VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

April 13, 2010

U. S. Nuclear Regulatory Commission
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Washington, DC 20555

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VIRGINIA ELECTRIC AND POWER COMPANY
SURRY POWER STATION UNITS 1 AND 2
NRC GENERIC LETTER 2004-02
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
RESULTS OF FINITE ELEMENT ANALYSIS OF PIPE INSULATION JACKETING AND BAND SPACING

By letter dated December 17, 2009 (ADAMS ML093521426), Virginia Electric and Power Company (Dominion) provided its response to an NRC request for additional information (RAI) for Surry Power Station (Surry) Units 1 and 2 regarding its resolution of the issues identified in Generic Letter (GL) 2004-02, *Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors*. In the response to RAI question number 2, Dominion committed to address the difference in band spacing and jacket material used in the Surry containments for encapsulating pipe insulation with the band spacing and jacket material used in the Ontario Power Generation (OPG) air jet impact testing. To address the differences, Dominion performed finite element analysis (FEA) modeling to demonstrate that the stresses induced on the jacketing due to a high energy line break (HELB) would be significantly less than the tensile strength of the stainless steel jacketing and bands used in the Surry Units 1 and 2 containments.

The FEA evaluation is summarized in the attachment. The evaluation: 1) documents the differences in piping insulation/jacketing responses due to the different band spacing and jacketing material used in the OPG testing versus the band spacing and jacketing material installed in the Surry Units 1 and 2 containments, and 2) documents that the maximum stresses in the jacketing material and bands used in the Surry insulation jacketing configurations are less than the material allowables. The FEA evaluation includes bounding cases that provide reasonable assurance that the stainless steel jacketing configurations installed in the Surry Units 1 and 2 containments on asbestos and calcium-silicate insulation would maintain their structural integrity and intended functionality under impingement from a HELB jet.

Should you have any questions or require additional information, please contact Mr. Gary D. Miller at (804) 273-2771.

Sincerely,

J. Alan Price
Vice President – Nuclear Engineering

Commitments made in this correspondence: None

Attachment:

- Finite Element Analysis of Stainless Steel Jacketing and Band Spacing for In-Containment Piping Insulation, Surry Power Station Units 1 and 2

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Mr. J. Alan Price, who is Vice President – Nuclear Engineering, of Virginia Electric and Power Company. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 13TH day of April, 2010.

My Commission Expires: May 31, 2010.

VICKI L. HULL
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140542
My Commission Expires May 31, 2010

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Attachment

FINITE ELEMENT ANALYSIS OF STAINLESS STEEL JACKETING AND BAND SPACING FOR IN-CONTAINMENT PIPING INSULATION

SURRY POWER STATION UNITS 1 AND 2

**VIRGINIA ELECTRIC AND POWER COMPANY
(DOMINION)**

Finite Element Analysis of Stainless Steel Jacketing and Band Spacing for In-Containment Piping Insulation

Surry Power Station Units 1 and 2

Purpose & Applicability

By letter dated December 17, 2009 (ADAMS ML093521426), Virginia Electric and Power Company (Dominion) provided its response to an NRC request for additional information (RAI) for Surry Power Station (Surry) Units 1 and 2 regarding its resolution of the issues identified in Generic Letter (GL) 2004-02, *Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors.* In the response to RAI question number 2, Dominion committed to disposition the difference in band spacing and jacket material used in the Surry containments for encapsulating pipe insulation versus the band spacing and jacket material used in the Ontario Power Generation (OPG) Air Jet Impact Testing (AJIT). To address the differences, Dominion stated that it would perform finite element analysis (FEA) modeling to demonstrate that the stresses induced on the jacketing due to a high energy line break (HELB) would be significantly less than the tensile strength of the stainless steel jacketing used at Surry. The FEA modeling and evaluation have been completed and the results are provided below.

References

1.0 NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," September 13, 2004.

2.0 Nuclear Energy Institute (NEI) document NEI 04-07 Rev. 0, December 2004, "Pressurized Water Reactor Sump Performance Evaluation Methodology."

3.0 NRC's SER to NEI 04-07, Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Volume 2, December 6, 2004.

4.0 OPG Test Report N-REP-34320-10000, Revision 0, "Jet Impact Tests – Preliminary Results and their Application", Ontario Power Generation, April 2001.

5.0 AISC Manual of Steel Construction, 8th Edition.

6.0 Surry Specification SUI-0009, Revision 4, "Installation of Thermal Insulation."

7.0 Surry Specification NUS-0117, Revision 5, "Thermal Insulation."

8.0 Surry Calculation ME-0777, Rev.1, "Debris Generation due to LOCA within Containment for Resolution of GSI-191."

9.0 STAAD.Pro 2007, Finite Element Structural Analysis & Design Program, Sargent & Lundy Program Number 03.7.745-7.4, QA Verified Program.

10.0 DOM001-RPT-002, Rev. 0, Including Add 001, "Report on Surry Unit 1 Containment Building Walkdowns for Emergency Sump Strainer Issues", October 7, 2003. (Enercon Services)

11.0 DOM001-RPT-003, Rev. 0, "Report on Surry Unit 2 Containment Building Walkdowns for Emergency Sump Strainer Issues", May 24, 2004. (Enercon Services)

12.0 Marks Standard Handbook for Mechanical Engineers, 7th Edition, McGraw-Hill Book Company.

13.0 ASTM Designation: C1423-98, "Standard Guide for Selecting Jacketing Materials for Thermal Insulation."

14.0 ASTM Designation: A240/A240M-09, "Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications."

15.0 DOM001-RPT-003-BINDER1, Rev. 0, Add. 001, "Surry Unit 2 Debris Walkdown Packages S2-DWD-001A through S2-DWD-006D."

16.0 DOM001-RPT-003-BINDER2, Rev. 0, Add. 001, "Surry Unit 2 Debris Walkdown Packages S2-DWD-006E through S2-DWD-010M."

17.0 DOM001-RPT-003-BINDER3, Rev. 0, Add. 001, "Surry Unit 2 Debris Walkdown Packages S2-DWD-010N through S2-DWD-017G."

18.0 DOM001-RPT-003-BINDER4, Rev. 0, Add. 001, "Surry Unit 2 Debris Walkdown Packages S2-DWD-018A through S2-DWD-032A."

19.0 DOM001-RPT-003-BINDER5, Rev. 0, Add. 001, "Surry Unit 2 Debris Walkdown Packages S2-DWD-032B through S2-DWD-MISC."

Design Inputs

1.0 The insulation jacketing configuration for the baseline model (Model 1) simulates the test samples used in the OPG Test Report (Reference 4.0). The configuration of the test samples used in the OPG Test Report is described below.

- Test samples installed on 2 inch nominal diameter pipe,
- Test samples included 1 inch thick calcium-silicate (cal-sil) insulation,
- 0.016 inch thick Aluminum 1100 jacketing, and
- Secured with 0.5 inch wide by 0.020 inch thick stainless steel bands spaced 8 inches apart.

2.0 The ultimate tensile strength of Aluminum 1100 is 13 ksi (Reference 12.0).

3.0 The insulation jacketing installed on calcium silicate (cal-sil) and asbestos (AS) insulation at Surry Power Station is type 304 or 316 stainless steel (Reference 6.0). The ultimate tensile strength, as specified by the Standard Handbook for Mechanical Engineers (Reference 12.0), for both types 304 and 316 stainless steel is 85 ksi. The Standard Handbook uses the book of ASTM Standards for its source of material properties.

The ASTM designations C1423 and A240 (References 13.0 and 14.0) document the material composition and properties used for stainless steel sheet metal. ASTM A240 identifies that for type 304 and 316 stainless steel the tensile strength is 75 ksi. However, there are certain subtypes of 304 and 316 stainless steel with a tensile strength upwards of 90 ksi.

This analysis is performed utilizing an ultimate tensile strength of 85 ksi for the stainless steel jacketing systems at Surry Power Station. However, for completeness the results of this analysis are evaluated against a tensile strength of 85 ksi and 75 ksi.

4.0 Insulation stiffness values (From Pittsburgh Corning Product Brochures).

Insulation Type	Compressive Strength at 5% Deformation (lbs/in^2)	Young's Modulus – E_C (psi)
Asbestos (Unibestos)	12.5	250
Cal-Sil	100	2000

Young's Modulus for cal-sil and asbestos is calculated using compression strength of insulation for 5% strain (i.e. for asbestos E_C = 12.5 / 0.05 = 250 psi).

5.0 Zone of Influence (ZOI) and destruction pressure for insulation materials (References 3.0 and 8.0).

Insulation System Type	ZOI (Note 1)	Corresponding Destruction Pressure (psi)
Cal-Sil w/ Stainless Steel Jacketing	5.45D	24.0
Asbestos w/ Stainless Steel Jacketing	7.0D	20.6

Note1: D represents the pipe diameter in feet of the hypothetical Loss of Coolant Accident (LOCA) break.

6.0 Calculation of spring constants (K) used to model the radial stiffness of the insulation material in the FEA.

For a typical Finite Element Model (FEM) node representing the jacketing/insulation components, the radial stiffness can be calculated as follows:

Radial stiffness of typical node:

$$K = \frac{F}{\Delta T} \qquad \text{Eq. \#1}$$

Where:

K = spring constant in lbs/in for FEM nodes
F = radial force applied at the FEM node
ΔT = compressive deformation of insulation thickness under load F, (in)

The relationship between stress (σ) and strain (ε) of a linear elastic material can be written as:

$$E_C = \frac{\sigma}{\varepsilon} = \frac{F/A}{\Delta T/T} \qquad \text{Eq. \#2}$$

Rearranging Eq. #2,

$$\frac{F}{\Delta T} = \frac{A \cdot E_C}{T}$$

Where:

A = Insulation area per node

$$= \frac{\pi \cdot D_m \cdot L}{N}$$

E_C = Compression Young's Modulus of Insulation (psi)
D_m = mean diameter of the insulation (in) = D_{OD} + T
D_{OD} = outside diameter of pipe (in)
L = length of the model (in) = clear span + band width
N = number of nodes on the surface area of the jacketing in FEA models
T = insulation thickness, (in)

From Eq. #1 and #2,

$$K = \frac{\pi \cdot D_m \cdot L}{N} \cdot \frac{E_C}{T}$$

Example spring constant calculation for Model 1 (P02T1CS).

$$K = \frac{\pi \cdot 3.375 \cdot 8.75}{2070} \cdot \frac{2000}{1} = 89.64 lb/in$$

Model #	ID	Pipe Size (in)	D_{OD} (in)	T (in)	L (in)	Spring Constant, K (lbs/in)
1	P02T1CS	2	2.375	1	8.75	89.64
2	P02T2CS	2	2.375	2	18.75	124.50
3	P08T3CS	8	8.625	3	18.75	220.54
4	P12T4CS	12	12.75	4	18.75	238.32
5	P02T2AS	2	2.375	2	18.75	15.56
6	P08T3AS	8	8.625	3	18.75	27.57
7	P12T4AS	12	12.75	4	18.75	29.79
8	P14T4CS21L	14	14.00	4	21.00	286.84
9	P14T4CS24L	14	14.00	4	24.00	327.82
10	P14T4AS21L	14	14.00	4	21.00	35.86
11	P14T4AS24L	14	14.00	4	24.00	40.98
12	P14T4AS24LB	14	14.00	4	24.00	40.98
13	P02T2AS24LB	2	2.375	2	24.00	19.92
14	P12T4AS18LB	12	12.75	4	18.00	28.60

Note 1: The length (L) for Models 8 to 14 is the length of the clear span only. This is conservative as it slightly reduces the spring constant.

Discussion

1.0 FEA Model Representation

FEA was used to simulate the impact of a HELB jet on the stainless steel jacketing system installed on cal-sil and asbestos insulated pipes in the Surry containments.

The FEA models developed were used to simulate the potential failure mechanism shown in the OPG test report (Reference 4.0). The OPG test report documented that the mode of failure from a HELB jet was exclusively tearing of the jacketing due to pressure acting on the edge of the jacketing seam. The pressure acting on the jacketing seam initiated a peeling effect, where the jacketing was torn along the contact edge of the banding straps securing the insulation to the pipe. The OPG test report documented an FEA model that confirmed the failure mechanism seen in testing. The failure mode documented in the OPG test report FEA model was jacketing tearing due to the high stresses induced in the jacketing along the band interface. The FEA model documented the Von Mises stress in the aluminum jacketing along the band interface peaked at 13 ksi. The peak Von Mises stress equaled the ultimate tensile stress for Aluminum 1100 (13 ksi).

This evaluation compares the same parameters as the OPG test report. In this evaluation the maximum Von Mises stress in the jacketing material is compared to the ultimate tensile strength of the jacketing material.

2.0 Methodology

The FEA evaluated the insulation jacketing system installed on cal-sil and asbestos insulation in the Surry containments. The analysis was performed using FEA program STAAD.Pro 2007 (Reference 9.0). Fourteen (14) three-dimensional (3-D) FEM (Finite Element Models) were developed. The models consisted of 3-noded and 4-noded plate (shell) elements with 6 degrees of freedom per node, and radial elastic springs representing insulation stiffness and contact characteristics with the jacketing.

Plate (shell) elements were used to model the jacketing and band straps. Elastic radial springs are used to model the insulation stiffness characteristics using the specified modulus of elasticity of insulation. The springs act only under compression forces to accurately represent the insulation material contact/interfacing with the jacketing and band materials.

<u>Plant Configuration</u>

Per Specification SUI-0009 (Reference 6.0), the jacketing system used at Surry is type 304 or 316 stainless steel jacketing secured with 0.75 inch wide by 0.02 inch thick (3.0 Assumptions) stainless steel bands spaced 18 inches apart. The stainless steel jacketing can be 0.010, 0.016, or 0.020 inch thick depending on the level of personnel traffic in the location of the pipe.

The insulation systems installed within the Surry Units 1 and 2 containments were inventoried during the 2003 and 2004 refueling outages and documented in References 10.0 and 11.0. Subsequent to the initial inventory, insulation modifications were performed as a result of the GL 2004-02 effort. The modifications installed stainless steel jacketing on previously cloth jacketed asbestos and cal-sil insulated piping. The changes to the insulation systems were documented and included as Addendum 001 to the debris inventory reports (References 10.0 and 11.0).

The insulation inventory was reviewed, and it was determined that cal-sil and asbestos insulation is installed on pipes varying in diameter from 0.75 to 14 inches. The majority of the cal-sil and asbestos insulation is installed on pipes 2 inch NPS (Nominal Pipe Size). Only one 14 inch NPS pipe has asbestos insulation installed. Additionally, it was determined that asbestos and cal-sil insulation installed on pipes greater than 2 inches in diameter are jacketed with 0.016 inch thick stainless steel or greater. The 0.010 inch thick stainless steel sheets are only used on select pipes 2 inches in diameter or less.

FEA Models

To evaluate the Surry stainless steel jacketing configuration, a baseline FEA model was created to reproduce the jacketing system tested in the OPG test report. The jacketing system used in this analysis to model the OPG tested jacketing system was 0.016 inch thick aluminum 1100 jacketing secured with stainless steel bands. The bands were 0.75 inch wide by 0.02 inch thick and spaced approximately 8 inches apart edge to edge.

In addition to the baseline model, thirteen FEA models were created to evaluate the Surry specific jacketing assembly installed on cal-sil and asbestos insulation materials. The thirteen models were created to evaluate the jacketing system installed on different piping configurations at Surry. The jacketing system used at Surry and modeled in this analysis is type 304 stainless steel jacketing secured by either 0.50 or 0.75 inch wide by 0.02 inch thick stainless steel bands spaced 18 inches apart (Reference 6.0 and Assumptions 3.0). The stainless steel jacketing evaluated in the FEA models was either 0.010 or 0.016 inch thick. Table 2.1 documents the models analyzed and the corresponding parameters.

Per specification SUI-0009 (Reference 6.0), the bands are installed to maintain a maximum center to center distance of 18 inches. The FEA evaluates jacketing configurations with bands spaced 18, 21, and 24 inches apart to bound potential plant configurations. FEA Models 8 to 13 had bands spaced 21 and 24 inches apart.

FEA models for four representative pipe sizes were chosen to limit the scope of the FEA. The FEA models were simulated on pipe sizes of 2, 8, 12, and 14 inches. Table 2.1 below provides a list of the fourteen FEA models analyzed.

Table 2.1 – FEA Models

Model Number	Description	Model ID	Pipe Size (in)	Jacketing Thickness (in)	Insulation Material	Insulation Thickness (in)	Band Clear Spacing (in)	Band Width (in)
1	Baseline Model – OPG Test Case	P02T1CS	2	0.016	Cal-Sil	1	8	0.75
2	SS Jacketing on 2" Pipe with Cal-Sil Insulation	P02T2CS	2	0.016	Cal-Sil	2 (Note 1)	18	0.75
3	SS Jacketing on 8" Pipe with Cal-Sil Insulation	P08T3CS	8	0.016	Cal-Sil	3 (Note 1)	18	0.75
4	SS Jacketing on 12" Pipe with Cal-Sil Insulation	P12T4CS	12	0.016	Cal-Sil	4 (Note 1)	18	0.75
5	SS Jacketing on 2" Pipe with Asbestos Insulation	P02T2AS	2	0.016	Asbestos	2 (Note 1)	18	0.75
6	SS Jacketing on 8" Pipe with Asbestos Insulation	P08T3AS	8	0.016	Asbestos	3 (Note 1)	18	0.75
7	SS Jacketing on 12" Pipe with Asbestos Insulation	P12T4AS	12	0.016	Asbestos	4 (Note 1)	18	0.75
8	SS Jacketing on 14" Pipe with Cal-Sil Insulation	P14T4CS21L	14	0.016	Cal-Sil	4 (Note 1)	21	0.75
9	SS Jacketing on 14" Pipe with Cal-Sil Insulation	P14T4CS24L	14	0.016	Cal-Sil	4 (Note 1)	24	0.75
10	SS Jacketing on 14" Pipe with Asbestos Insulation	P14T4AS21L	14	0.016	Asbestos	4 (Note 1)	21	0.75
11	SS Jacketing on 14" Pipe with Asbestos Insulation	P14T4AS24L	14	0.016	Asbestos	4 (Note 1)	24	0.75
12	SS Jacketing on 14" Pipe with Asbestos Insulation	P14T4AS24LB	14	0.016	Asbestos	4 (Note 1)	24	0.50
13	SS Jacketing on 2" Pipe with Asbestos Insulation	P02T2AS24LB	2	0.010	Asbestos	2 (Note 1)	24	0.50
14	SS Jacketing on 12" Pipe with Asbestos Insulation	P12T4AS18LB	12	0.010	Asbestos	4 (Note 1)	18	0.50

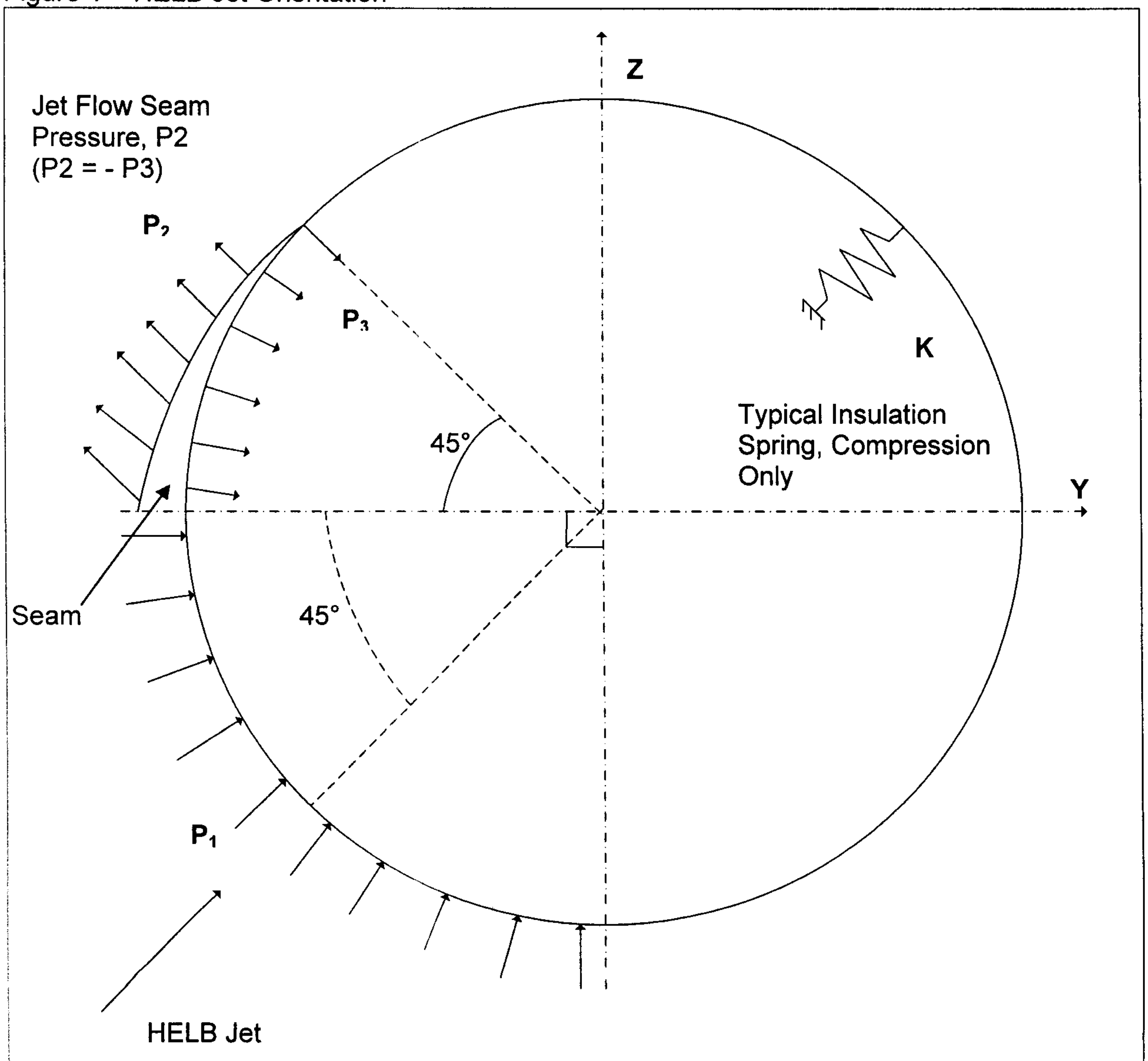
Note 1: A representative insulation thickness was selected from References 10.0 and 11.0 for a specified pipe size.

Industry guidance has determined, through jet impingement testing, the distance where insulation systems will become debris from a postulated LOCA break. This distance is defined as the ZOI radius. The ZOI radius for cal-sil and asbestos insulation is shown in Design Input 5.0. The ZOI radius correlates the LOCA break pressure to the pressure at a distance (ZOI radius) from the break location. The correlation between ZOI radius and destruction pressure is shown in Table I-3 of Appendix I to Reference 3.0. The insulation destruction pressures listed in Design Input 5.0 are used in the FEA models with the respective insulation types.

HELB Jet Orientation

The OPG test report documented that the critical orientation for jacketing failure was when a jet blast was offset 45° from the horizontal jacketing seam. Therefore, each of the FEA models simulates a jet blast offset 45° from the horizontal seam of the overlapping portion of the jacketing. The simulated HELB jet effects are imposed on the FEA models as pressures P_1, P_2, and P_3 shown in Figure 1. Figure 1 is shown below to illustrate the simulated blast scenario.

Figure 1 – HELB Jet Orientation



FEA Model Group Numbering

To differentiate the components of the FEA model, plate elements are labeled in group numbers. The grouping is the same between all 14 models. Figures 2 and 3 together with Table 2.2 describe the grouping used in the modeling.

Figure 2 – FEA Model Groups – Pipe Jacketing

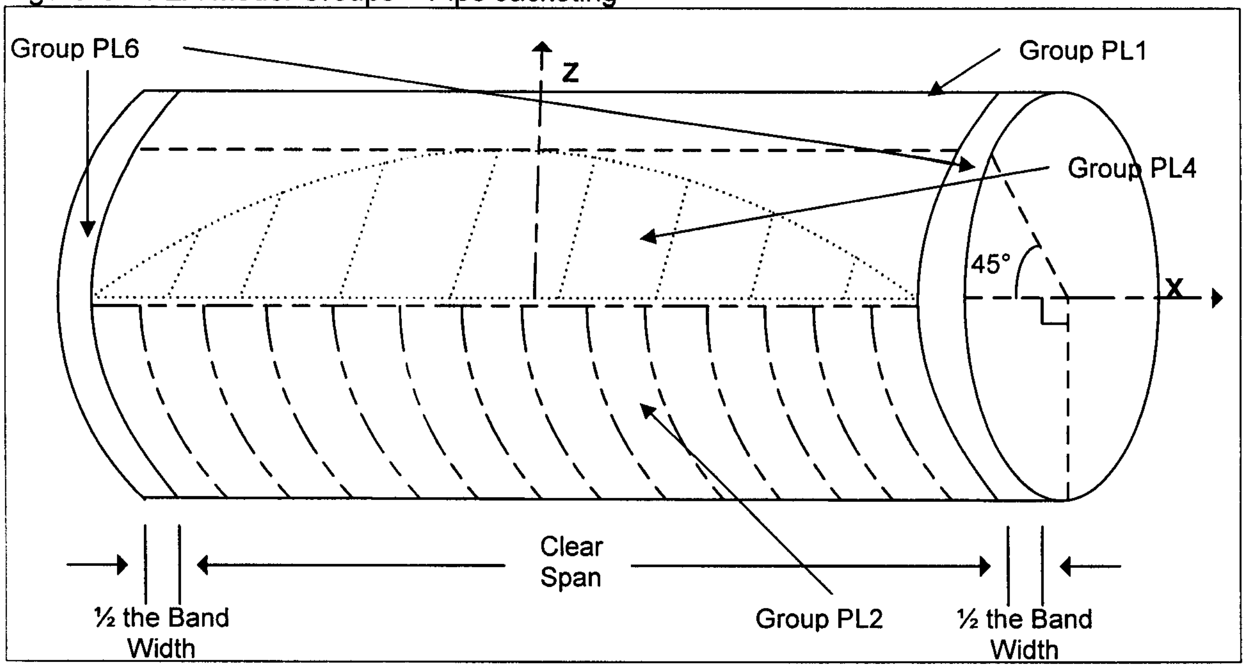


Figure 3 – FEA Model Groups – Overlap Jacketing

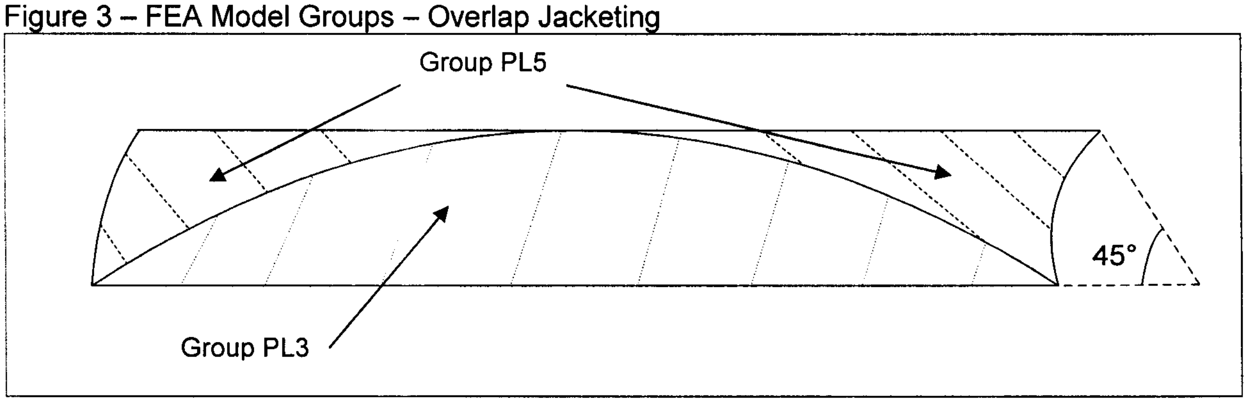


Table 2.2 – FEA Model Groups

FEA Groups	Group Description
PL1	Group designates the plate elements for the entire portion of jacketing that is not impacted by jet pressure.
PL2	Group designates the plate elements for the jacketing directly impacted by the HELB jet blast (90° Cylindrical Section).
PL3	Group designates the plate elements for the portion of overlapped jacketing that is impacted by the seam pressure (Outward).
PL4	Group designates the plate elements for the portion of pipe jacketing that is impacted by the seam pressure (Inward).
PL5	Group designates the plate elements for the portion of overlapped jacketing that is not impacted by the seam pressure
PL6	Group designates the plate elements for the band straps.

Each FEM includes one span of pipe between two bands. The Boundary Condition (BC) of the FEM at both ends includes radial and longitudinal (local Z-axis or global X-axis) springs. The rotations at both ends of the FEM are set free to conservatively maximize jacketing stresses.

FEA models for cal-sil insulation have common nodes for group PL1 and group PL6 at the boundary condition of both ends. However, FEA models for asbestos do not have common nodes for group PL1 and group PL6 at the boundary condition of both ends for the circumferential area under external pressure (total of 60 degrees). This is due to correctly modeling the asbestos behavior under external pressure. Asbestos has a softer spring constant compared to cal-sil insulation; therefore, it experiences a larger deformation under HELB jet pressure. This will cause the jacket (group PL1) to separate from the band (group PL6) when the external pressure is applied to the jacket (group PL2).

The spring constant of each FEM is calculated using the insulation compressive modulus of elasticity, insulation thickness, insulation length, insulation average diameter and the number of FEM nodes. This calculation has been performed in Design Input 6.0. The spring constants of FEA models are summarized in Design Input 6.0. The springs included in the models act radially over the entire FEM.

Pressure Applied to Overlapped Seam

The HELB jet impacts the insulation jacketing at a 45° offset from the seam. The jet stream impacts the jacketing material and is diverted around the jacketing material. The peeling effect on the overlapped jacketing section shown in the OPG test report is the result of the higher pressure (normal to the jacketing surface) inside the seam overlap to that outside of the seam overlap. This net differential pressure caused the failure of the jacketing system used in the OPG test report. The net pressure differential between the inside and outside of the seam overlap is applied to the overlap section (Group PL3) as P_2 and to the inner pipe jacketing section (Group PL4) as P_3 (equals negative P_2).

The baseline model (P02T1CS) has been iteratively analyzed to find the corresponding seam pressure P_2 and P_3 (see Figure 1) that causes jacketing failure. Jacketing failure happens when the maximum stress in group PL3 reaches the ultimate tensile stress for aluminum of 13 Ksi. This pressure has been determined to equal 0.96 psi.

The pressure determined through the iterative process (equal to 0.96 psi) has been applied to the five FEA models that include the same insulation type (cal-sil) as the baseline model. This pressure, P_2 and P_3, has been adjusted for the five FEA models that include asbestos insulation. The models are adjusted by the ratio of the external jet destruction pressure for asbestos to cal-sil insulation (see Design Input 5.0). The adjusted pressure is applied to the asbestos FEA models at the same region as the baseline model. The seam pressure for models with asbestos insulation is equal to:

$P_{Asbestos}$ = (20.6 psi / 24 psi) * 0.96 psi = 0.824 psi

<u>Load Cases Applied</u>

There are three pressure loads applied to each model. The three loads are listed below. Figure 1 shows the location of the 3 pressure loads.

Pressure load 1 (P_1) is applied to Group PL2. This pressure load is for the direct pressure force exerted by the HELB jet blast.

Pressure load 2 (P_2) is applied to Group PL3. This pressure load is applied outward on PL3 and simulates the pressure force that causes the jacketing peeling effect.

Pressure load 3 (P_3) is applied to Group PL4. This pressure load is applied inward on PL4.

Table 2.3 – Model Loads

FEA Model	P_1 (psi)	P_2 (psi)	P_3 (psi)
1	-24.0	0.96	-0.96
2	-24.0	0.96	-0.96
3	-24.0	0.96	-0.96
4	-24.0	0.96	-0.96
5	-20.6	0.824	-0.824
6	-20.6	0.824	-0.824
7	-20.6	0.824	-0.824
8	-24.0	0.96	-0.96
9	-24.0	0.96	-0.96
10	-20.6	0.824	-0.824
11	-20.6	0.824	-0.824
12	-20.6	0.824	-0.824
13	-20.6	0.824	-0.824
14	-20.6	0.824	-0.824

The three pressure loads are linearly summed and imposed on the model.

3.0 Assumptions

3.1 The band dimensions per SUI-0009 (Reference 6.0) can be 0.5 inch wide by 0.02 inch thick for piping up to 12 inches in diameter and 0.75 inch wide by 0.02 inch thick for piping 12 inches in diameter and greater. This evaluation uses bands 0.75 inch wide by 0.02 inch thick for the baseline model (Model 1) and Models 2 through 11.

To understand the effect of using 0.5 inch wide bands for piping up to 14 inches in diameter, Model 12 (P14T4AS24LB) has been developed. This model is a bounding analysis for large bore pipes with 0.5 inch wide bands. The results of the analysis are discussed in Section 5.0.

3.2 The stainless steel jacketing material per SUI-0009 can be either type 304 or 316 stainless steel. This evaluation uses type 304. The ultimate tensile strength for these material types is the same; therefore, this assumption does not impact the results.

3.3 The same Compression Strength/Young's Modulus value corresponding to 5% strain has been used for strains higher than 5%. Compression Strength generally increases with higher strain; therefore, using a Young's Modulus value corresponding to 5% strain in this evaluation would yield conservative results.

4.0 Acceptance Criteria

The jacketing system is considered to be qualified for the prescribed ZOI radii specified in Design Input 5.0 if the following criterion is met:

- The maximum Von Mises stress in the jacketing material is less than the ultimate tensile strength of the jacketing material. The ultimate tensile strength is shown in Design Inputs 2.0 and 3.0.

5.0 Results

Stress plots were performed and the results documented for each model. The results of this analysis are summarized in the tables included in Sections 5.1, 5.2, and 5.3 below. Section 5.1 summarizes the results for each model and compares the maximum stress ratio to the ultimate tensile strength of 85 ksi. Section 5.2 summarizes the results and compares the maximum stress ratio to an alternate stainless steel ultimate tensile strength of 75 ksi. (Refer to Design Input 3.0 for a discussion of the tensile strength of stainless steel.) Section 5.3 summarizes the models and their corresponding load capacity ratios (L/Cs).

5.1 *Summary Tables – Stainless Steel Tensile Strength 85 ksi*

Table 5.1 – Baseline Model Results – Model 1*

Description	P02T1CS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	2.80	4.47	12.97	3.07	4.10	9.16
Allowable Stress (Ksi)	13	13	13	13	13	85
L/C Ratio	0.22	0.34	0.998	0.24	0.32	0.11
Max Displacement (in)	0.019	0.022	0.057	0.013	0.014	0.02
Insulation Max Strain (%)	1.90	2.20	N/A	1.30	1.40	N/A

* Baseline model reaches the onset of failure stresses.

Table 5.2 – 0.016" Thick Jacketing on 2" Pipe w/ 2" Thick Cal-Sil Insulation – Model 2

Description	P02T2CS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	7.60	15.39	32.12	9.95	9.69	14.84
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.09	0.18	0.38	0.12	0.11	0.17
Max Displacement (in)	0.046	0.05	0.141	0.031	0.035	0.043
Insulation Max Strain (%)	2.30	2.50	N/A	1.55	1.75	N/A

Table 5.3 – 0.016" Thick Jacketing on 8" Pipe w/ 3" Thick Cal-Sil Insulation – Model 3

Description	P08T3CS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	11.05	28.92	43.21	11.60	13.88	23.28
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.13	0.34	0.51	0.14	0.16	0.27
Max Displacement (in)	0.079	0.074	0.428	0.05	0.055	0.079
Insulation Max Strain (%)	2.63	2.47	N/A	1.67	1.83	N/A

Table 5.4 – 0.016" Thick Jacketing on 12" Pipe w/ 4" Thick Cal-Sil Insulation – Model 4

Description	P12T4CS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	12.72	35.38	46.42	13.02	16.42	28.97
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.15	0.42	0.55	0.15	0.19	0.34
Max Displacement (in)	0.116	0.10	0.652	0.074	0.077	0.116
Insulation Max Strain (%)	2.90	2.50	N/A	1.85	1.93	N/A

Table 5.5 – 0.016" Thick Jacketing on 2" Pipe w/ 2" Thick Asbestos Insulation – Model 5

Description	P02T2AS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	16.92	25.92	40.51	21.30	14.29	27.62
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.20	0.30	0.48	0.25	0.17	0.32
Max Displacement (in)	0.229	0.274	0.226	0.175	0.174	0.263
Insulation Max Strain (%)	11.45	13.70	N/A	8.75	8.70	N/A

Table 5.6 – 0.016" Thick Jacketing on 8" Pipe w/ 3" Thick Asbestos Insulation – Model 6

Description	P08T3AS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	19.37	33.51	48.24	19.18	18.03	42.73
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.23	0.39	0.57	0.23	0.21	0.50
Max Displacement (in)	0.389	0.415	0.514	0.26	0.26	0.392
Insulation Max Strain (%)	12.97	13.83	N/A	8.67	8.67	N/A

Table 5.7 – 0.016" Thick Jacketing on 12" Pipe w/ 4" Thick Asbestos Insulation – Model 7

Description	P12T4AS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	21.92	41.19	52.03	21.64	20.20	48.48
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.26	0.48	0.61	0.25	0.24	0.57
Max Displacement (in)	0.578	0.566	0.799	0.397	0.399	0.578
Insulation Max Strain (%)	14.45	14.15	N/A	9.93	9.98	N/A

Table 5.8 – 0.016" Thick Jacketing on 14" Pipe w/ 4" Thick Cal-Sil Insulation – Model 8

Description	P14T4CS21L FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	15.57	41.18	53.25	15.64	18.33	34.45
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.18	0.48	0.63	0.18	0.22	0.41
Max Displacement (in)	0.123	0.103	0.883	0.081	0.086	0.123
Insulation Max Strain (%)	4.10	3.43	N/A	2.70	2.87	N/A

Table 5.9 – 0.016" Thick Jacketing on 14" Pipe w/ 4" Thick Cal-Sil Insulation – Model 9

Description	P14T4CS24L FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	18.32	46.11	60.5	18.26	20.28	38.74
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.22	0.54	0.71	0.21	0.24	0.46
Max Displacement (in)	0.126	0.103	1.124	0.083	0.095	0.126
Insulation Max Strain (%)	4.20	3.43	N/A	2.77	3.17	N/A

Table 5.10 – 0.016" Thick Jacketing on 14" Pipe w/ 4" Thick Asbestos Insulation – Model 10

Description	P14T4AS21L FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	23.20	50.49	57.50	22.81	21.02	53.46
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.27	0.59	0.68	0.27	0.25	0.63
Max Displacement (in)	0.614	0.591	1.036	0.418	0.418	0.614
Insulation Max Strain (%)	15.35	14.78	N/A	10.45	10.45	N/A

Table 5.11 – 0.016" Thick Jacketing on 14" Pipe w/ 4" Thick Asbestos Insulation – Model 11

Description	P14T4AS24L FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	24.25	59.00	63.36	23.44	21.89	55.56
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.29	0.69	0.75	0.28	0.26	0.65
Max Displacement (in)	0.623	0.599	1.27	0.421	0.413	0.623
Insulation Max Strain (%)	15.58	14.98	N/A	10.53	10.33	N/A

The results of Tables 5.2 – 5.11 show that the maximum L/C ratio is 0.75 (Model 11 – PL3). Therefore, the stresses in the Surry jacketing configurations remain under the allowable stress levels.

The Tables 5.2 – 5.11 results also indicate that structural integrity would be maintained for either cal-sil or asbestos insulation installed on piping up to 14 inches in diameter, with 0.016 inch thick stainless steel jacketing, using 0.75 inch wide bands spaced at a maximum distance of 24 inches.

Model 11 is the controlling finite element (FE) model; therefore, Model 12 has been developed using Model 11 to investigate the effects of using 0.5" wide bands on calculated L/C values. Per Specification SUI-0009, 0.5 inch wide bands are used on piping smaller than 12 inches NPS and 0.75 inch wide bands on pipes 12 inches NPS and greater. Therefore, Model 12 is a hypothetical case used to bound plant configurations. Model 12 results are presented in Table 5.12.

Table 5.12 – 0.016" Thick Jacketing on 14" Pipe w/ 4" Thick Asbestos Insulation – Model 12

Description	P14T4AS24LB FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	26.18	40.43	63.51	26.85	26.34	49.26
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.31	0.48	0.75	0.32	0.31	0.58
Max Displacement (in)	0.649	0.624	1.293	0.442	0.435	0.649
Insulation Max Strain (%)	16.23	15.60	N/A	11.05	10.88	N/A

The maximum L/C ratio in Model 12 is 0.75. Model 12 is considered the controlling FE model for large bore piping representing cal-sil or asbestos insulations on piping up to 14 inches in diameter, with 0.016 inch thick stainless steel jacketing, using 0.50 inch wide bands spaced at a maximum distance of 24 inches.

Some of the small bore pipes (≤ 2 inches) insulated in asbestos or cal-sil have been jacketed with 0.010 inch stainless steel. Models 13 and 14 have been created to evaluate the effect of using stainless steel jacketing with a thickness of 0.010" rather than the 0.016" or thicker material.

The results summary for Model 13 (P02T2AS24LB) is presented in Table 5.13.

Table 5.13 – 0.010" Thick Jacketing on 2" Pipe w/ 2" Thick Asbestos Insulation – Model 13

Description	P02T2AS24LB FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	22.38	36.87	74.80	28.48	21.30	50.96
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.26	0.43	0.88	0.34	0.25	0.60
Max Displacement (in)	0.271	0.322	0.607	0.219	0.232	0.297
Insulation Max Strain (%)	13.55	16.10	N/A	10.95	11.60	N/A

The results of Table 5.13 show that the maximum L/C ratio is 0.88. Therefore, the results shown in Table 5.13 demonstrate the acceptability of the small bore piping (≤ 2 inches) configurations in use at Surry.

Model 14 was created to evaluate a limiting pipe size that can be insulated with asbestos or cal-sil and jacketed with 0.010 inch thick stainless steel. Model 14 results are presented in Table 5.14.

Table 5.14 – 0.010" Thick Jacketing on 12" Pipe w/ 4" Thick Asbestos Insulation – Model 14

Description	P12T4AS18LB FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	29.38	34.22	76.53	29.62	30.57	61.65
Allowable Stress (Ksi)	85	85	85	85	85	85
L/C Ratio	0.35	0.40	0.90	0.35	0.36	0.73
Max Displacement (in)	0.679	0.606	1.758	0.521	0.516	0.679
Insulation Max Strain (%)	16.98	15.15	N/A	13.03	12.90	N/A

The results of Table 5.14 show that the L/C ratio is 0.90. The results of Table 5.14 demonstrate that a 12 inch pipe insulated in asbestos, jacketed in 0.010 inch thick stainless steel, and secured with bands 0.5 inch wide spaced 18 inches apart would maintain its insulation jacketing structural integrity.

5.2 *Summary Tables – Stainless Steel Tensile Strength 75 ksi*

Table 5.15 – Baseline Model Results – Model 1*

Description	P02T1CS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	2.80	4.47	12.97	3.07	4.10	9.16
Allowable Stress (Ksi)	13	13	13	13	13	75
L/C Ratio	0.22	0.34	0.998	0.24	0.32	0.12
Max Displacement (in)	0.019	0.022	0.057	0.013	0.014	0.02
Insulation Max Strain (%)	1.90	2.20	N/A	1.30	1.40	N/A

* Baseline model reaches the onset of failure stresses.

Table 5.16 – 0.016" Thick Jacketing on 2" Pipe w/ 2" Thick Cal-Sil Insulation – Model 2

Description	P02T2CS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	7.60	15.39	32.12	9.95	9.69	14.84
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.10	0.21	0.43	0.13	0.13	0.20
Max Displacement (in)	0.046	0.05	0.141	0.031	0.035	0.043
Insulation Max Strain (%)	2.30	2.50	N/A	1.55	1.75	N/A

Table 5.17 – 0.016" Thick Jacketing on 8" Pipe w/ 3" Thick Cal-Sil Insulation – Model 3

Description	P08T3CS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	11.05	28.92	43.21	11.60	13.88	23.28
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.15	0.39	0.58	0.15	0.19	0.31
Max Displacement (in)	0.079	0.074	0.428	0.05	0.055	0.079
Insulation Max Strain (%)	2.63	2.47	N/A	1.67	1.83	N/A

Table 5.18 – 0.016" Thick Jacketing on 12" Pipe w/ 4" Thick Cal-Sil Insulation – Model 4

Description	P12T4CS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	12.72	35.38	46.42	13.02	16.42	28.97
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.17	0.47	0.62	0.17	0.22	0.39
Max Displacement (in)	0.116	0.10	0.652	0.074	0.077	0.116
Insulation Max Strain (%)	2.90	2.50	N/A	1.85	1.93	N/A

Table 5.19 – 0.016" Thick Jacketing on 2" Pipe w/ 2" Thick Asbestos Insulation – Model 5

Description	P02T2AS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	16.92	25.92	40.51	21.30	14.29	27.62
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.23	0.35	0.54	0.28	0.19	0.37
Max Displacement (in)	0.229	0.274	0.226	0.175	0.174	0.263
Insulation Max Strain (%)	11.45	13.70	N/A	8.75	8.70	N/A

Table 5.20 – 0.016" Thick Jacketing on 8" Pipe w/ 3" Thick Asbestos Insulation – Model 6

Description	P08T3AS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	19.37	33.51	48.24	19.18	18.03	42.73
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.26	0.45	0.64	0.26	0.24	0.57
Max Displacement (in)	0.389	0.415	0.514	0.26	0.26	0.392
Insulation Max Strain (%)	12.97	13.83	N/A	8.67	8.67	N/A

Table 5.21 – 0.016" Thick Jacketing on 12" Pipe w/ 4" Thick Asbestos Insulation – Model 7

Description	P12T4AS FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	21.92	41.19	52.03	21.64	20.20	48.48
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.29	0.55	0.69	0.29	0.27	0.65
Max Displacement (in)	0.578	0.566	0.799	0.397	0.399	0.578
Insulation Max Strain (%)	14.45	14.15	N/A	9.93	9.98	N/A

Table 5.22 – 0.016" Thick Jacketing on 14" Pipe w/ 4" Thick Cal-Sil Insulation – Model 8

Description	P14T4CS21L FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	15.57	41.18	53.25	15.64	18.33	34.45
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.21	0.55	0.71	0.21	0.24	0.46
Max Displacement (in)	0.123	0.103	0.883	0.081	0.086	0.123
Insulation Max Strain (%)	4.10	3.43	N/A	2.70	2.87	N/A

Table 5.23 – 0.016" Thick Jacketing on 14" Pipe w/ 4" Thick Cal-Sil Insulation – Model 9

Description	P14T4CS24L FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	18.32	46.11	60.5	18.26	20.28	38.74
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.24	0.61	0.81	0.24	0.27	0.52
Max Displacement (in)	0.126	0.103	1.124	0.083	0.095	0.126
Insulation Max Strain (%)	4.20	3.43	N/A	2.77	3.17	N/A

Table 5.24 – 0.016" Thick Jacketing on 14" Pipe w/ 4" Thick Asbestos Insulation – Model 10

Description	P14T4AS21L FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	23.20	50.49	57.50	22.81	21.02	53.46
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.31	0.67	0.77	0.30	0.28	0.71
Max Displacement (in)	0.614	0.591	1.036	0.418	0.418	0.614
Insulation Max Strain (%)	15.35	14.78	N/A	10.45	10.45	N/A

Table 5.25 – 0.016" Thick Jacketing on 14" Pipe w/ 4" Thick Asbestos Insulation – Model 11

Description	P14T4AS24L FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	24.25	59.00	63.36	23.44	21.89	55.56
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.32	0.79	0.84	0.31	0.29	0.74
Max Displacement (in)	0.623	0.599	1.27	0.421	0.413	0.623
Insulation Max Strain (%)	15.58	14.98	N/A	10.53	10.33	N/A

Table 5.26 – 0.016" Thick Jacketing on 14" Pipe w/ 4" Thick Asbestos Insulation – Model 12

Description	P14T4AS24LB FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	26.18	40.43	63.51	26.85	26.34	49.26
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.35	0.54	0.85	0.36	0.35	0.66
Max Displacement (in)	0.649	0.624	1.293	0.442	0.435	0.649
Insulation Max Strain (%)	16.23	15.60	N/A	11.05	10.88	N/A

Table 5.27 – 0.010" Thick Jacketing on 2" Pipe w/ 2" Thick Asbestos Insulation – Model 13

Description	P02T2AS24LB FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	22.38	36.87	74.80	28.48	21.30	50.96
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.30	0.49	0.997	0.38	0.28	0.68
Max Displacement (in)	0.271	0.322	0.607	0.219	0.232	0.297
Insulation Max Strain (%)	13.55	16.10	N/A	10.95	11.60	N/A

Table 5.28 – 0.010" Thick Jacketing on 12" Pipe w/ 4" Thick Asbestos Insulation – Model 14

Description	P12T4AS18LB FEM					
Group	PL1	PL2	PL3	PL4	PL5	PL6
Max Von Mises Stress (Ksi)	29.38	34.22	76.53	29.62	30.57	61.65
Allowable Stress (Ksi)	75	75	75	75	75	75
L/C Ratio	0.39	0.46	1.02	0.39	0.41	0.82
Max Displacement (in)	0.679	0.606	1.758	0.521	0.516	0.679
Insulation Max Strain (%)	16.98	15.15	N/A	13.03	12.90	N/A

5.3 *Overall Summary Table*

Table 5.29 provides a summary of each of the fourteen FEA models and the corresponding maximum load capacity ratio from Sections 5.1 and 5.2.

Table 5.29 – Summary of Maximum L/C Ratio for FEA Models

Model Number	Pipe Size (in)	Insulation Material	Jacketing Thickness (in)	Band Clear Spacing (in)	Band Width (in)	L/C Ratio (Section 5.1)	L/C Ratio (Section 5.2)
1	2	Cal-Sil	0.016	8	0.75	0.998	0.998
2	2	Cal-Sil	0.016	18	0.75	0.38	0.43
3	8	Cal-Sil	0.016	18	0.75	0.51	0.58
4	12	Cal-Sil	0.016	18	0.75	0.55	0.62
5	2	Asbestos	0.016	18	0.75	0.48	0.54
6	8	Asbestos	0.016	18	0.75	0.57	0.64
7	12	Asbestos	0.016	18	0.75	0.61	0.69
8	14	Cal-Sil	0.016	21	0.75	0.63	0.71
9	14	Cal-Sil	0.016	24	0.75	0.71	0.81
10	14	Asbestos	0.016	21	0.75	0.68	0.77
11	14	Asbestos	0.016	24	0.75	0.75	0.84
12	14	Asbestos	0.016	24	0.50	0.75	0.85
13	2	Asbestos	0.010	24	0.50	0.88	0.997
14	12	Asbestos	0.010	18	0.50	0.90	1.02

Conclusions

The results provided above demonstrate that twelve of the thirteen FEA models created for the Surry insulation jacketing configurations remain below a L/C ratio of 1.0. Model 14 slightly exceeds the L/C ratio of 1.0 and provides the upper bounds of an acceptable jacketing configuration as discussed in greater detail below. These results demonstrate that for each configuration analyzed, there is reasonable assurance that the jacketing system's structural integrity would be maintained under the simulated LOCA jet conditions.

For large bore piping (> 2 inches NPS), Model 12 represents the bounding analysis. The results summarized in Section 5.0 above demonstrate that the jacketing system for a 14 inch diameter pipe insulated in asbestos (asbestos is the controlling insulation for this analysis), jacketed in 0.016 inch stainless steel, and secured with bands 0.5 inch wide spaced 24 inches apart would maintain its structural integrity. Per Specification SUI-0009, the stainless steel bands used at Surry for this application are 0.75 inch wide, rather than the 0.50" bands assumed in this model, for piping ≥ 12 inches NPS. Additionally, the bands are to be spaced at a maximum span of 18 inches. Therefore, this model represents the bounding analysis for the plant insulation jacketing configuration on large bore piping.

For small bore piping (≤ 2 inches NPS), Model 13 bounds the plant configuration. The results summarized in Section 5.0 above demonstrate that the jacketing system for a 2 inch diameter pipe insulated in asbestos, jacketed in 0.010 inch stainless steel, and secured with bands 0.5 inch wide spaced 24 inches apart would maintain its structural integrity. Per Specification SUI-0009, the stainless steel bands used at Surry for this application are to be spaced at a maximum span of 18 inches, rather than the 24 inches assumed in the model. Therefore, this model represents the bounding analysis for the plant insulation jacketing configuration on small bore piping.

Model 14 was developed to establish an upper bound on the pipe size that could be jacketed in 0.010 inch thick stainless steel and maintain its structural integrity. Model 14 demonstrates that a jacketing system for a 12 inch diameter pipe insulated in asbestos, jacketed in 0.010 inch stainless steel, and secured with 0.5 inch wide bands spaced 18 inches apart would slightly exceed (by approx. 2%) the qualification requirements needed to maintain its structural integrity. This configuration (12 inch diameter pipe with asbestos insulation and 0.010 inch stainless steel jacketing) is not installed in the Surry Units 1 and 2 containments. The 0.010 inch stainless steel jacketing is used on small bore (≤ 2-inch diameter) piping.

This evaluation demonstrates the differences in piping insulation / jacketing responses due to the different band spacing used in the OPG testing versus the band spacing installed at Surry. This evaluation also documents that the maximum stresses expected to be imposed in the jacketing material and bands for the Surry in-containment insulation jacketing systems due to LOCA jet conditions are less than the material allowables.