR behavior:

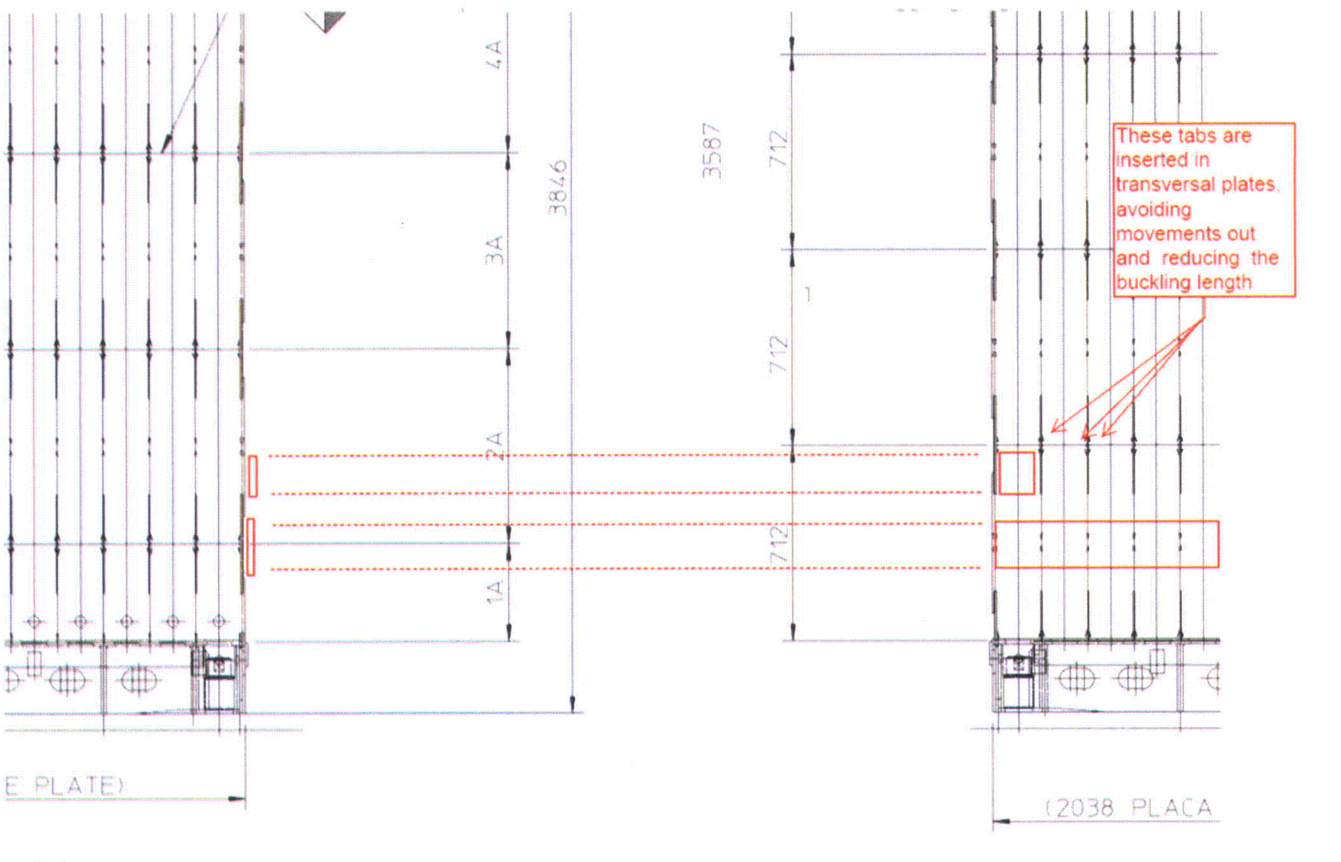
- It is assumed that the material of the structure (stainless steel) has a linear elastic behavior within the field of the small displacement/deformations.

APPENDIX B1 - Analysis Of Compressive Stresses

The conceptual design of the Interlock cell matrix racks includes multiple connections between plates. So the lateral Plain SS structural plates are braced, at several points, to transversal plates that limit the buckling length. Additionally, for this ESBWR application, we are using thick plates (10 mm and 7 mm)*. As a result, the buckling stress limits are greater than the allowable stress limit considered in this report.

Following is a calculation of the allowable buckling stress:

For lateral 10 mm plate, the typical unbraced portion of lateral plates can be seen below.



The typical unbraced length is about 712/4= 178 mm.

Therefore, the buckling calculation is peformed for a 10 mm plate with a span of 178 mm.

* The allowable buckling stress depends on the relation between the thickness of the plate and the length of the plate.

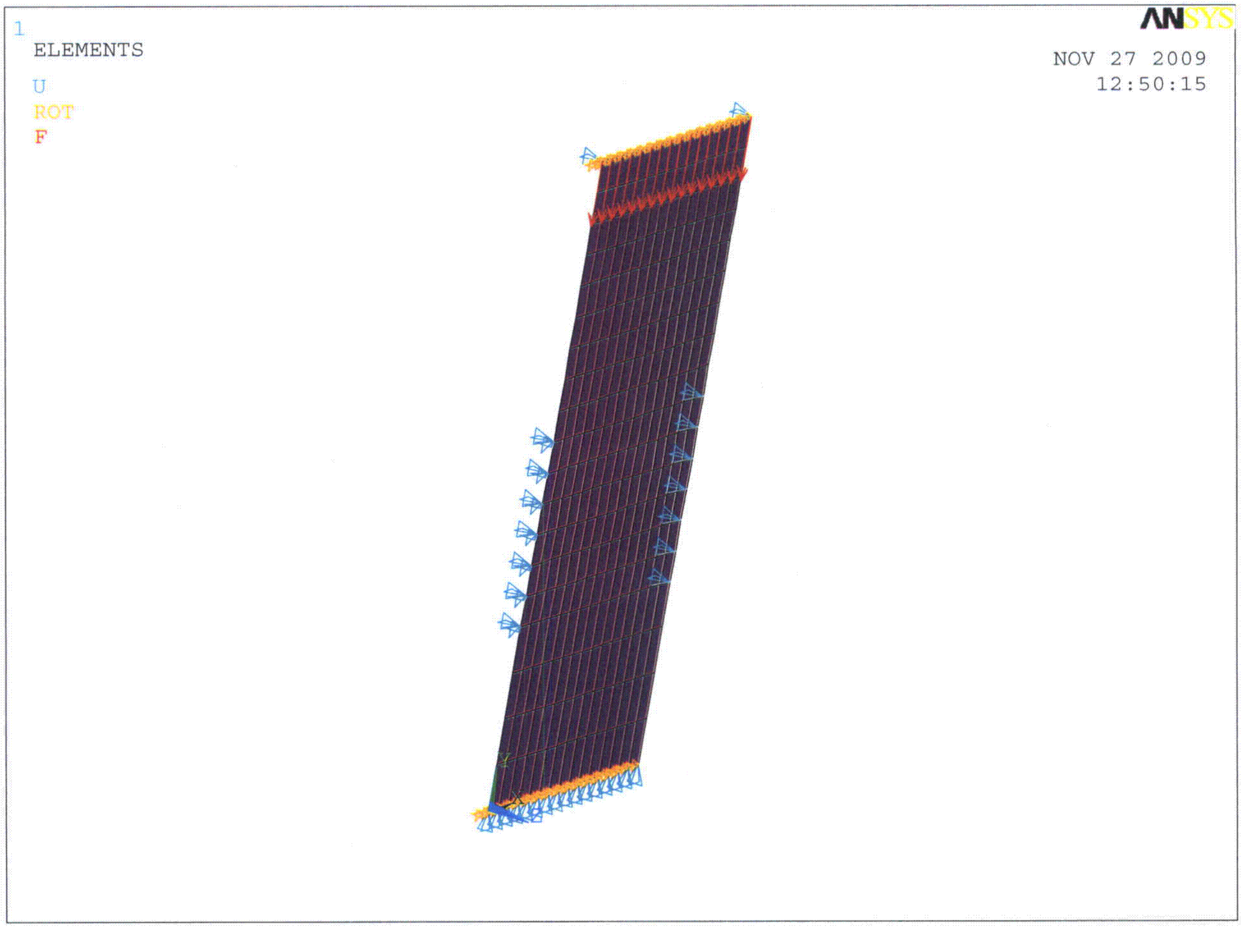
The Euler buckling formula, which is too conservative for this case, gives a buckling stress of

$$\sigma = \frac{\pi^2 \cdot E}{12 \cdot (1-\upsilon^2)} \cdot (\frac{e}{h})^2 = \frac{\pi^2 \cdot 1.95E5}{12 \cdot (1-\upsilon^2)} \cdot (\frac{10}{178})^2 = 555.68 N / mm^2$$

But additionally, since the boundary conditions for the above plates are somewhat complicated, an ANSYS FEM eigen buckling analysis was made.

The typical lateral plate portion located between two transversal plates (pitch = 168 mm) is modeled.

The mesh corresponds to a portion of 168x(712/2= 356) mm.



Mesh for Eigen Buckling and Boundary Conditions

A unitary 10 N/mm^2 stress was considered.

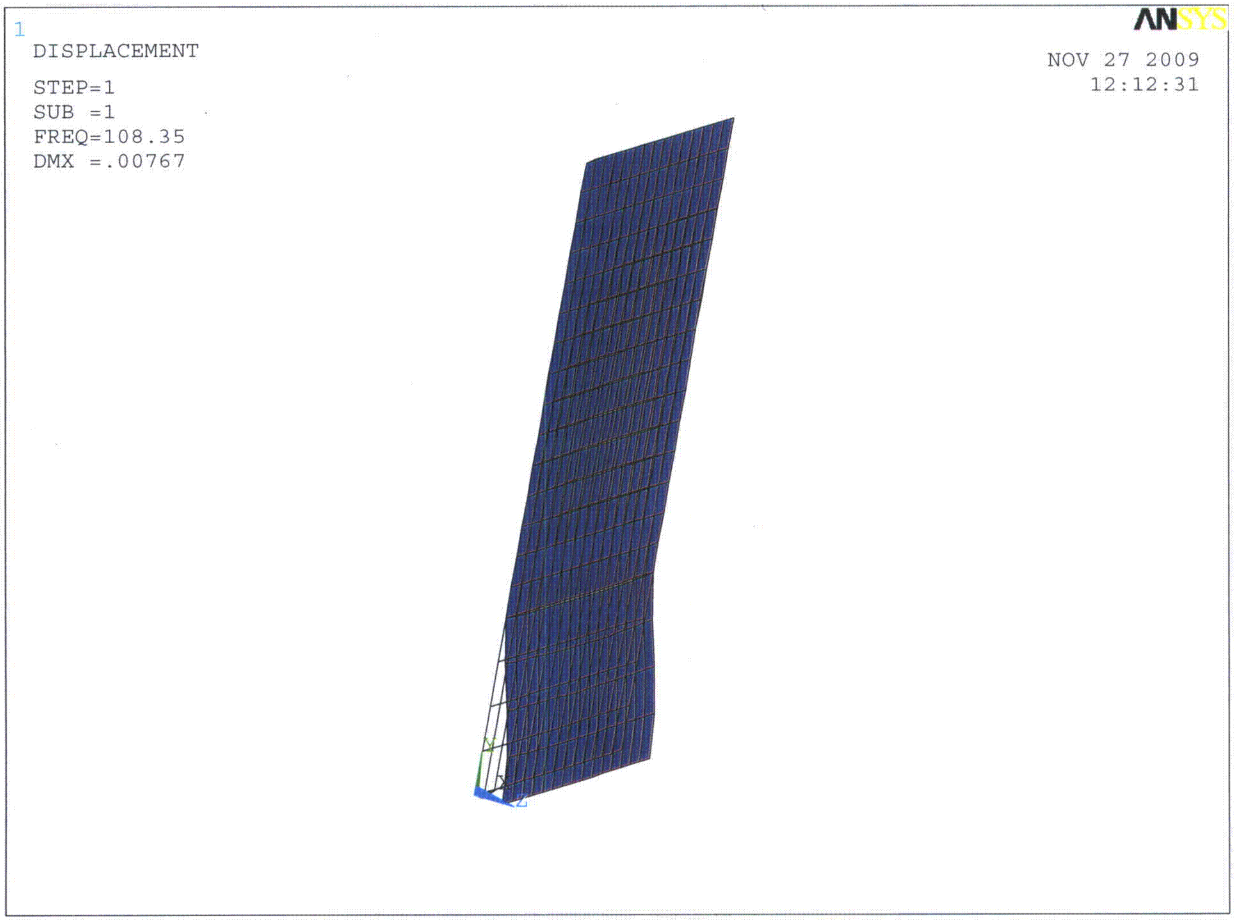
The ANSYS results are:

***** EIGENVALUES (LOAD MULTIPLIERS FOR BUCKLING) *****

*** FROM BLOCK LANCZOS ITERATION ***

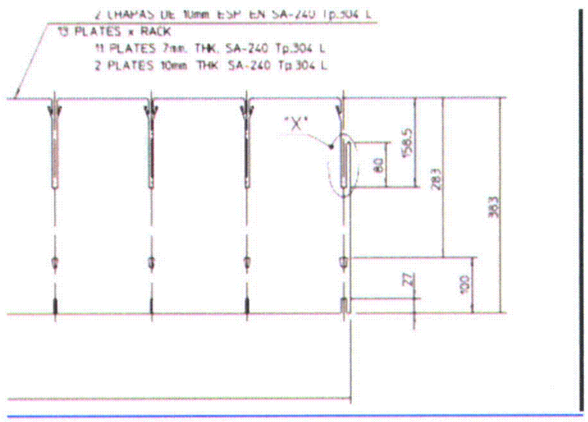
SHAPE NUMBER	LOAD MULTIPLIER
1	108.35012
2	204.05621
3	248.95131

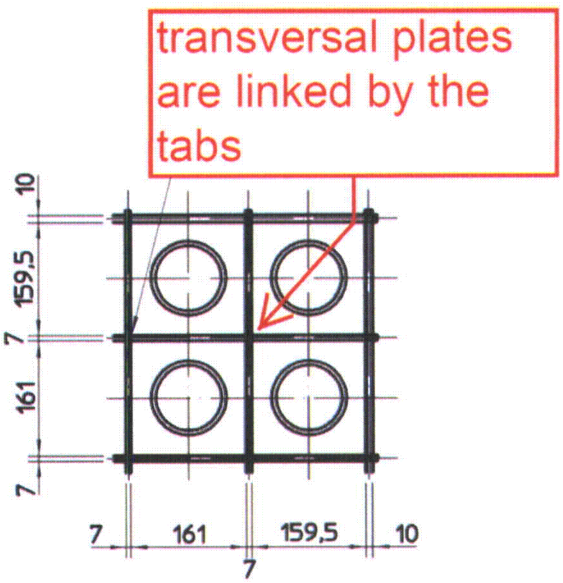
First buckling mode



So the allowable buckling stress is $10 \cdot 108.35$ N/mm^2 = 1083.5 N/mm^2. If we use the safety coefficient required in F-1331.5, the allowable buckling stress = $2/3 \cdot 1083.5 = 722.3$ N/mm^2, which is larger than the allowable limits considered in the analysis and much larger than any compressive general membrane stress in lateral plate. Therefore, allowable buckling loads are not limiting.

Upper 7 and 10 mm plates:





Applying the conservative euler formula, and considering a free span of a pitch = 168 mm for 10 mm plates:

$$\sigma = \frac{\pi^2 \cdot E}{12 \cdot (1-\upsilon^2)} \cdot (\frac{e}{h})^2 = \frac{\pi^2 \cdot 1.95E5}{12 \cdot (1-\upsilon^2)} \cdot (\frac{10}{178})^2 = 555.68 N/mm^2$$

And considering the internal 7 mm plates have some intermediate between clamped and simple supported boundary condition:

If we use the safety coefficient required in F-1331.5, as follows:

$$\sigma = \frac{\pi^2 \cdot E}{12 \cdot (1-\upsilon^2)} \cdot \left(\frac{e}{h}\right)^2 = \frac{\pi^2 \cdot 1.95E5}{12 \cdot (1-\upsilon^2)} \cdot \left(\frac{7}{0.7 \cdot 168}\right)^2 = 623.8 N/mm^2$$

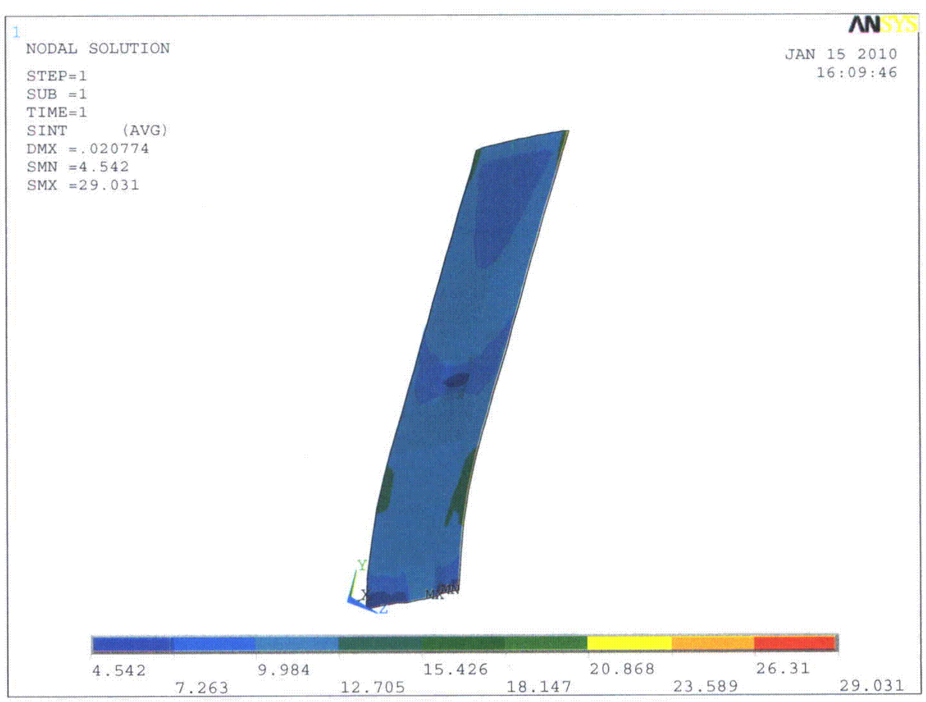
The allowable buckling stress = 2/3·555.68 = 370.5 N/mm^2, which is larger than the allowable limits considered in the analysis and much larger than any compressive general membrane stress in the lateral plate. Therefore, allowable buckling loads are not limiting.

Potential Manufacturing Imperfections

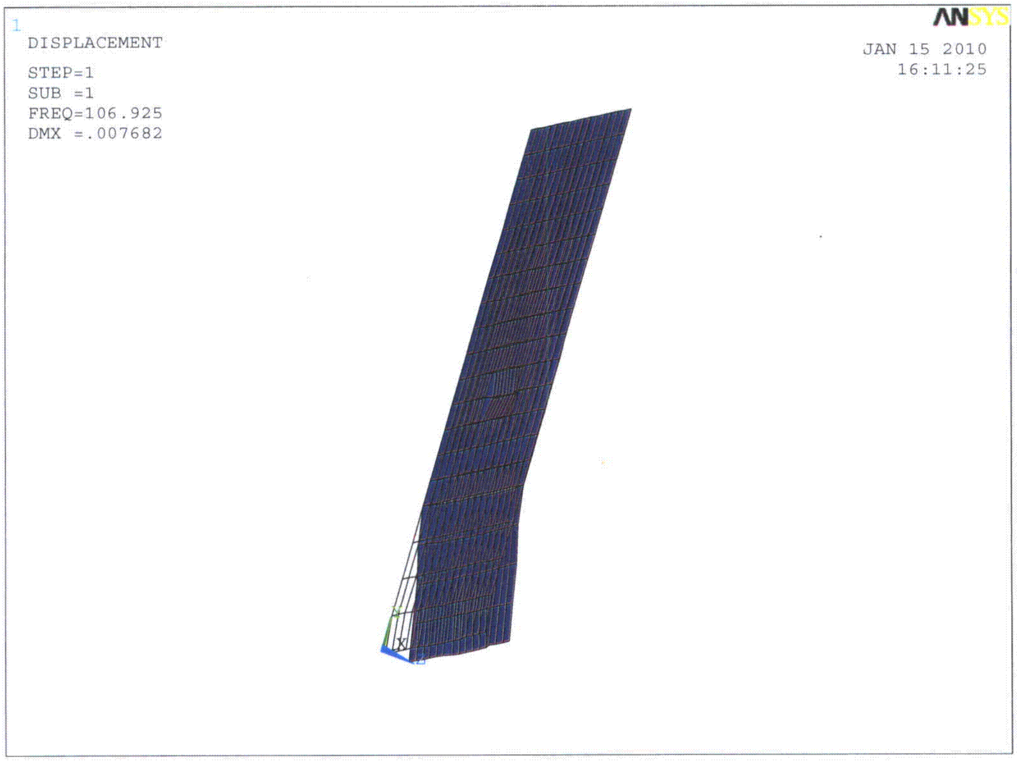
The manufacturing of racks will be done according to the ASME Code, which limits the imperfections. The allowable compressible stress, if we consider potential imperfections, is very similar to the results obtained above.

Considering a typical 5 mm imperfection, which is bigger than allowed by the ASME Code, an ANSYS buckling analysis was peformed using the same mesh, boundary conditions, etc. as above.

The unitary stress field is:



And the new eigenvalue and deformed shape are:



It is seen that the new value (106.9 N/mm^2) is very similar to value determined above with no imperfections (108.35 N/mm^2).

~~P_L or~~ $P_m + P_b \leq 1.5$ ~~all~~ $\cdot$ (P_m limit) = 292.8 MPa

$\tau \leq 0.42 \cdot S_u$ = 198.6 MPa

For compressive stress, see Appendix D.

Bolting Material SA-564 Type 630 H1075

Level A Conditions (NF-3324.6 for austenitic steel)

Average normal stress = $f_t \leq F_{tb} = S_u/3.33$ = 300.2 MPa

Shear stress = $f_v \leq F_{vb} = 0.62S_u/5$ = 123.9 MPa

Combined tensile and shear stress: $f_t^2/F_{tb}^2 + f_v^2/F_{vb}^2 \leq 1$

Level D Conditions (Appendix F.F-1335)

Average normal stress = $f_t \leq F_{tb}$ = Minimum of S_y or 0.7 S_u = 699.8 MPa

Shear stress = $f_v \leq F_{vb}$ = Minimum of $0.42 \cdot S_u$ or 0.6 S_y = 419.8 MPa

Combined tensile and shear stress: $f_t^2/F_{tb}^2 + f_v^2/F_{vb}^2 \leq 1$

Welds

Level A Conditions (NF-3324.5 and Table NF-3324.5(a)-1)

Fillet welds:

Shear Stress on effective throat $\leq 0.3 \cdot S_u^{(1)}$ =165.4 MPa

Shear Stress on base metal $\leq 0.4 \cdot S_y$ =65.1 MPa

Tension or compression parallel to axis of weld ≤ Same as base metal(1)

(1) Base metal tensile strength range between 472.9 MPa and 551.5 MPa (68.6 and 80 ksi), minimum weld metal tensile strength, 551.5 MPa (80 ksi).

Level D Conditions (Appendix F:F-1332)

Shear Stress $\leq 0.42\ S_u$ = 198.6 MPa

Tension or compression parallel to axis of weld ≤ Same as base metal

2.5 RESULTS OF THE ANALYSIS

The ANSYS output for static, modal and spectrum analyses, including the modal combination, is included in Appendix D.

Table 2-6 presents the main eigenfrequencies, obtained from the modal analysis, with of the associated effective mass. Additionally, two lower frequency modes (modes 2 and 4) are

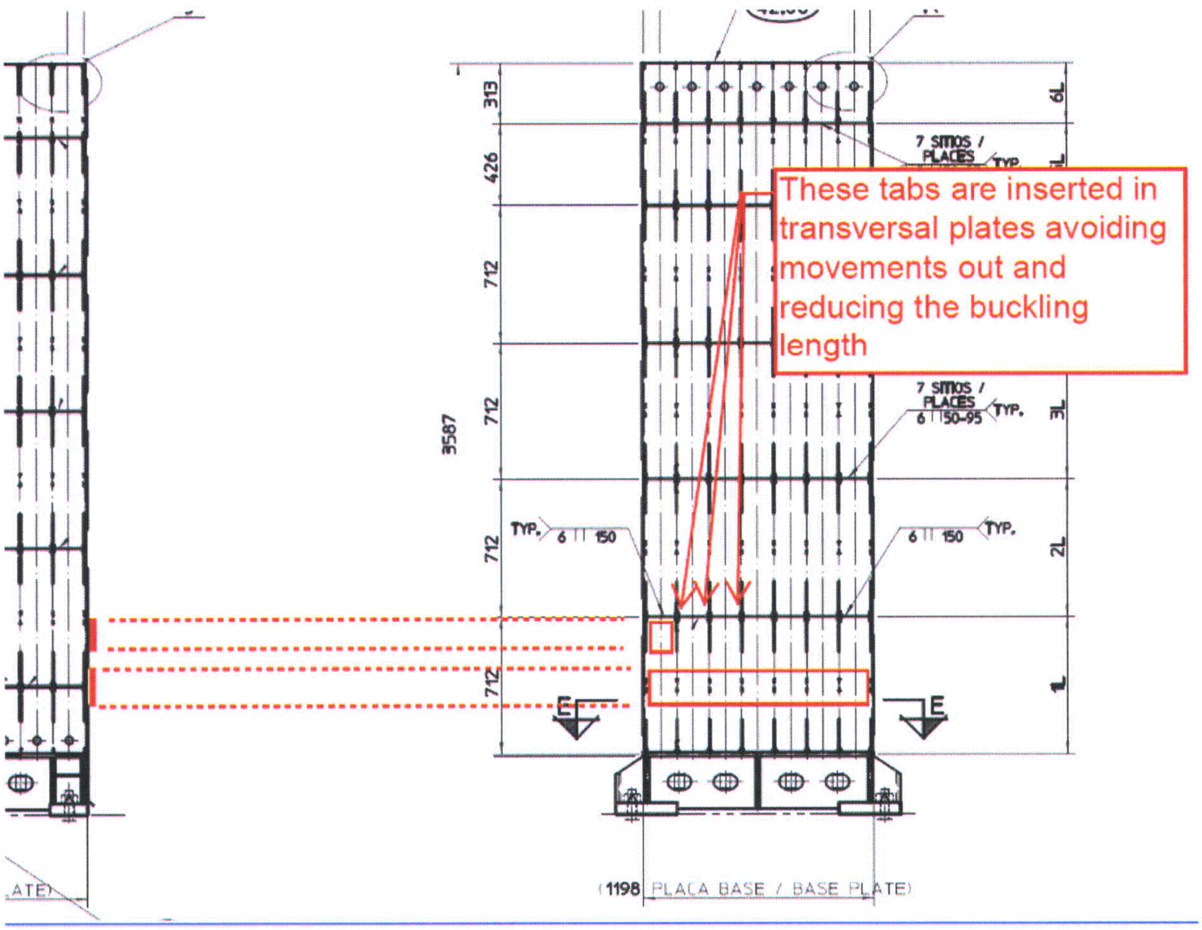
APPENDIX D - Analysis Of Compressive Stresses(DELETED)

The conceptual design of the Interlock cell matrix racks includes multiple connections between plates. So the lateral Plain SS structural plates are braced, at several points, to transversal plates that limit the buckling length. Additionally, for this ESBWR application, we are using thick plates (10 mm and 7 mm)*. As a result the buckling stress limits are greater than the allowable stress limit considered in report.

Allowable buckling stress is calculated below:

For lateral 10 mm plate:

The typical unbraced portion of lateral plates can be seen below.



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Therefore, the buckling calculation is peformed for a 10 mm plate with a span of 178 mm.

The Euler buckling formula, that is too much conservative for this case, gives a buckling stress of

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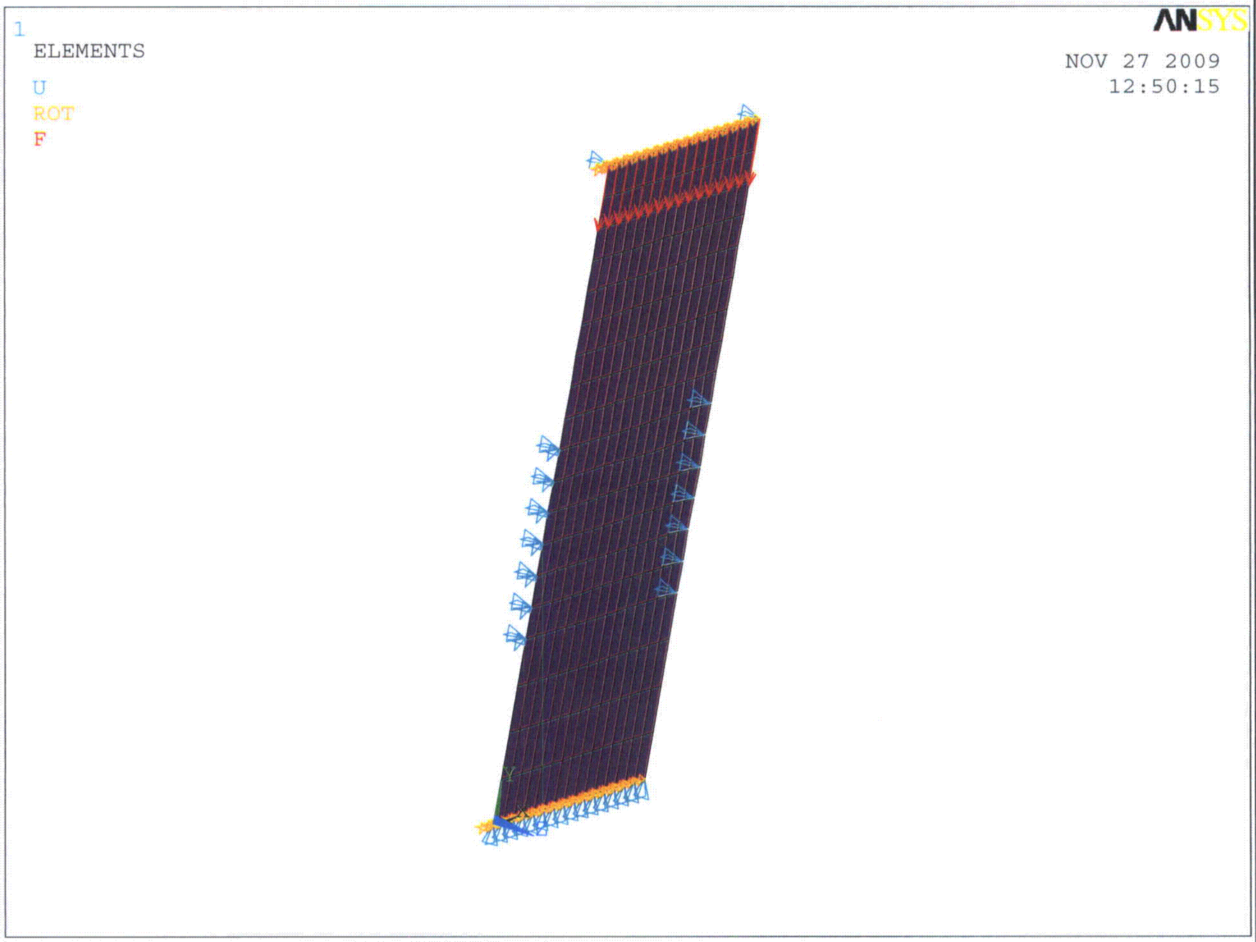
But additionally, since the boundary conditions for the above plates are complicated, an ANSYS FEM eigen buckling analysis was performed.

The typical lateral plate portion located between two transversal plates (pitch = 168 mm) is modeled. The mesh corresponds to a portion of 168x(712/2= 356) mm.



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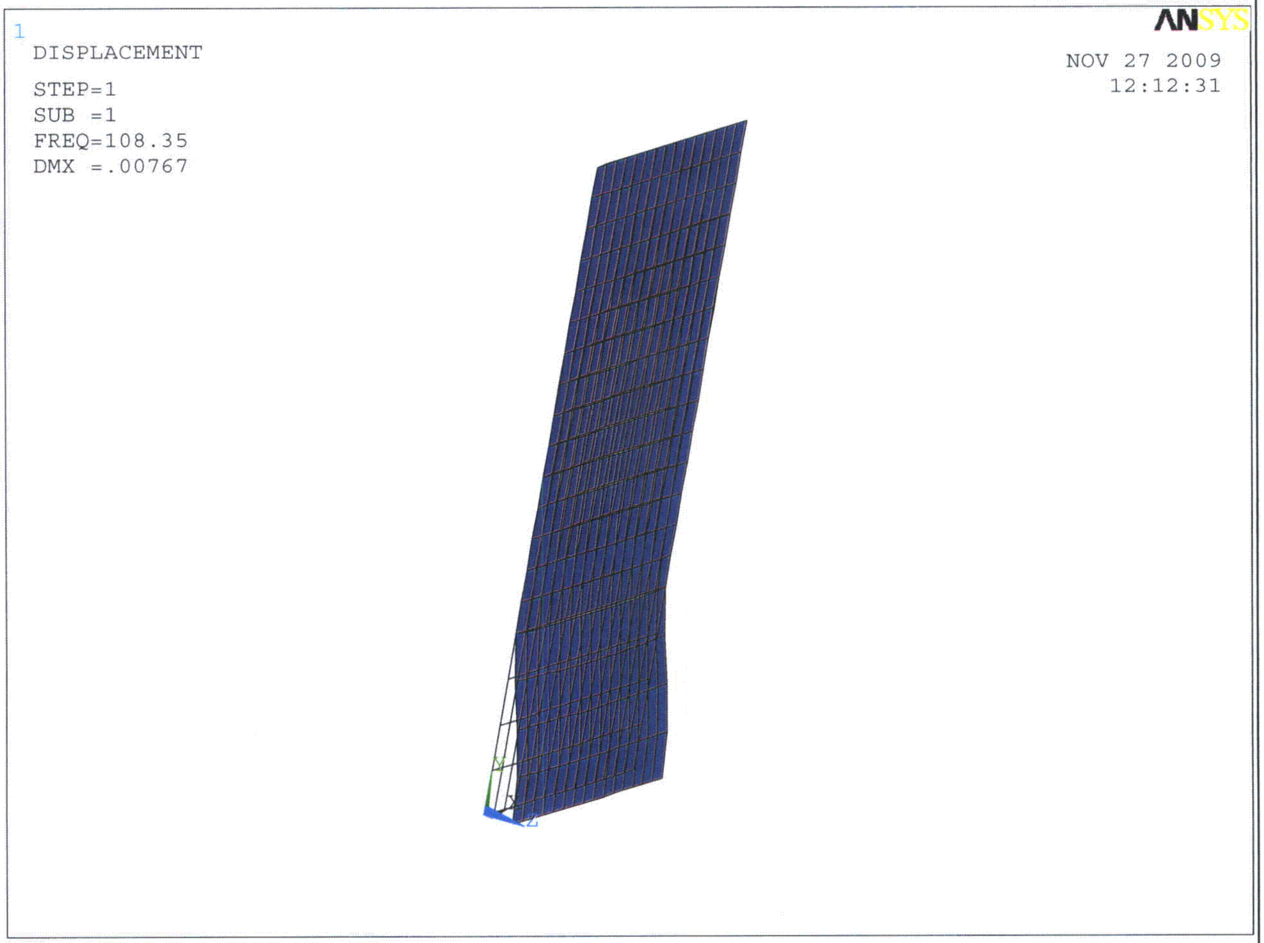

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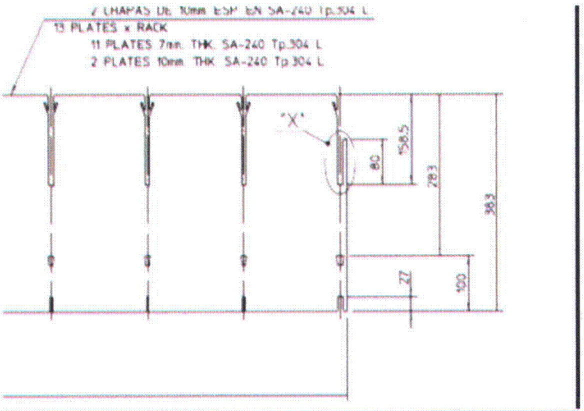

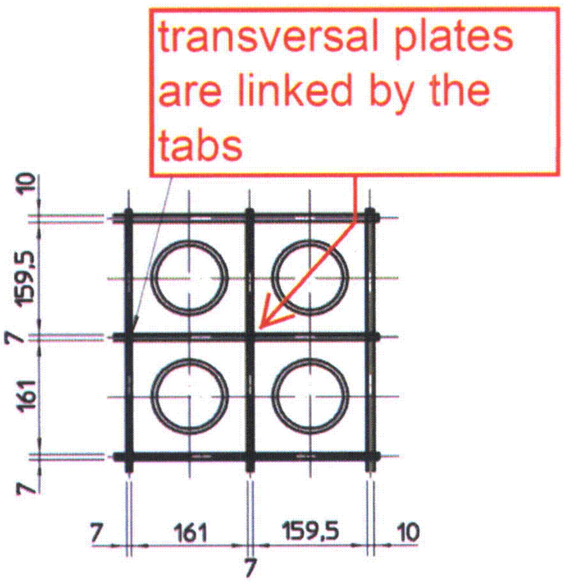

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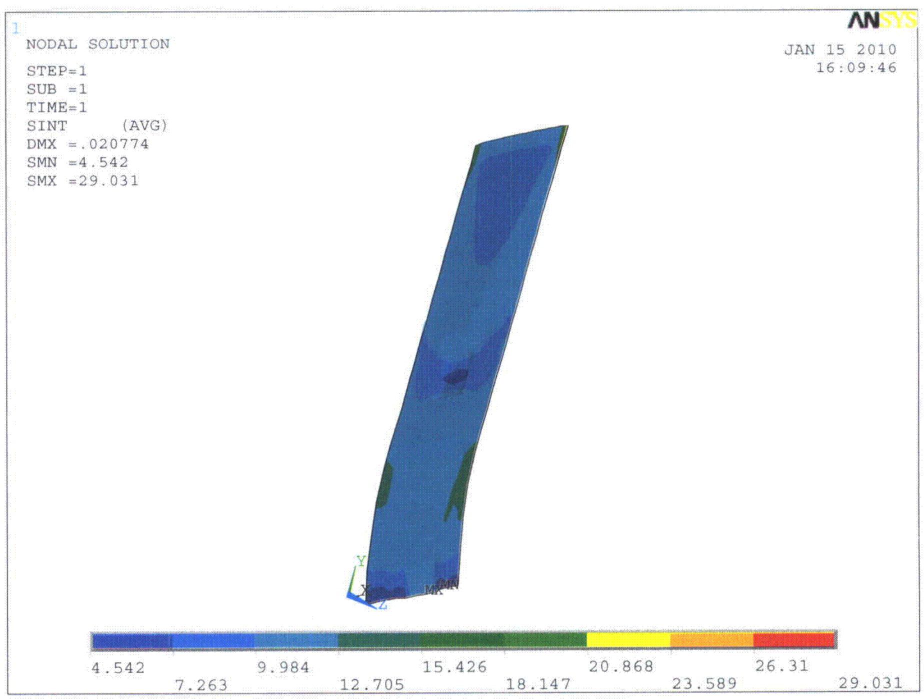
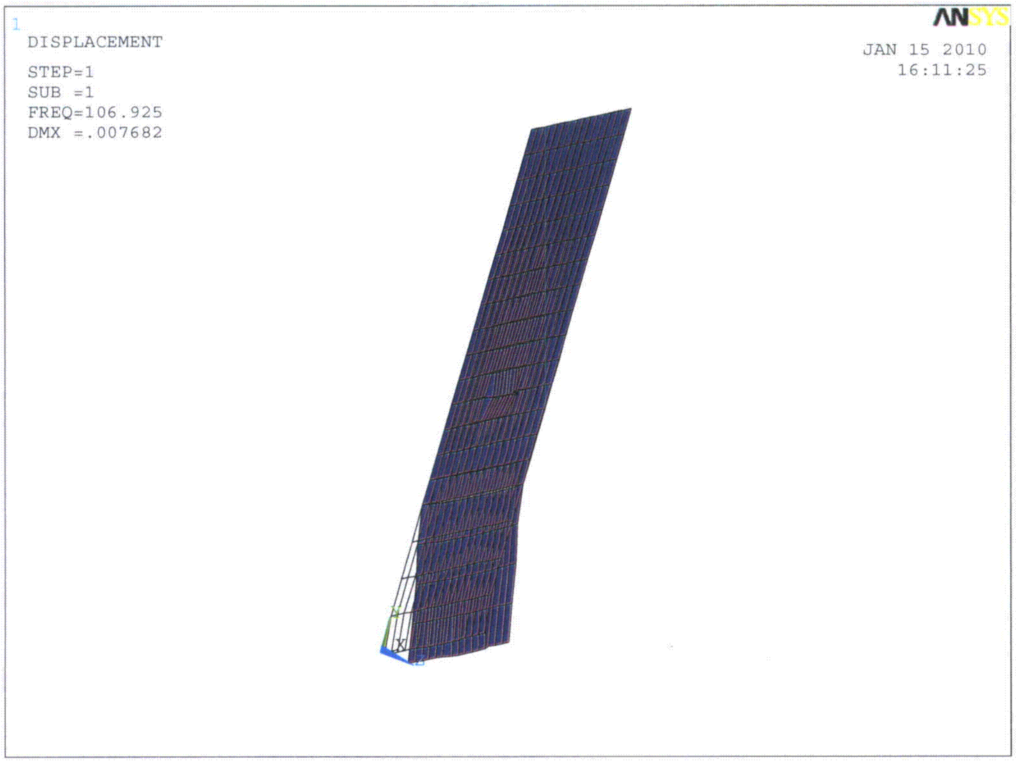


And the new eigenvalue and deformed shape are:



It is seen that the new value (106.9 N/mm^2) is very similar to value determined above with no imperfections (108.35 N/mm^2).