ENCLOSURE 7

MONTICELLO NUCLEAR GENERATING PLANT

LICENSE AMENDMENT REQUEST

REVISE THE TECHNICAL SPECIFICATIONS TO INCLUDE A PRESSURE TEMPERATURE LIMITS REPORT

CALCULATION CA 11-020

FINITE ELEMENT STRESS ANALYSIS OF MONTICELLO RPV RECIRCULATION INLET NOZZLE

(SIA No. 1000720.301)

(30 pages follow)

Xcel Energy

Calculation Signature Sheet

Document Information			
NSPM Calculation (Doc) No: 11-020			Revision: 0
Title: Finite Element Analysis of RPV Recirculation Inlet Nozzle			
Facility: ☒ MT ☐ PI		Unit: ☒ 1 ☐ 2	
Safety Class: ☒ SR ☐ Aug Q ☐ Non SR			
Special Codes: ☐ Safeguards ☐ Proprietary			
Type: **Calc** Sub-Type:			

NOTE:	Print **and** sign name in signature blocks, as required.

Major Revisions			☐ N/A
EC Number: 17657	☒ Vendor Calc		
Vendor Name or Code: Structural Integrity Associates (SIA)	Vendor Doc No: 1000720.301		
Description of Revision: New Calculation Issuance			
The following calculation and attachments have been reviewed and deemed acceptable as a legible QA record			☒
Prepared by: (sign) By Vendor / (print) SIA		Date: 2/9/2011	
Reviewed by: (sign) Wynter L McGruder / (print) Wynter McGruder		Date: 2/9/2011	
Type of Review: ☐ Design Verification ☐ Tech Review ☒ Suitability Review			
Method Used (For DV Only): ☐ Review ☐ Alternate Calc ☐ Test			
Approved by: (sign) [signature] / (print) Steve Kibler		Date: 2/17/11	

Minor Revisions			☐ N/A
EC No:	☐ Vendor Calc:		
Minor Rev. No:			
Description of Change:			
Pages Affected:			
The following calculation and attachments have been reviewed and deemed acceptable as a legible QA record			☐
Prepared by: (sign) / (print)		Date:	
Reviewed by: (sign) / (print)		Date:	
Type of Review: ☐ Design Verification ☐ Tech Review ☐ Suitability Review			
Method Used (For DV Only): ☐ Review ☐ Alternate Calc ☐ Test			
Approved by: (sign) / (print)		Date:	

Record Retention: Retain this form with the associated calculation for the life of the plant.

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NOTE:	This reference table is used for data entry into the PassPort Controlled Documents Module reference tables (C012 Panel). It may also be used as the reference section of the calculation. The input documents, output documents and other references should all be listed here. Add additional lines as needed by using the "TAB" key and filling in the appropriate information in each column.

Reference Documents (PassPort C012 Panel from C020)

#	Controlled* Doc? + Type		Document Name	Document Number	Doc Rev	Ref Type**	
						INPUT	OUTPUT
1			US Nuclear Regulatory Commission, Reactor Vessel Integrity Database, Version 2.0.1	N/A	N/A	X	
2			GE Stress Report No. 23A1627, Revision 1, "Recirculation Inlet Nozzle,"	23A1627	1	X	
3			ASME Boiler and Pressure Vessel Code, Section III including Appendices, 1980 Edition with Addenda through Winter 1980	N/A	N/A	X	
4	X	DRAW	CB&I Drawing No. 7, Revision 9, "12" Nozzle MK. A/K 17'-2" I.D. x 63'-2" Ins. Heads Nuclear Reactor, Monticello Drawing NX-8290-90	8290-90	9	X	
5			GE Design Specification No. 25A5744, Revision 1, "Reactor Vessel-Power Rerate"	25A5744	1	X	
6			GE Design Specification No. 23A1581, Revision 3, "Reactor Vessel-Recirculation Inlet Safe End"	23A1581	3	X	
7			CB&I Stress Report, Section T8, "Thermal Analysis, Recirculation Inlet Nozzle, Monticello Reactor Pressure Vessel"	N/A	N/A	X	
8			ANSYS Mechanical and PrepPost, Release 11.0 (w/Service Pack 1), ANSYS, Inc., August 2007	N/A	N/A	X	
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17							

* Controlled Doc marked with an "X" means the reference can be entered on the C012 panel in black. Unmarked lines will be yellow. If marked with an "X", also list the Doc Type, e.g., CALC, DRAW, VTM, PROC, etc.

** Mark with an "X" if the calculation provides inputs and/or outputs or both. If not, leave blank. (Corresponds to PassPort "Ref Type" codes: **Inputs / Both** = "ICALC", **Outputs** = "OCALC", **Other / Unknown** = blank)

Other PassPort Data

Associated System (PassPort C011, first three columns) **OR** **Equipment References** (PassPort C025, all five columns):

Facility	Unit	System	Equipment Type	Equipment Number
MT	1	RPV		

Superseded Calculations (PassPort C019):

Facility	Calc Document Number	Title
N/A	N/A	N/A

Description Codes - Optional (PassPort C018):

Code	Description (optional)	Code	Description (optional)

Notes (Nts) - Optional (PassPort X293 from C020):

Topic Notes	Text

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☐ Calc Introduction	☐ Copy directly from the calculation Intro Paragraph **or** ☐ See write-up below
☐ (Specify)	

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Monticello Specific Information

☒ YES ☐ N/A Topic Code(s) (See MT Form 3805): PLEX, RATE
☐ YES ☒ N/A Structural Code(s) (See MT Form 3805):______

Does the Calculation:

☐ YES ☒ No Require Fire Protection Review? (Using MT Form 3765, "Fire Protection Program Checklist", determine if a Fire Protection Review is required.) If YES, document the engineering review in the EC. If NO, then attach completed MT Form 3765 to the associated EC.

☐ YES ☒ No Affect piping or supports? (If Yes, Attach MT Form 3544.)

☐ YES ☒ No Affect IST Program Valve or Pump Reference Values, and/or Acceptance Criteria? (If Yes, inform IST Coordinator and provide copy of calculation.)

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Structural Integrity Associates, Inc.

CALCULATION PACKAGE

File No.: 1000720.301	
Project No.: 1000720	Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
Evaluation of N2 Nozzle for Monticello P-T Curves

CONTRACT NO.:
00001005, Rev. 16

CLIENT:	**PLANT:**
Xcel Energy, Inc.	Monticello Nuclear Generating Plant

CALCULATION TITLE:
Finite Element Stress Analysis of Monticello RPV Recirculation Inlet Nozzle

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 24 A-1	Initial Issue	Timothy Griesbach TJG 6/17/10	Eric Houston EJH 6/16/10 Chris Lohse CSL 6/16/10

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1.0 OBJECTIVE

The objective of this calculation is to perform finite element stress analysis on the recirculation inlet (N2) nozzles, at Monticello Nuclear Generating Plant. Pressure-temperature (P-T) curves for the N2 nozzles are to be generated using the results of this analysis.

2.0 METHODOLOGY

A three-dimensional finite element model (FEM) is constructed for the recirculation inlet nozzle to be evaluated. The finite element model also includes a portion of the reactor pressure vessel (RPV) as well as the internal cladding. The safe end, thermal sleeve and attached piping are not modeled since these components are far from the location of interest, which is the nozzle blend radius. A unit internal pressure load and applicable thermal transients are applied. Multiple paths through the nozzle blend radius are selected at different azimuths based on the maximum hoop stress at the inside surface of the nozzle, excluding the cladding. The hoop stress along these paths is curve fit with a 3rd order polynomial. For thermal transient loading, the polynomial coefficients are reported for all time steps.

3.0 DESIGN INPUTS

The following design inputs are used in this calculation:

- RPV material = SA-533 Gr. B [1]
- N2 material = SA-508 Cl II [2]
- Cladding (or overlay) material = Type 304 stainless steel {1, §4.0}
- N2 Design Code of Record [2, Sheet No. 2]= ASME Section III, 1980 Edition with Addenda through Winter 1980 [3]
- Temperature dependent material properties are obtained from Reference [3] and are listed in Tables 1 through 3
- RPV and N2 geometry are taken from Reference [4] and reproduced in Figure 1
- Maximum temperature under normal operating condition = 549°F [5, Section 4.4.3.1.c]
- Normal operating thermal transient applicable to N2 is heatup/cooldown [6, Figure 4; 7] {2, §4.0}:
    - Fluid initial steady state condition = 549°F [5]
    - Fluid final steady state condition = 100°F
    - Fluid rate of change = -100°F per hour
- Heat transfer coefficients (see Figure 6 and Section 6.0 for application areas on the model)
    - Vessel region heat transfer coefficient (Btu/hr-ft^2-°F) = 87.8 $\Delta T^{1/3}$ [7, p. I-T8-12]
    - Nozzle region heat transfer coefficient (Btu/hr-ft^2-°F) = 11.5 $\Delta T^{0.511}$ [7, p. I-T8-11]
    - Nozzle blend radius heat transfer coefficient = Vessel region heat transfer coefficient {4, §4.0}

4.0 ASSUMPTIONS

The assumptions made in order to define the evaluation approach and perform the analysis are summarized in the following list. The application of these assumptions is indicated throughout the document using a set of braces containing the appropriate assumption number; for example, Assumption #1 would be indicated as {1, §4.0}.

1. RPV and N2 nozzle cladding material is assumed to be Type 304 stainless steel. Note that Reference [4] refers to the cladding as "overlay."

2. Reference [6] defines both the heatup and cooldown transient. However, the cooldown transient typically produces more severe hoop stress at the inner surface of the nozzle and vessel. Because the analysis will be used in generating pressure-temperature limit curves, the location of interest is near the inner surface of the nozzle blend radius. Therefore, the analysis is run only for the cooldown transient. The cooldown transient has the following characteristics:

    a. The maximum temperature under normal operating conditions in [6, Figure 4] is modified by Reference [5] to 549°F.

    b. The heat transfer coefficients in [7] for heatup are assumed applicable to cooldown.

3. The effect of the thermal sleeve is conservatively ignored when determining the fluid temperature boundary condition at the nozzle inner surface. That is, the stagnant region is conservatively assumed to have bulk fluid temperature present. This results in more rapid cooling of the nozzle blend radius, which in turn increases the thermal gradient from the outer to the inner surface of the blend radius. The increased thermal gradient increases the hoop stresses in the blend radius.

4. The nozzle blend radius heat transfer coefficient uses the maximum of the vessel and nozzle heat transfer coefficients, which are calculated using guidance from Reference [7]. The full delta T of the transient is used in calculating the heat transfer coefficients. Therefore, the vessel region heat transfer coefficient is the bounding, or maximum, heat transfer coefficient.

5. All external surfaces are conservatively assumed to be insulated. No thermal boundary conditions are specified for these locations, which results in adiabatic boundaries.

6. Density is assumed constant at 0.283 lb/in^3 and Poison's ratio is assumed constant at 0.3.

5.0 FINITE ELEMENT MODEL

The three-dimensional (3-D) finite element model is developed for the N2 nozzle using the ANSYS finite element software package [8] using 8-node SOLID45 3-D linear structural elements. The dimensions used for the nozzle and RPV shell are provided in Reference [4]. In order to reduce the complexity of the FEM, some features remote from the area of interest are not modeled. This includes the safe end, safe end-to-nozzle weld (including overlay shown in [2, Section 30.3.2]), thermal sleeve

and some radii (which are modeled as points). The dimensions used in the model are presented in Figure 1.

The one-quarter 3D model extends the end of the machined portion of the nozzle a total of 5 inches, while the RPV shell extends 22.2° circumferentially and 40 inches axially from the nozzle axis. These dimensions are large enough such that boundary conditions do not introduce non-representative effects in the FEA solution at the nozzle blend radius region. The finite element model is shown in Figures 2 and 3. The ANSYS input files used to generate the FEM are included with the electronic supporting files listed in Appendix A.

6.0 LOADS AND BOUNDARY CONDITIONS

Two load conditions, one steady state and one transient, are applied to the FEM. The steady state load is a unit pressure case of 1,000 psig. The transient is normal shutdown {2, §4.0} and is described in Section 3.0.

For the unit pressure case, a uniform pressure of 1,000 psig is applied to the inside surface of the RPV and nozzle bore. Note that the cladding is not included in the unit pressure analysis. A cap load, P_{cl1}, is applied to the upper horizontal cut plane in the model, which is calculated as:

$$P_{cl1} = \frac{P_{unit} IR_{ves}^2}{OR_{ves}^2 - IR_{ves}^2}$$

where:

P_{unit} = unit pressure, psig
IR_{ves} = inside radius of RPV excluding cladding, in
OR_{ves} = outside radius of RPV, in.

A cap load, P_{cl2}, is also applied to the free end of the nozzle, which is calculated as:

$$P_{cl2} = \frac{P_{unit} IR_{noz}^2}{OR_{noz}^2 - IR_{noz}^2}$$

where:

IR_{noz} = inside radius of nozzle excluding cladding, in
OR_{noz} = outside radius of nozzle free end, in.

Symmetry boundary conditions are applied on both of the vertical cut planes. The lower horizontal cut plane in the 3-D model is fixed in the axial degree of freedom. The nodes at the free end of the nozzle are coupled in the axial direction, as are the RPV nodes on the upper horizontal cut plane. The unit pressure loads and boundary conditions are shown in Figures 4 and 5, respectively. The ANSYS input file for the unit load is included with the electronic supporting files listed in Appendix A.

For the transient case, heat transfer coefficients for the RPV and nozzle are calculated from the equations in Section 3.0. The full temperature difference of 449°F (maximum under normal operating condition – ambient) is conservatively used in calculating the heat transfer coefficients {4, §4.0}. Bounding heat

transfer coefficients of 265 and 675 Btu/hr-ft^2-°F for the nozzle and vessel region, respectively, are used in the analysis. The larger of the two values is used for the nozzle blend radius {4, §4.0}. All external surfaces are conservatively assumed to be perfectly insulated {5, §4.0}. The bulk fluid temperature is conservatively assumed to act on all internal surfaces {3, §4.0}. Note that the calculated heat transfer coefficients bound the maximum values for the nozzle [2, Section 4.2.2] and vessel [2, Section 4.2.4.4] given in more recent analysis and are conservatively used in the analysis herein. Figure 6 shows the heat transfer coefficients applied to the FEM.

The thermal boundary conditions are applied to the surface of the cladding. However, the stresses due to the thermal gradient are calculated without taking credit for this additional thickness. The ANSYS input files used to generate the thermal stresses are included with the electronic supporting files listed in Appendix A.

7.0 RESULTS OF ANALYSIS

After running the unit pressure load case, the nodes along the blend radius at both cut planes are queried for the location of maximum hoop stress. A path is defined for each cut plane that includes this maximum location and the hoop stress is extracted along these paths. Figures 7 and 8 show the path locations. The transient load case is run, and the hoop stress is extracted (along the same paths used for pressure stress extraction) for all time steps. The temperature response is shown in Figures 9 and 10 for selected times.

The hoop stress is curve fit with a 3rd order polynomial. The coefficients are presented in Tables 4 through 6 and are included in the .csv files included with the electronic supporting files listed in Appendix A. The ANSYS stress extraction files are included with the electronic supporting files listed in Appendix A.

8.0 REFERENCES

1. US Nuclear Regulatory Commission, Reactor Vessel Integrity Database, Version 2.0.1.
2. GE Stress Report No. 23A1627, Revision 1, "Recirculation Inlet Nozzle," SI File No. MONT-14Q-211.
3. ASME Boiler and Pressure Vessel Code, Section III including Appendices, 1980 Edition with Addenda through Winter 1980.
4. CB&I Drawing No. 7, Revision 9, "12"Ø Nozzle MK. N2 A/K 17'-2" I.D. x 63'-2" Ins. Heads Nuclear Reactor," Monticello Document No. NX-8920-90, SI File No. 1000720.201.
5. GE Certified Design Specification No. 25A5744, Revision 1, "Reactor Vessel – Power Rerate," SI File No. XCEL-05Q-212.
6. GE Design Specification No. 23A1581, Revision 3, "Reactor Vessel – Recirculation Inlet Safe End," SI File No. 1000720.202.
7. CB&I Stress Report, Section T8, "Thermal Analysis, Recirculation Inlet Nozzle, Monticello Reactor Pressure Vessel," SI File No. MONT-14Q-202.
8. ANSYS Mechanical and PrepPost, Release 11.0 (w/ Service Pack 1), ANSYS, Inc., August 2007.

Table 1: RPV Material Properties (SA-533 Gr. B)

Temperature (°F)	Thermal Conductivity[1] (Btu/hr-ft-°F)	Thermal Diffusivity[1] (ft^2/hr)	Specific Heat[2] (Btu/lb-°F)	Mean Coefficient of Thermal Expansion[3] x 10^{-6} (in/in/°F)	Elastic Modulus[4] x 10^6 (psi)
-100	22.3	0.429	0.1063	7.02	30.4
70	22.3	0.429	0.1063	7.02	29.9
200	23.4	0.420	0.1139	7.25	29.5
300	23.8	0.408	0.1193	7.43	29.0
400	23.8	0.389	0.1251	7.58	28.6
500	23.5	0.366	0.1313	7.70	28.0
600	23.0	0.342	0.1375	7.83	27.4

Notes:
1. Reference [3], Table I-4.0
2. Calculated assuming constant density of 0.283 lb/in³ {6, § 4.0}
3. Reference [3], Table I-5.0, Material Group D. For 70°F and below the instantaneous coefficient of thermal expansion is used.
4. Reference [3], Table I-6.0

Table 2: Nozzle Material Properties (SA-508 Class II)

Temperature (°F)	Thermal Conductivity[1] (Btu/hr-ft-°F)	Thermal Diffusivity[1] (ft^2/hr)	Specific Heat[2] (Btu/lb-°F)	Mean Coefficient of Thermal Expansion[3] x 10^{-6} (in/in/°F)	Elastic Modulus[4] x 10^6 (psi)
-100	23.6	0.454	0.1063	6.41	30.4
70	23.6	0.454	0.1063	6.41	29.9
200	24.0	0.427	0.1149	6.67	29.5
300	23.9	0.406	0.1204	6.87	29.0
400	23.6	0.385	0.1253	7.07	28.6
500	23.1	0.362	0.1305	7.25	28.0
600	22.4	0.339	0.1351	7.42	27.4

Notes:
1. Reference [3], Table I-4.0
2. Calculated assuming constant density of 0.283 lb/in³ {6, § 4.0}
3. Reference [3], Table I-5.0, Material Group A. For 70°F and below the instantaneous coefficient of thermal expansion is used.
4. Reference [3], Table I-6.0

Table 3: Cladding Material Properties (Type 304 Stainless Steel)

Temperature (°F)	Thermal Conductivity[1] (Btu/hr-ft-°F)	Thermal Diffusivity[1] (ft^2/hr)	Specific Heat[2] (Btu/lb-°F)	Mean Coefficient of Thermal Expansion[3] x 10^{-6} (in/in/°F)	Elastic Modulus[4] x 10^6 (psi)
-100	8.6	0.151	0.1165	7.93	29.4
70	8.6	0.151	0.1165	7.93	28.3
200	9.3	0.156	0.1219	8.37	27.7
300	9.8	0.160	0.1252	8.70	27.1
400	10.4	0.165	0.1289	8.97	26.6
500	10.9	0.170	0.1311	9.23	26.1
600	11.3	0.174	0.1328	9.42	25.4

Notes:

1. Reference [3], Table I-4.0
2. Calculated assuming constant density of 0.283 lb/in^3 {6, § 4.0}
3. Reference [3], Table I-5.0. For 70°F and below the instantaneous coefficient of thermal expansion is used.
4. Reference [3], Table I-6.0

Table 4: Polynomial Coefficients for Unit Pressure Load Case

Path	C0	C1	C2	C3
1	49213.37	-10902.90	1312.79	-69.57
2	14173.12	-811.72	-65.35	18.81

Table 5: Polynomial Coefficients for Shutdown Transient Load Case, Path 1

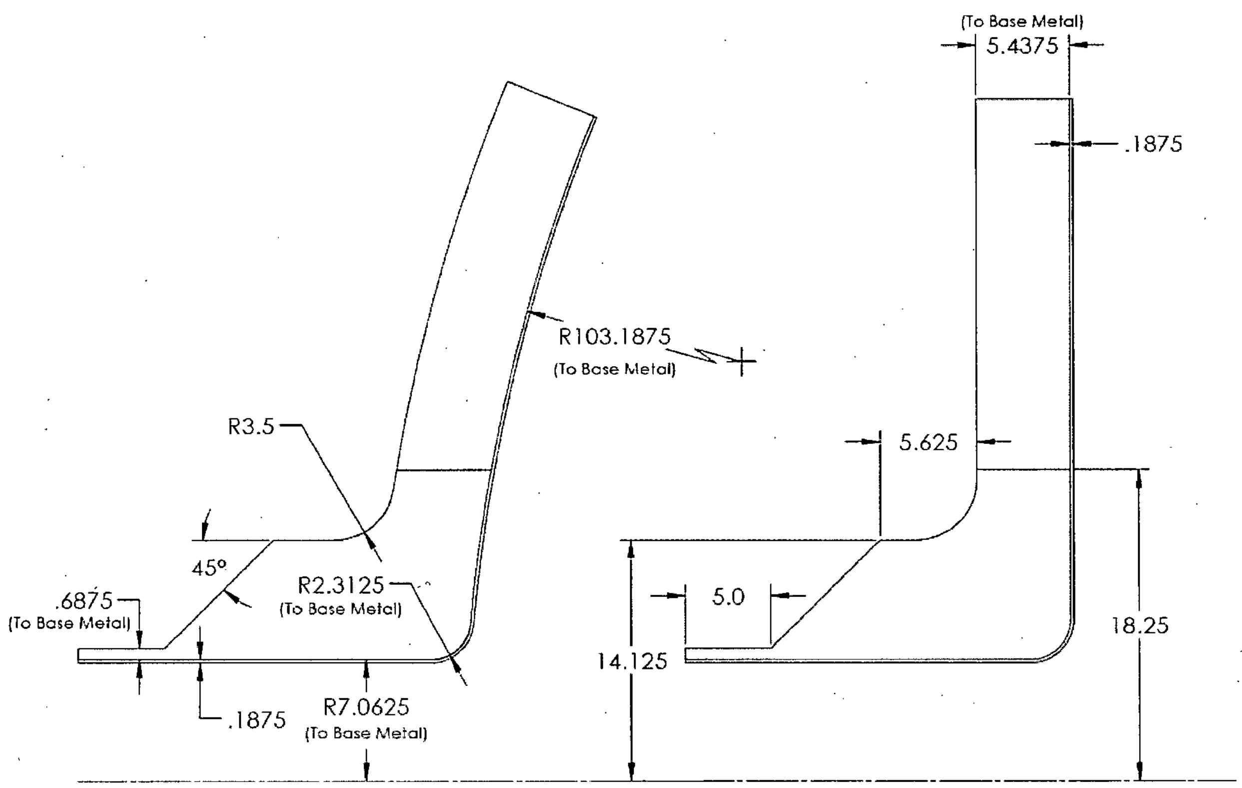
Time (sec)	C0	C1	C2	C3
1	-6722.08	8696.04	-1912.93	116.83
254	-5531.75	7947.40	-1793.43	110.78
506	-4346.28	7318.64	-1709.45	107.12
759	-3307.22	6822.85	-1651.66	104.93
1011	-2418.18	6418.89	-1607.81	103.39
1264	-1660.09	6076.91	-1571.06	102.11
1516	-1013.77	5779.70	-1538.20	100.90
1769	-460.83	5515.83	-1507.48	99.71
2021	21.38	5271.41	-1476.63	98.39
2274	462.89	5027.22	-1442.28	96.77
2526	850.85	4800.84	-1408.83	95.13
2779	1191.14	4593.47	-1377.07	93.55
3032	1490.50	4402.57	-1346.67	91.98
3284	1756.12	4222.81	-1316.43	90.36
3537	1994.29	4049.00	-1285.52	88.64
3789	2208.44	3883.19	-1255.06	86.93
4042	2402.20	3724.10	-1224.84	85.19
4294	2578.78	3570.67	-1194.84	83.45
4547	2740.49	3422.22	-1165.03	81.69
4799	2889.54	3278.02	-1135.41	79.93
5052	3027.71	3137.56	-1105.96	78.15
5304	3156.48	3000.29	-1076.66	76.38
5557	3277.22	2865.73	-1047.50	74.60
5810	3396.17	2729.05	-1017.50	72.76
6062	3514.35	2590.69	-987.03	70.88
6315	3626.38	2457.02	-957.63	69.08
6567	3727.94	2331.85	-930.11	67.40
6820	3814.07	2215.50	-904.03	65.80
7072	3891.92	2099.85	-877.09	64.09
7325	3969.13	1979.51	-848.68	62.29
7577	4043.46	1860.99	-820.78	60.54
7830	4115.59	1743.34	-792.98	58.78
8083	4185.63	1626.56	-765.29	57.04
8335	4253.77	1510.50	-737.70	55.29
8588	4320.05	1395.16	-710.20	53.55
8840	4384.58	1280.47	-682.79	51.82
9093	4447.38	1166.46	-655.49	50.09
9345	4514.89	1047.52	-627.10	48.29
9598	4585.64	924.71	-597.89	46.45
9850	4653.43	802.99	-568.91	44.61
10103	4718.14	682.45	-540.16	42.80
10355	4777.90	563.53	-511.66	41.00
10608	4835.19	446.06	-483.49	39.22
10861	4891.19	330.05	-455.65	37.46
11113	4946.07	215.02	-428.00	35.72
11366	4999.59	101.07	-400.58	33.98
11618	5051.74	-11.92	-373.35	32.26
11871	5102.55	-123.91	-346.34	30.55
12123	5151.88	-234.89	-319.53	28.86
12376	5199.72	-344.84	-292.93	27.18
12628	5246.15	-453.89	-266.52	25.50
12881	5291.13	-561.95	-240.31	23.85
13133	5333.52	-668.39	-214.40	22.20
13386	5374.00	-774.05	-188.59	20.57
13639	5414.28	-880.18	-162.64	18.92
13891	5454.30	-986.08	-136.79	17.28
14144	5493.21	-1090.68	-111.28	15.67

Time (sec)	C0	C1	C2	C3
14396	5530.64	-1193.71	-86.15	14.08
14649	5566.23	-1295.23	-61.33	12.51
14901	5600.19	-1395.47	-36.77	10.95
15154	5632.42	-1494.40	-12.49	9.41
15406	5662.90	-1592.05	11.52	7.89
15659	5691.63	-1688.48	35.28	6.38
15911	5718.61	-1783.64	58.77	4.89
16164	5743.72	-1877.50	81.99	3.42
16202	5639.01	-1805.17	68.89	4.15
16241	5492.42	-1708.29	52.31	5.03
16356	4992.41	-1433.42	13.29	6.82
16701	3749.82	-911.66	-36.90	8.20
17085	2714.93	-538.48	-61.41	8.25
17468	1950.48	-281.31	-74.02	7.94
17852	1387.31	-96.61	-81.55	7.58
18235	972.25	38.97	-86.53	7.26
18619	665.99	139.59	-90.03	7.00
19003	439.73	214.67	-92.55	6.79
19386	272.34	270.87	-94.41	6.63
19770	148.33	313.01	-95.78	6.50
20000	86.80	334.10	-96.46	6.44

Table 6: Polynomial Coefficients for Shutdown Transient Load Case, Path 2

Time (sec)	C0	C1	C2	C3
1	-6200.89	10439.62	-2600.90	179.75
254	-5087.74	9760.55	-2490.00	173.62
506	-4060.97	9240.06	-2422.53	170.48
759	-3205.24	8844.50	-2378.54	168.69
1011	-2499.22	8523.97	-2344.30	167.33
1264	-1914.76	8250.25	-2313.73	166.04
1516	-1427.61	8007.39	-2284.12	164.66
1769	-1019.86	7787.39	-2254.62	163.18
2021	-666.29	7574.87	-2222.46	161.42
2274	-337.14	7350.53	-2184.00	159.15
2526	-50.29	7139.61	-2146.07	156.88
2779	200.06	6942.86	-2109.27	154.63
3032	422.32	6755.95	-2072.55	152.33
3284	626.03	6570.24	-2033.77	149.81
3537	811.60	6388.89	-1994.73	147.25
3789	982.60	6211.28	-1955.43	144.64
4042	1140.81	6037.03	-1915.89	141.99
4294	1288.24	5865.67	-1876.17	139.31
4547	1426.65	5696.82	-1836.32	136.61
4799	1557.40	5530.08	-1796.36	133.87
5052	1681.55	5365.32	-1756.35	131.12
5304	1800.04	5202.25	-1716.30	128.36
5557	1913.67	5040.56	-1676.21	125.58
5810	2029.06	4874.51	-1634.78	122.70
6062	2145.02	4707.48	-1593.22	119.82
6315	2254.04	4547.65	-1553.63	117.09
6567	2351.13	4398.12	-1516.46	114.52
6820	2431.66	4253.25	-1479.27	111.90
7072	2510.07	4102.41	-1439.51	109.08
7325	2588.36	3952.02	-1400.20	106.31
7577	2666.64	3801.65	-1360.94	103.54
7830	2743.03	3652.10	-1321.81	100.79
8083	2817.57	3503.30	-1282.79	98.03
8335	2890.25	3355.20	-1243.87	95.29
8588	2961.03	3207.85	-1205.08	92.55
8840	3029.98	3061.12	-1166.38	89.82
9093	3097.02	2915.16	-1127.83	87.09
9345	3169.57	2762.80	-1087.71	84.26
9598	3245.44	2606.21	-1046.60	81.36
9850	3318.00	2451.15	-1005.85	78.48
10103	3386.15	2297.91	-965.50	75.63
10355	3445.77	2147.25	-925.60	72.81
10608	3501.87	1998.65	-886.19	70.04
10861	3556.69	1851.41	-847.08	67.28
11113	3610.05	1705.41	-808.25	64.54
11366	3661.94	1560.66	-769.71	61.82
11618	3712.23	1417.13	-731.45	59.12
11871	3760.90	1274.78	-693.47	56.44
12123	3807.78	1133.72	-655.78	53.77
12376	3852.89	993.89	-618.37	51.13
12628	3896.12	855.37	-581.26	48.51
12881	3937.75	717.85	-544.38	45.90
13133	3976.47	582.16	-507.87	43.32
13386	4013.29	446.86	-471.33	40.73
13639	4049.87	311.16	-434.69	38.14
13891	4085.75	176.35	-398.36	35.57
14144	4119.86	43.67	-362.63	33.05

Time (sec)	C0	C1	C2	C3
14396	4151.84	-86.95	-327.39	30.56
14649	4181.70	-215.98	-292.50	28.09
14901	4209.47	-343.33	-258.00	25.65
15154	4235.17	-469.15	-223.85	23.24
15406	4258.58	-593.29	-190.08	20.85
15659	4279.86	-715.89	-156.67	18.48
15911	4298.91	-836.90	-123.62	16.14
16164	4315.68	-956.29	-90.95	13.83
16202	4203.65	-882.83	-104.76	14.66
16241	4055.95	-792.80	-120.19	15.54
16356	3594.44	-570.25	-148.47	16.79
16701	2552.53	-205.01	-169.10	16.61
17085	1742.38	30.75	-169.71	15.41
17468	1178.12	180.79	-164.84	14.17
17852	785.17	281.50	-159.27	13.12
18235	511.57	350.98	-154.27	12.27
18619	321.23	399.56	-150.11	11.60
19003	188.95	433.77	-146.73	11.08
19386	97.16	457.94	-144.02	10.67
19770	33.57	475.05	-141.87	10.35
20000	3.47	483.29	-140.76	10.19



Notes:
1. Dimensions from Reference [4].
2. Units in inches.

Figure 1: Finite Element Model Geometry

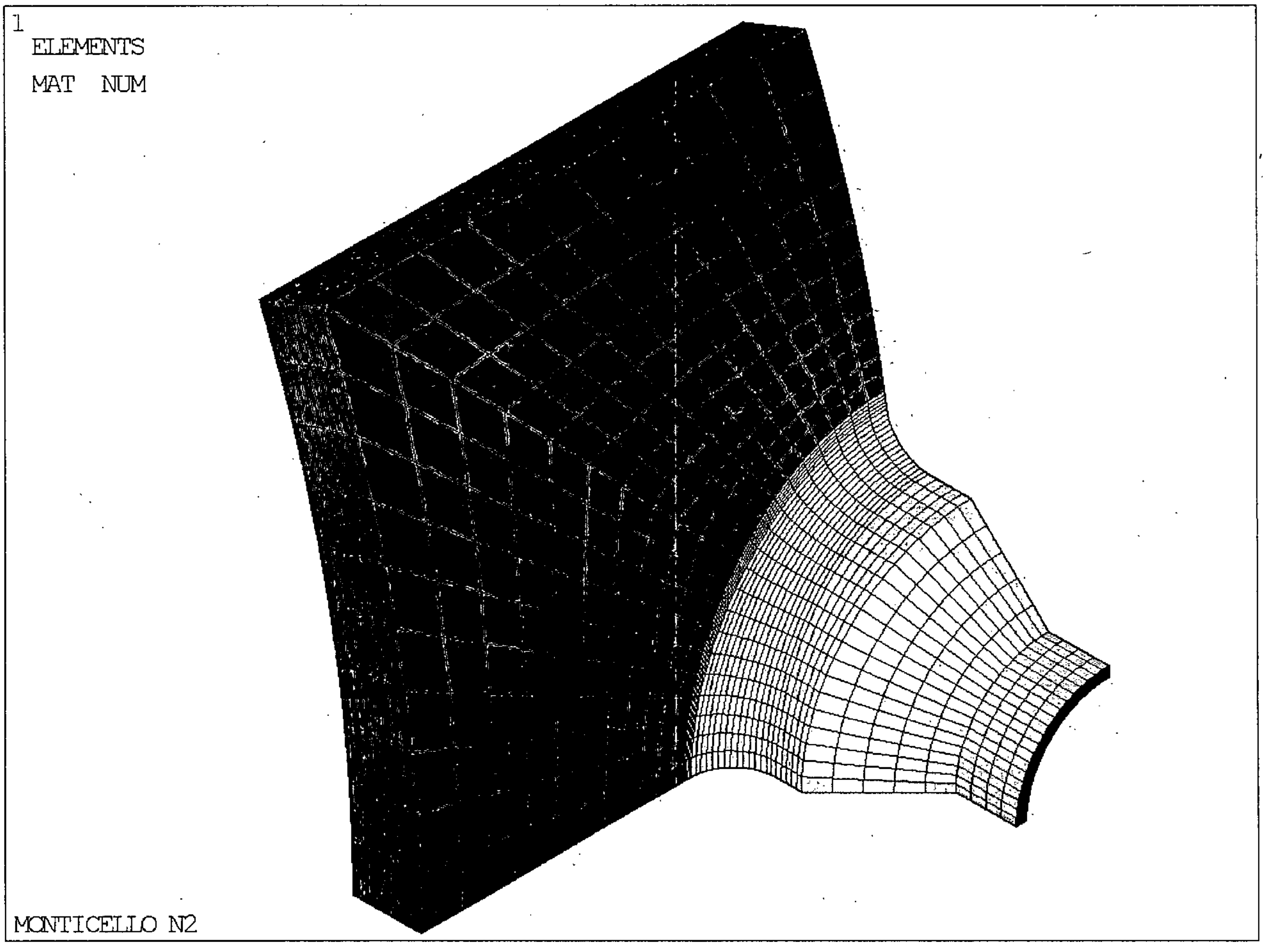


Figure 2: FEM Overview

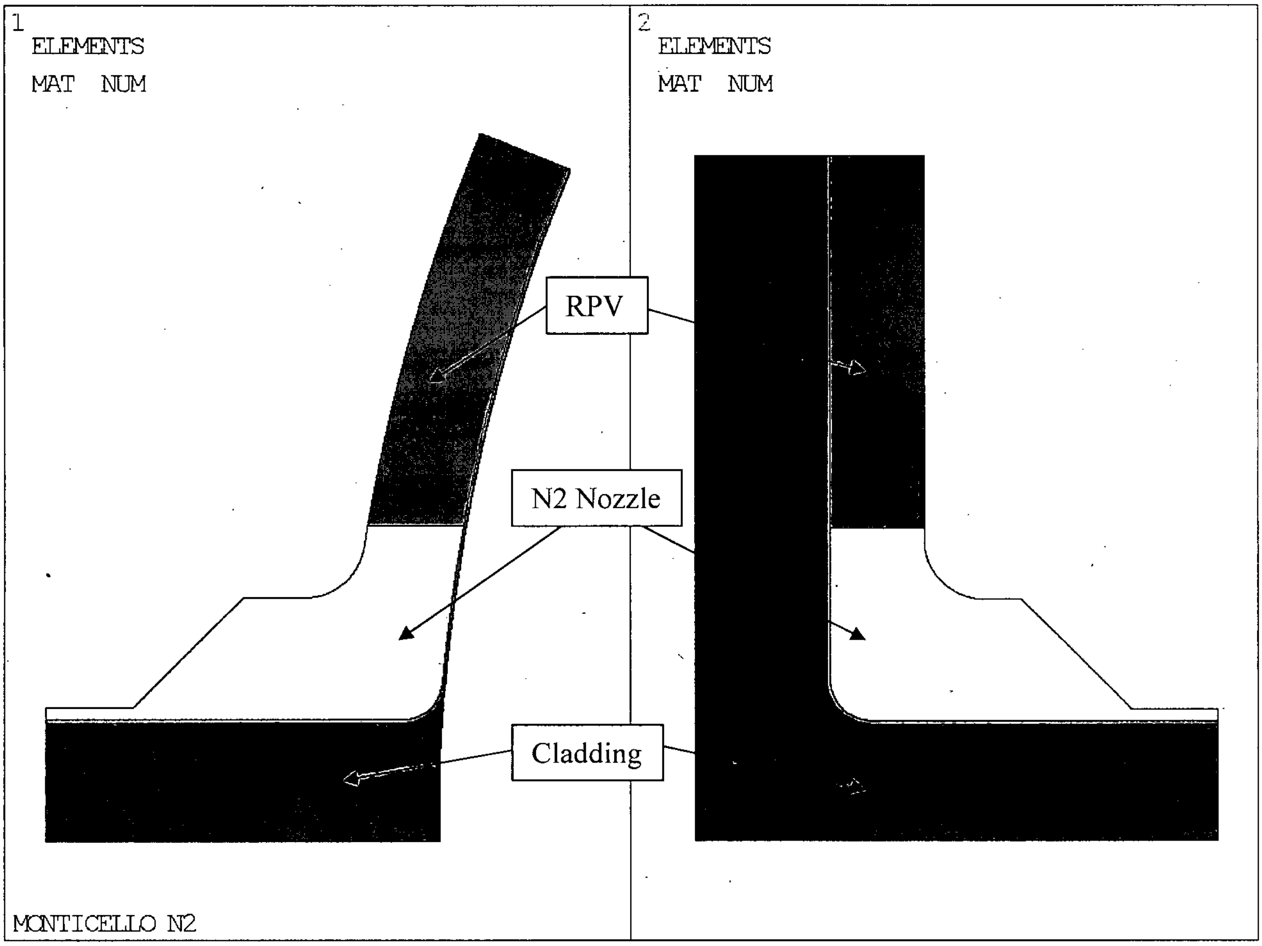


Figure 3: FEM Detail

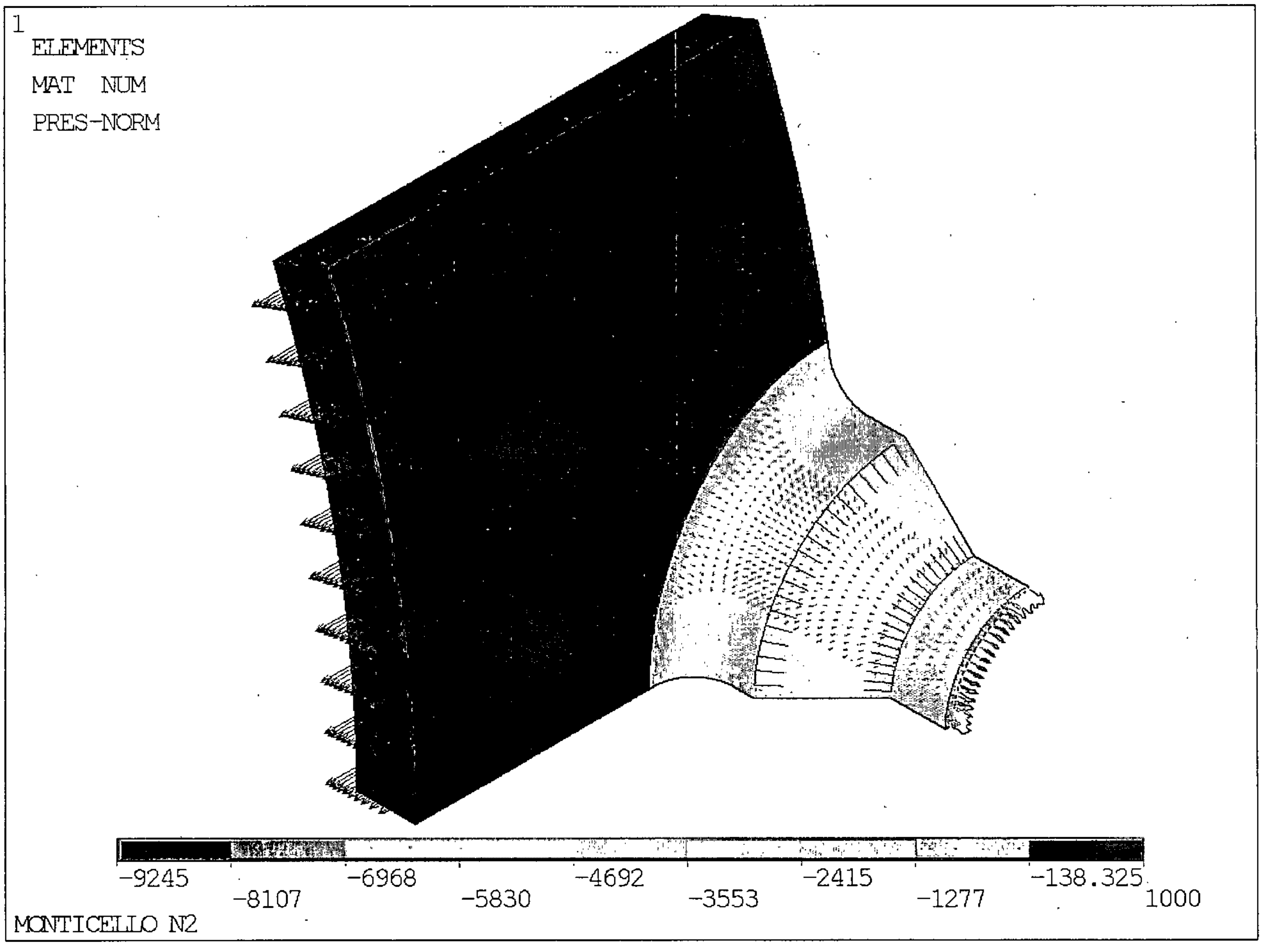


Figure 4: Unit Pressure Loading with Cap Loads

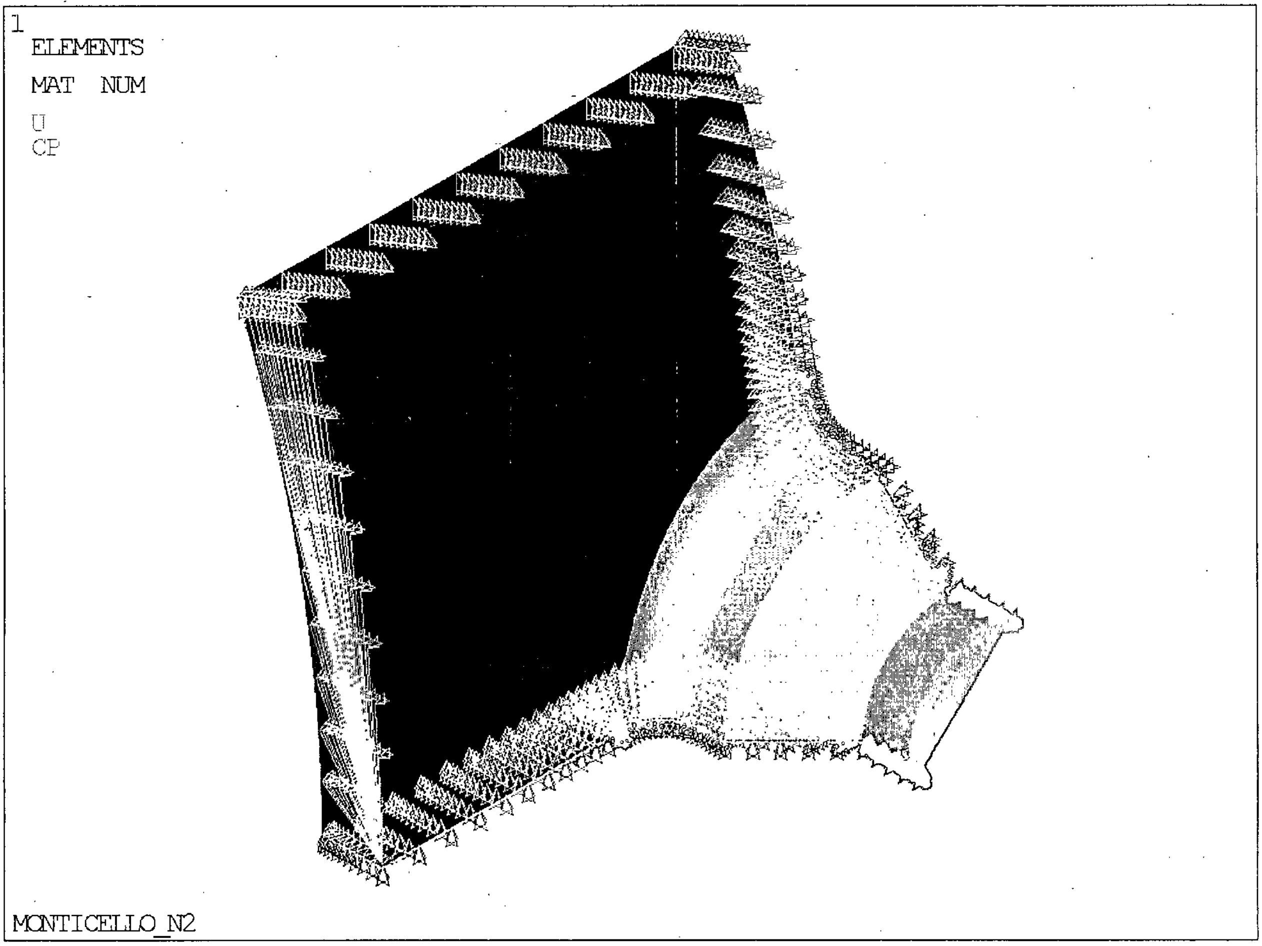


Figure 5: FEM Boundary Conditions

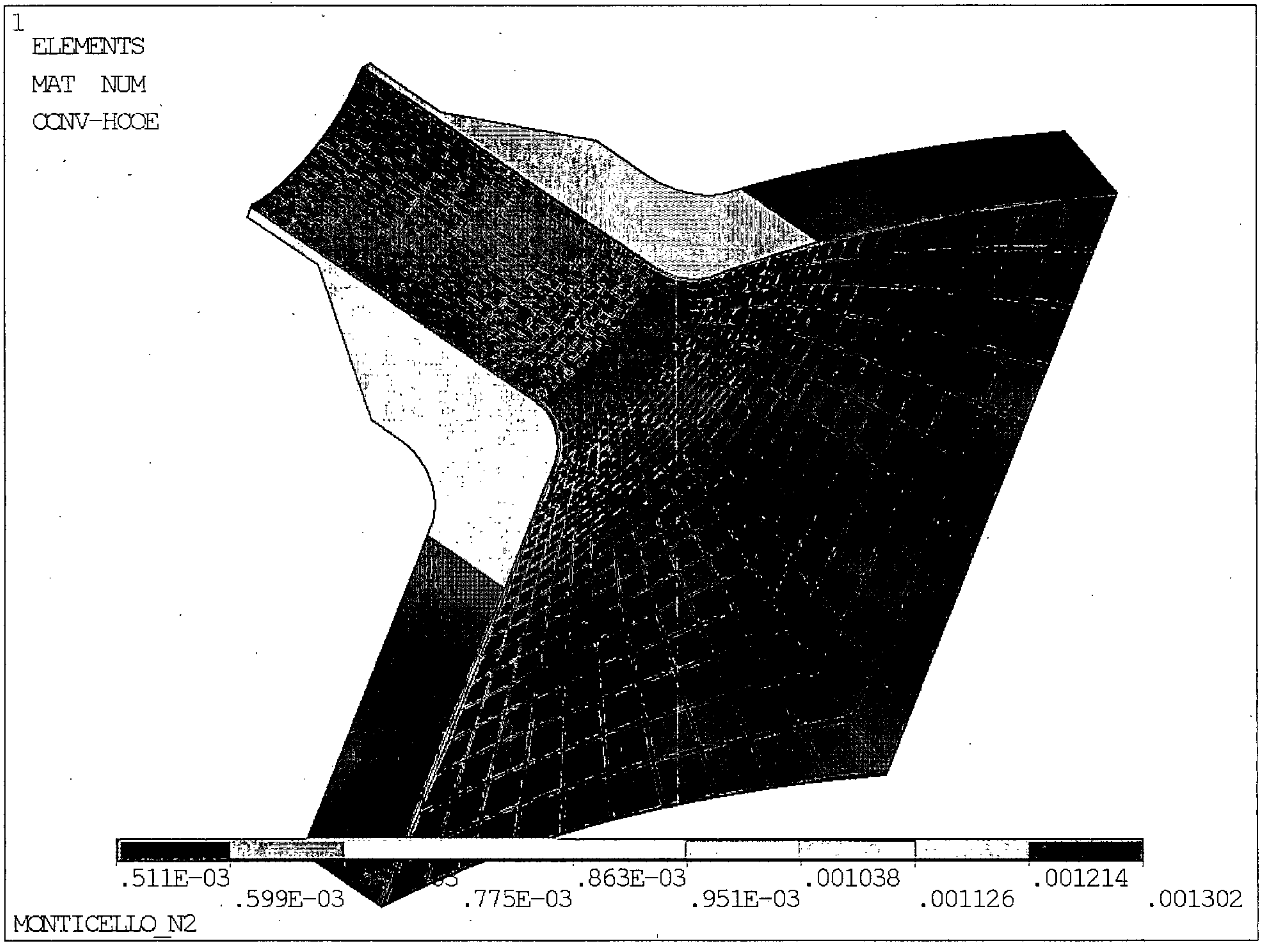


Figure 6: FEM Convection Film Coefficients (Btu/sec-in^2-°F)

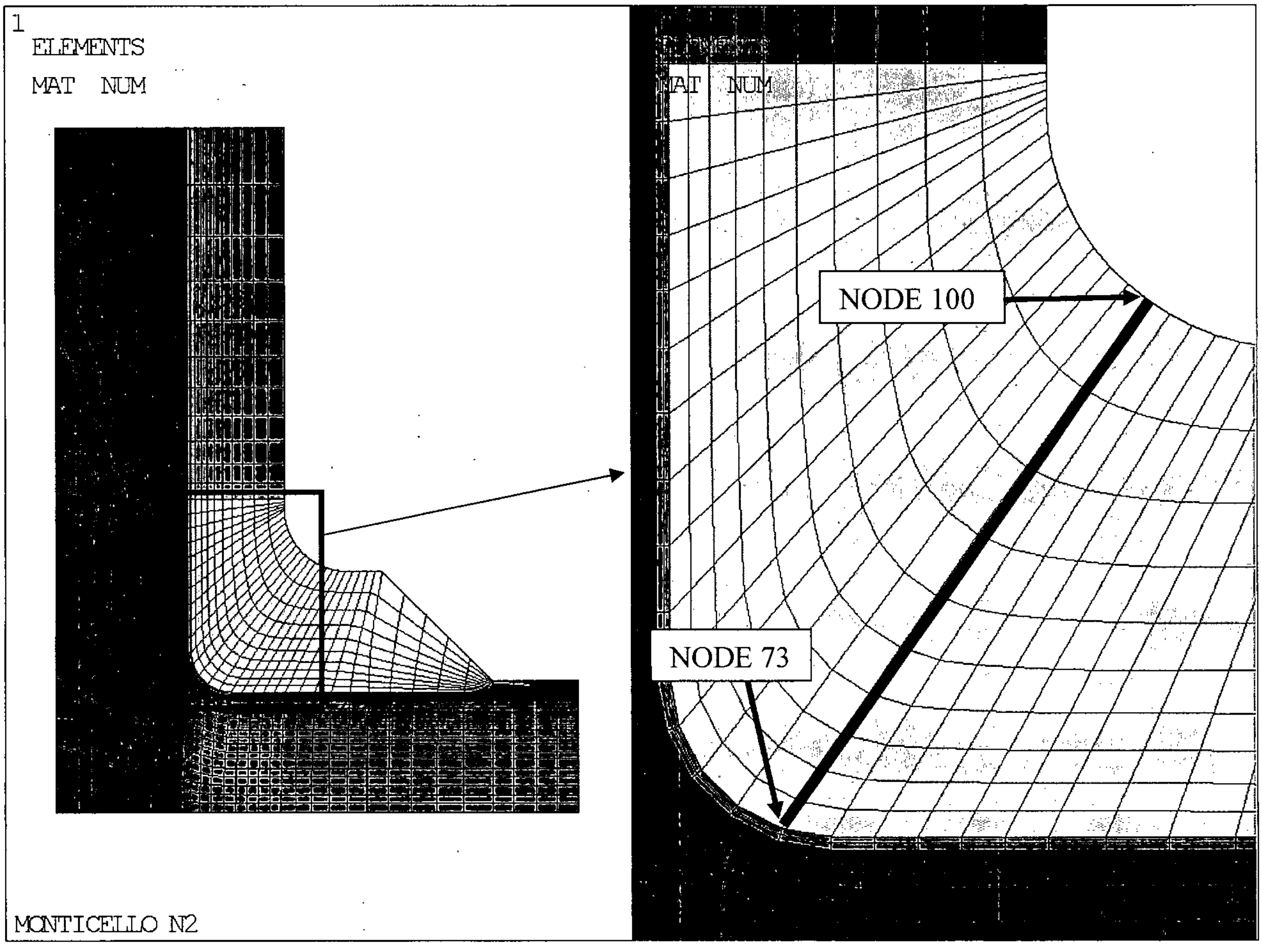


Figure 7: Path 1 Location

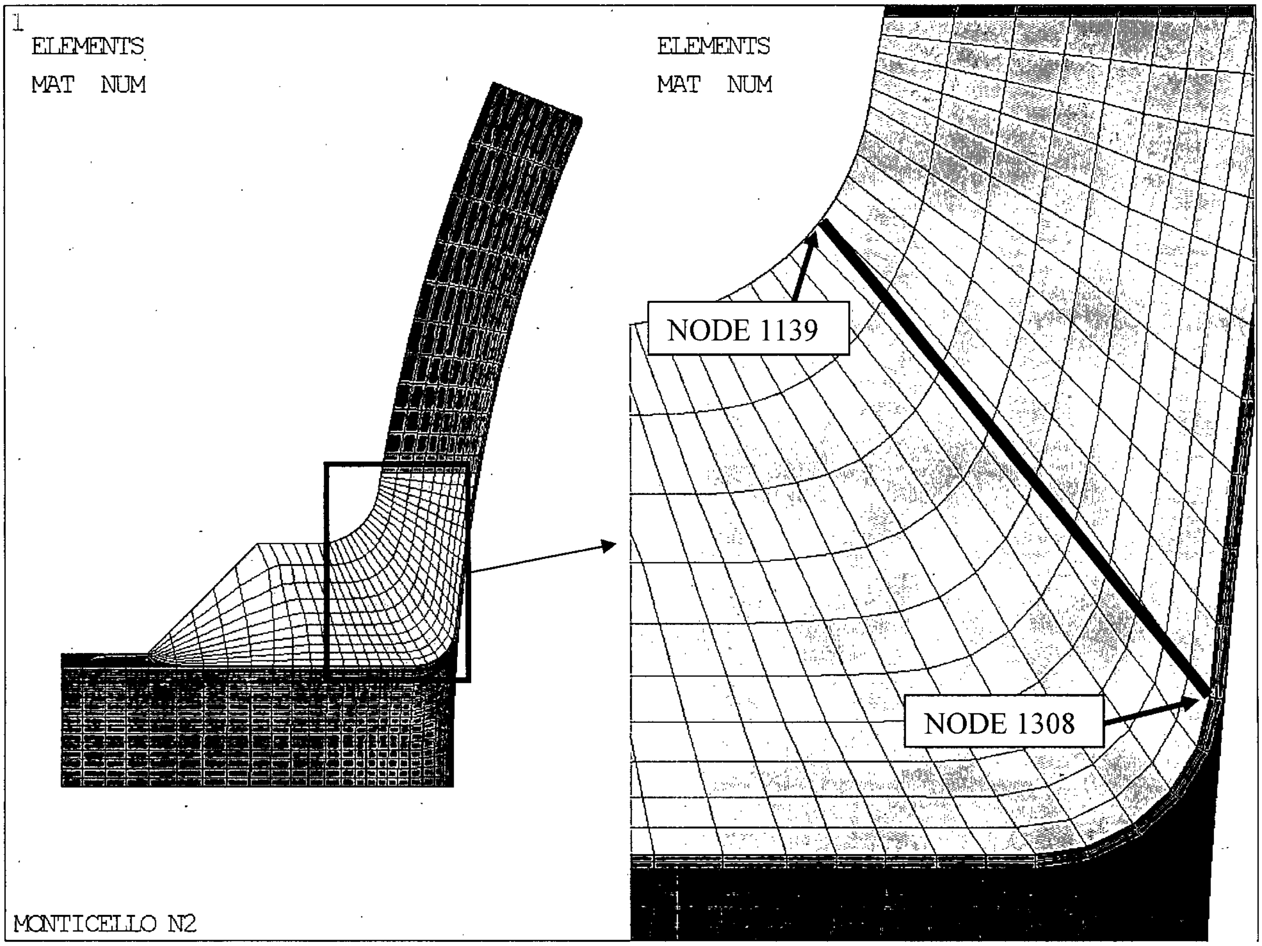


Figure 8: Path 2 Location

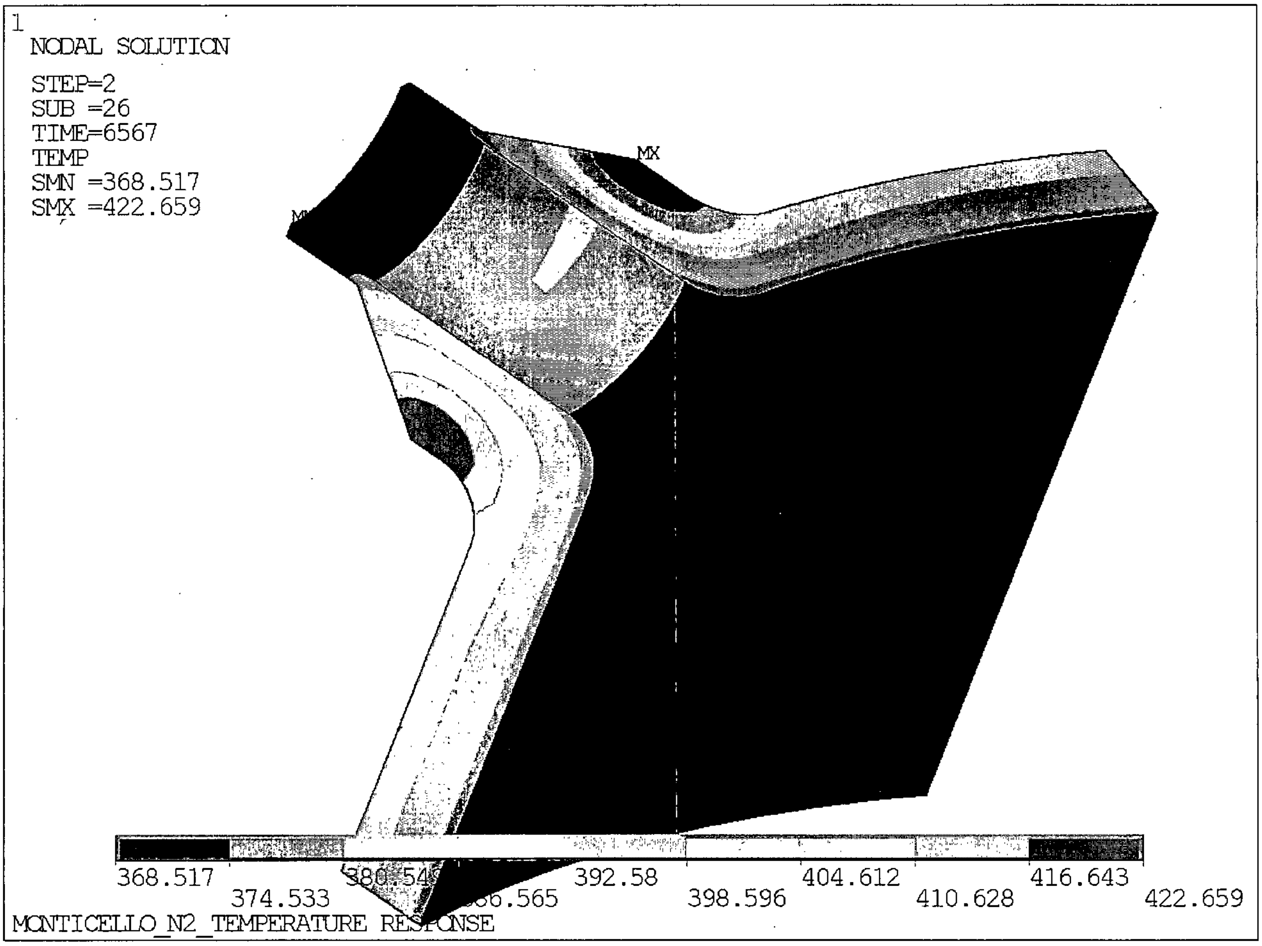


Figure 9: Temperature Response, Time = 6,567 Seconds

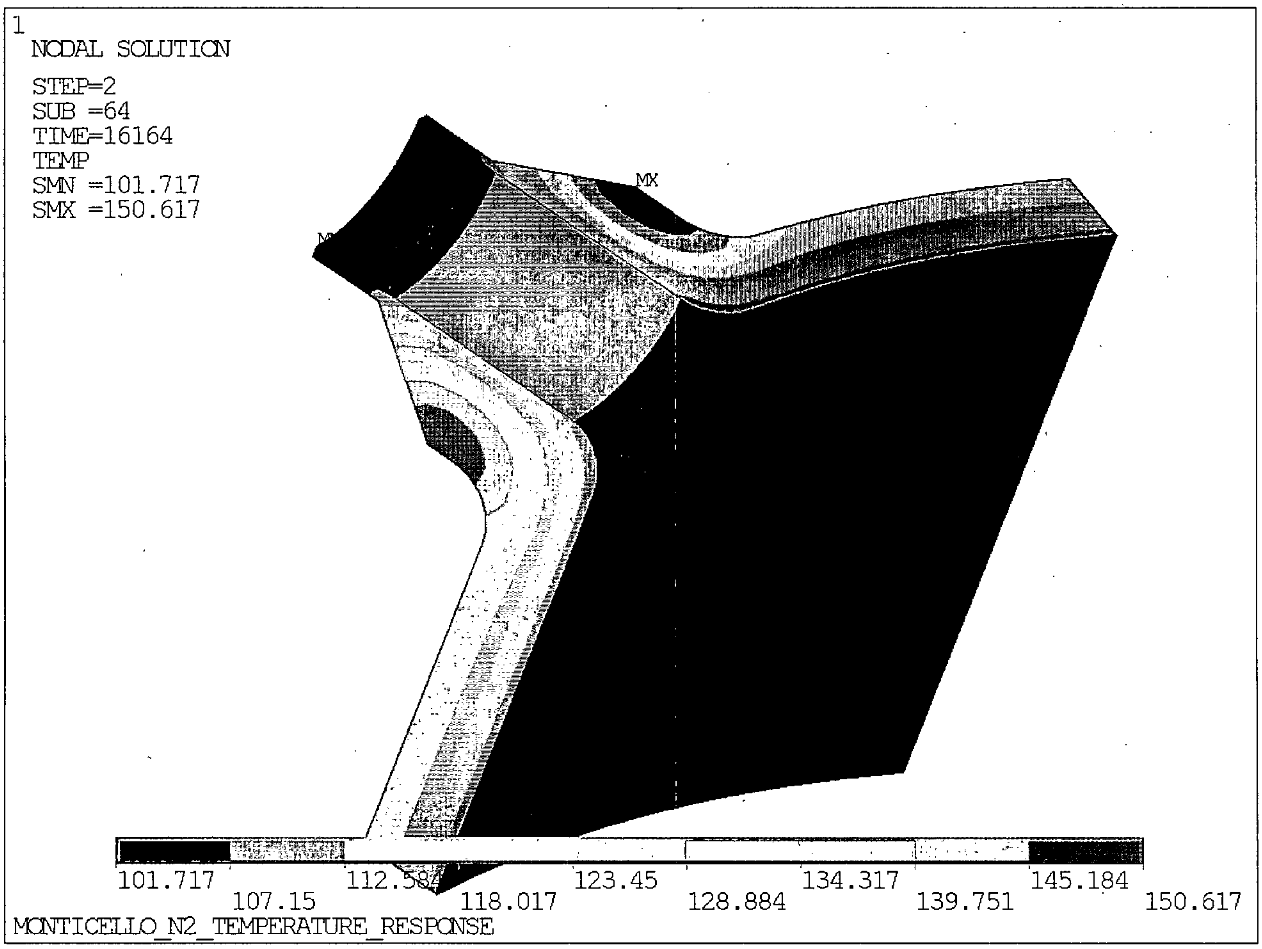


Figure 10: Temperature Response, Time = 16,164 Seconds

APPENDIX A: LIST OF SUPPORTING FILES

ANSYS File	Description
MONT_N2.INP	Finite element model geometry input file, including temperature dependent material properties
STR_MONT_N2.INP	Unit pressure input file
THM_MONT_N2.INP	Thermal transient input file
THMSTR_MONT_N2.INP	Thermal transient stress extraction file
THM_MONT_N2_mntr.INP	Thermal transient file containing LDREAD and SOLVE commands
PRSTR_PATH#.OUT	Hoop stress output file for unit pressure where #=1 for path 1 and #=2 for path 2
PRSTR_PATH#.CSV	Comma Separated Value file containing polynomial stress coefficients due to unit pressure for path #, where #=1 for path 1 and #=2 for path 2
THMSTR_PATH#.OUT	Hoop stress output file for thermal transient where #=1 for path 1 and #=2 for path 2
THMSTR_PATH#.CSV	Comma Separated Value file containing polynomial stress coefficients due to thermal transient for path #, where #=1 for path 1 and #=2 for path 2